

BIBLIOMETRIC OVERVIEW OF SCIENTIFIC OUTPUT ON THE USE OF MICROORGANISMS IN THE BIOLOGICAL CONTROL OF AGRICULTURAL PESTS

 <https://doi.org/10.63330/aurumpub.059-008>

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Abstract

The intensification of agricultural production and dependence on synthetic pesticides have increased the demand for more sustainable pest management alternatives. In this context, microorganism-based biological control stands out as a promising strategy, particularly through the use of fungi, bacteria, and other agents capable of acting against pests and phytopathogens. This study aimed to analyze the landscape of scientific output on the use of microorganisms in the biological control of agricultural pests through a bibliometric analysis of the Scopus database. The study encompassed publications from 2015 to 2025, considering open-access articles in Portuguese and English in the fields of *Agricultural and Biological Sciences* and Environmental Science, resulting in 1,034 documents for analysis. The most frequently cited articles, temporal evolution of publications, geographical distribution, keywords, leading authors, journals, and scientific collaboration networks were evaluated. The results showed substantial growth in scientific output, from 26 articles in 2015 to 221 in 2025. China and the United States exhibited the highest density of scientific output, while Brazil and Spain stood out as important points of connection. The keywords demonstrated the centrality of *biological control* and *biocontrol*, with particular emphasis on *Beauveria bassiana*, *Metarhizium anisopliae*, and *Bacillus thuringiensis*. The analysis also revealed an interdisciplinary scientific structure that was relatively fragmented in terms of coauthorship. It is concluded that the use of microorganisms in biological control constitutes an expanding scientific field associated with the development of more sustainable agricultural strategies and integrated pest management.

Keywords: Agriculture, Bibliometrics, Microbial agents.

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INTRODUCTION

The intensification of agricultural production has increased the demand for efficient pest management strategies, which have historically been based on the use of chemical pesticides (Ediagbonya et al., 2025). Large-scale global production has increased the use of synthetic pesticides to 3.5 billion kg/year. Although these products play an important role in maintaining productivity, they cause several adverse environmental and health impacts, driving the search for alternative pest control methods (Pretty; Bharucha, 2015).

In this context, biological control using microorganisms has become established as a promising alternative, employing bacteria, fungi, viruses, and other agents capable of reducing agricultural pest populations in a more selective and environmentally compatible manner (Chaudhary et al., 2024; Villavicencio-Vásquez et al., 2025). As Brazil has one of the world's largest agricultural sectors and extensive microbial biodiversity, research on this topic has grown in the country, contributing to advances in integrated pest management and sustainable agriculture (Boaventura; Quintela, 2025).

Despite this progress, few studies have elucidated the evolution of scientific output on the use of microorganisms in the biological control of agricultural pests. Bibliometric analysis can thus provide a broader perspective on productivity and impact within a given research topic by examining citations per year, researcher performance, the use of indicators, and keyword occurrence. It is an important tool for understanding and managing scientific research, providing both quantitative and qualitative information (Hassan; Duarte, 2024).

In view of the foregoing, this study aims to analyze the landscape of scientific output on the use of microorganisms in the biological control of agricultural pests through bibliometric indicators obtained from the Scopus database, thereby contributing to an understanding of the field's evolution and to the identification of future research prospects.

METHODOLOGY

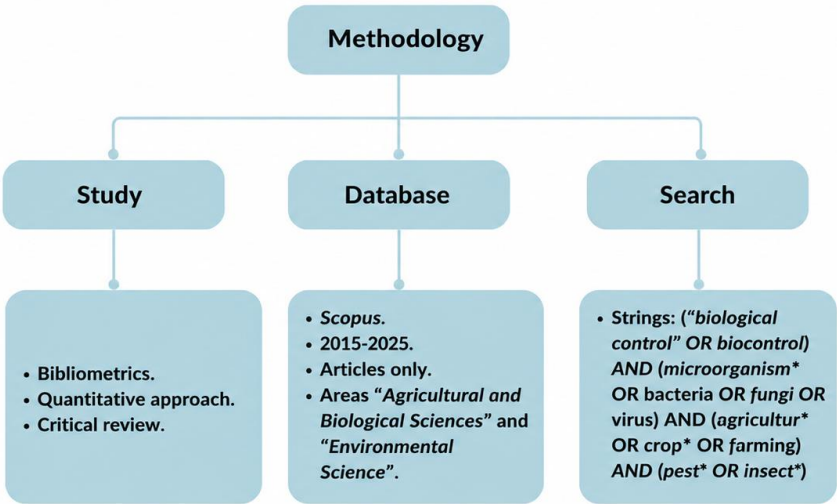
This research is characterized as a bibliometric study employing a qualitative and quantitative approach, with the objective of identifying the predominant characteristics and trends in scientific output on the use of microorganisms in the biological control of agricultural pests. The choice of bibliometric methodology is justified by its ability to quantify and analyze the evolution, distribution, and trends of scientific output in a given field of knowledge, enabling a structured understanding of the development of research on the topic over time (Hassan; Duarte, 2024).

The bibliometric search was conducted in the *Scopus* database using the following search strings, combined with the Boolean operators “OR” and “AND”: ((*“biological control” OR biocontrol*) AND (*microorganism* OR bacteria OR fungi OR virus*) AND (*agricultur* OR crop* OR farming*) AND (*pest* OR insect**)). At this stage, with no additional filters applied, 6,798 documents were identified.

Following the initial search, filters were applied to restrict the documents retrieved, retaining only those most relevant to this study. Only articles published between 2015 and 2025 were selected so that the time frame would encompass the most recent scientific output on the topic. In addition, the selection was restricted to articles in Portuguese and English, further narrowing the study. By limiting the search to the subject areas of “*Agricultural and Biological Sciences*” and “*Environmental Science*” and selecting only open-access articles, the number of documents was reduced from 6,798 to 1,034. Figure 1 therefore presents a flowchart of the search process.

Figure 1

Flowchart of the methodological process used to search for the topic in the database.



Source: Authors, 2026.

The file corresponding to the search conducted in the *Scopus* database was downloaded in CSV format to enable data processing and the development of the bibliometric analyses presented in Section 3, Results and Discussion. The graphs used to present and discuss the results were produced partly with the VOSviewer bibliometric tool and partly using the Canva platform. All 1,034 documents retrieved by the search were included, as the use of the entire dataset provides greater representativeness and robustness to the bibliometric analyses performed.

Subsequently, a list of the 10 most frequently cited articles among the documents analyzed was compiled. These studies were used as bibliographic references to support the discussion presented in Subsections 3.1 and 3.2. All figures were produced using Canva, an editor for images and other types of designs.

RESULTS AND DISCUSSION

HIGHEST-IMPACT ARTICLES

Based on the bibliometric survey, a list was compiled of the 10 articles with the highest numbers of citations among the documents identified in the *Scopus* database. The purpose of selecting these studies was to highlight the publications with the greatest impact and visibility within the body of research related to the topic under investigation. Bibliographic data such as title, authorship, year of publication, journal, and number of citations were considered for each article, allowing the principal references identified in the survey to be organized and characterized.

The 10 selected articles were used as bibliographic references to underpin and support the discussion presented in this section. Analysis of these studies made it possible to identify different approaches to biological control, including the use of invertebrates and microorganisms, entomopathogenic fungi, bacteria that promote phytopathogen control, microbial metabolites, mycoviruses, and other management strategies. The selected publications therefore helped establish a theoretical foundation for interpreting the results and contextualizing the principal trends identified in the literature analyzed. Table 1 lists the highest-impact studies within the body of literature analyzed, based on the total number of accumulated citations.

Table 1

The 10 most frequently cited articles on the topic in Scopus.

Article Title	Authors	Year	Journal	Citations
Biological control using invertebrates and microorganisms: plenty of new opportunities	van Lenteren J.C.; Bolckmans K.; Köhl J.; Ravensberg W.J.; Urbaneja A.	2018	<i>BioControl</i>	813
MAPK Signaling Pathway Alters Expression of Midgut ALP and ABCC Genes and Causes Resistance to <i>Bacillus thuringiensis</i> Cry1Ac Toxin in Diamondback Moth	Guo Z.; Kang S.; Chen D.; Wu Q.; Wang S.; Xie W.; Zhu X.; Baxter S.W.; Zhou X.; Jurat-Fuentes J.L.; Zhang Y.	2015	<i>PLoS Genetics</i>	236

Characterization and biotoxicity of <i>Hypnea musciformis</i> -synthesized silver nanoparticles as potential eco-friendly control tool against <i>Aedes aegypti</i> and <i>Plutella xylostella</i>	Roni M.; Murugan K.; Panneerselvam C.; Subramaniam J.; Nicoletti M.; Madhiyazhagan P.; Dinesh D.; Suresh U.; Khater H.F.; Wei H.; Canale A.; Alarfaj A.A.; Munusamy M.A.; Higuchi A.; Benelli G.	2015	<i>Ecotoxicology and Environmental Safety</i>	215
A review of the biology and control of whitefly, <i>Bemisia tabaci</i> (Hemiptera: Aleyrodidae), with special reference to biological control using entomopathogenic fungi	Sani I.; Ismail S.I.; Abdullah S.; Jalinas J.; Jamian S.; Saad N.	2020	<i>Insects</i>	191
Bio-organic soil amendment promotes the suppression of <i>Ralstonia solanacearum</i> by inducing changes in the functionality and composition of rhizosphere bacterial communities	Deng X.; Zhang N.; Li Y.; Zhu C.; Qu B.; Liu H.; Li R.; Bai Y.; Shen Q.; Falcao Salles J.	2022	<i>New Phytologist</i>	189
An endophytic <i>Beauveria bassiana</i> strain increases spike production in bread and durum wheat plants and effectively controls cotton leafworm (<i>Spodoptera littoralis</i>) larvae	Sánchez-Rodríguez A.R.; Raya-Díaz S.; Zamarreño Á.M.; García-Mina J.M.; del Campillo M.C.; Quesada Moraga E.	2018	<i>Biological Control</i>	178
Sustainable Crop and Weed Management in the Era of the EU Green Deal: A Survival Guide	Tataridas A.; Kanatas P.; Chatzigeorgiou A.; Zannopoulos S.; Travlos I.	2022	<i>Agronomy</i>	156
Fengycin produced by <i>Bacillus amyloliquefaciens</i> FZB42 inhibits <i>Fusarium graminearum</i> growth and mycotoxins biosynthesis	Hanif A.; Zhang F.; Li P.; Li C.; Xu Y.; Zubair M.; Zhang M.; Jia D.; Zhao X.; Liang J.; Majid T.; Yan J.; Farzand A.; Wu H.; Gu Q.; Gao X.	2019	<i>Toxins</i>	153
Pathogens and Molds Affecting Production and Quality of <i>Cannabis sativa</i> L.	Punja Z.K.; Collyer D.; Scott C.; Lung S.; Holmes J.; Sutton D.	2019	<i>Frontiers in Plant Science</i>	140
Mycoviruses in biological control: From basic research to field implementation	García-Pedrajas M.D.; Cañizares M.C.; Sarmiento Villamil J.L.; Jacquat A.G.; Dambolena J.S.	2019	<i>Phytopathology</i>	130

Source: Authors, 2026.

PEST CONTROL USING BIOLOGICAL AGENTS

The literature on biological control demonstrates the expansion of strategies used to reduce populations of agricultural pests and disease-causing organisms. Van Lenteren et al. (2018) discuss augmentative biological control using invertebrate organisms and microorganisms released in large quantities, highlighting its worldwide application and the commercial availability of more than 440 species of control agents. The authors associate the expansion of this approach with reduced use of synthetic pesticides, lower residue levels, and the possibility of integrating it into different management systems. However, the study by Guo et al. (2015) demonstrates that target organisms can also evolve resistance to biological control agents. In their study of *Plutella xylostella*, the authors found that resistance to the Cry1Ac toxin produced by *Bacillus thuringiensis* was associated with the differential expression of a midgut membrane alkaline phosphatase and genes from the ABCC family. The study also associated the mitogen-activated protein kinase (MAPK) signaling pathway with changes in the expression of these genes and with the resistance phenotype, demonstrating the importance of the molecular mechanisms involved in insect responses to control agents.

Biologically derived products and formulations based on entomopathogenic fungi also stand out among the alternatives for arthropod control. Roni et al. (2015) evaluated silver nanoparticles synthesized from an aqueous extract of the alga *Hypnea musciformis*. The nanoparticles were predominantly spherical, crystalline in nature, and had an average size of between 40 and 65 nm. They were evaluated under laboratory conditions against the larvae and pupae of *Aedes aegypti* and *Plutella xylostella*. The authors observed larvicidal and pupicidal toxicity, as well as reduced longevity and fecundity among treated adults. Sani et al. (2020), in turn, conducted a review of the biology and control of *Bemisia tabaci*, with an emphasis on entomopathogenic fungi. The study indicates that *B. tabaci* is a major pest of agricultural crops and a vector of plant viruses, while the intensive use of chemical insecticides is associated with problems such as resistance, environmental contamination, and effects on nontarget organisms. The authors highlight entomopathogenic fungi as an alternative within integrated pest

management and report that hyphomycete species are among the most widely used agents, with the second instar of *B. tabaci* identified as the stage most susceptible to infection.

Biological control can also occur through the modification of soil-associated microbial communities and the use of endophytic microorganisms. Deng et al. (2022) investigated the suppression of *Ralstonia solanacearum* through the continuous application of bio-organic fertilizers in a long-term field experiment. The results indicated that disease suppressiveness was primarily associated with changes in the composition of rhizosphere bacterial communities rather than solely with the abundance of the microorganism introduced as a biocontrol agent. Metagenomic analysis also revealed an enrichment of members of the families *Sphingomonadaceae* and *Xanthomonadaceae* capable of producing secondary metabolites, particularly following pathogen invasion. Sánchez-Rodríguez et al. (2018), meanwhile, evaluated the endophytic colonization of wheat plants by a strain of *Beauveria bassiana*. The fungus was able to colonize bread and durum wheat, and inoculation treatments involving seed coating and soil application increased spike production under certain conditions. In addition, *Spodoptera littoralis* larvae fed leaves from colonized plants exhibited mortality rates ranging from 30% to 57%, depending on the inoculation method, whereas larvae fed control leaves exhibited no mortality.

The search for agricultural systems that are less dependent on chemical products is also addressed by Tataridas et al. (2022), who present a comprehensive framework for sustainable crop and weed management in the context of the European Green Deal. The authors discuss the vulnerability of agricultural systems associated with dependence on herbicides and increased weed resistance, proposing the integration of nonchemical alternatives such as crop rotation and diversification, reduced tillage, intercropping, beneficial microorganisms, biological control agents, soil cover, and precision agriculture technologies. Regarding disease control, Hanif et al. (2019) studied fengycin produced by *Bacillus amyloliquefaciens* FZB42 and its activity against *Fusarium graminearum*, a pathogen associated with *Fusarium* head blight in cereal crops. The study investigated the ability of fengycin to inhibit fungal

BIBLIOMETRIC OVERVIEW OF SCIENTIFIC OUTPUT ON THE USE OF MICROORGANISMS IN THE BIOLOGICAL CONTROL OF AGRICULTURAL PESTS

growth and mycotoxin biosynthesis, thereby placing metabolites produced by bacteria of the genus *Bacillus* among the microbial compounds that may be used to control pathogens. The two studies therefore address distinct but complementary strategies for reducing dependence on chemical inputs, encompassing both agroecosystem management practices and products derived from microorganisms.

Finally, the studies by Punja et al. (2019) and García-Pedrajas et al. (2019) broaden the discussion to encompass disease management and new forms of control involving microorganisms. Punja et al. (2019) characterized pathogens and fungi associated with the production of *Cannabis sativa* under different cultivation systems, identifying, among others, *Fusarium* and *Pythium* species associated with root diseases, powdery mildew on leaves, and inflorescence rots caused by *Penicillium*, *Botrytis*, and *Fusarium*. The study also detected different fungi in cultivation environments and found that biocontrol products containing *Beauveria bassiana* and *Trichoderma* contributed to the presence of these fungi in air samples. García-Pedrajas et al. (2019), in turn, reviewed the potential of mycoviruses as biological control agents against phytopathogenic fungi. The authors emphasize that certain mycoviruses can induce hypovirulence, or reduced virulence, in their fungal hosts, but note that their application depends on their capacity for transmission and spread within natural pathogen populations. Transmission occurs primarily horizontally through hyphal anastomosis and vertically through conidia, while factors related to both the fungal host and the virus influence transmission efficiency.

In conclusion, the references analyzed demonstrate different levels of biological control activity, ranging from organisms and molecules applied directly against pests and pathogens to modifications in microbial communities and virus-fungus interactions.

TEMPORAL EVOLUTION OF SCIENTIFIC OUTPUT

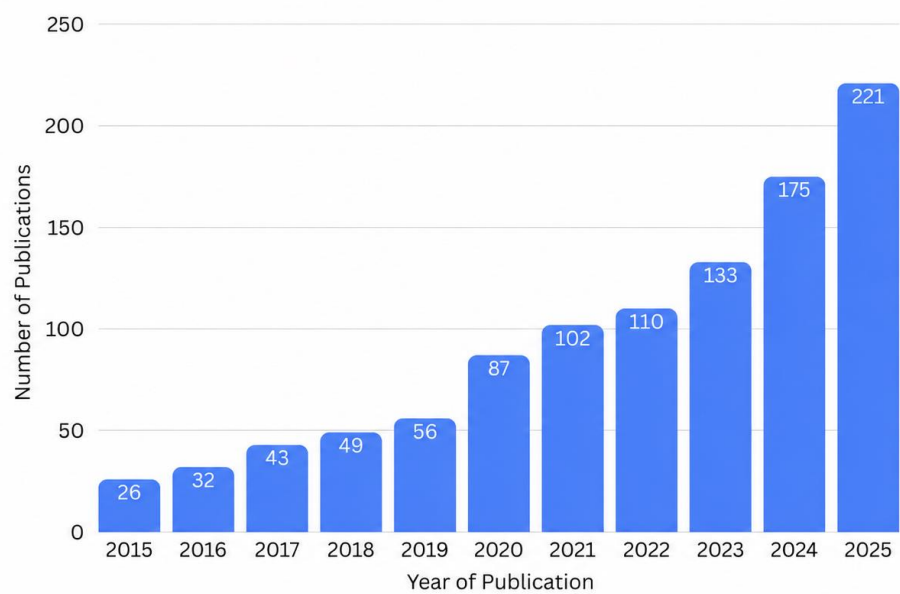
Global analysis of article output

The analysis of scientific output between 2015 and 2025, presented in Figure 2, shows continuous growth in research on the use of microorganisms to control agricultural pests. In 2015, 26 publications

were recorded, whereas this number reached 221 in 2025, demonstrating a substantial expansion of scientific interest in the topic.

During the initial years, growth occurred gradually, rising from 26 publications in 2015 to 56 in 2019. Beginning in 2020, however, a more pronounced acceleration can be observed, with 87 publications, followed by 102 in 2021, 110 in 2022, and 133 in 2023. This increase may be associated with the search for more sustainable alternatives to conventional pesticide use, as well as growing interest in biological control and integrated pest management.

Figure 2
Number of articles published per year from 2015 to 2025.



Source: Authors, 2026.

Growth became even more evident in the final years, with 175 publications in 2024 and 221 in 2025, the highest value in the entire series. This result indicates that the topic remains in expansion and is gaining prominence in agricultural research. Growing concern about the environmental impacts of pesticides, pest resistance, and the need for more sustainable agricultural systems may help explain this scenario.

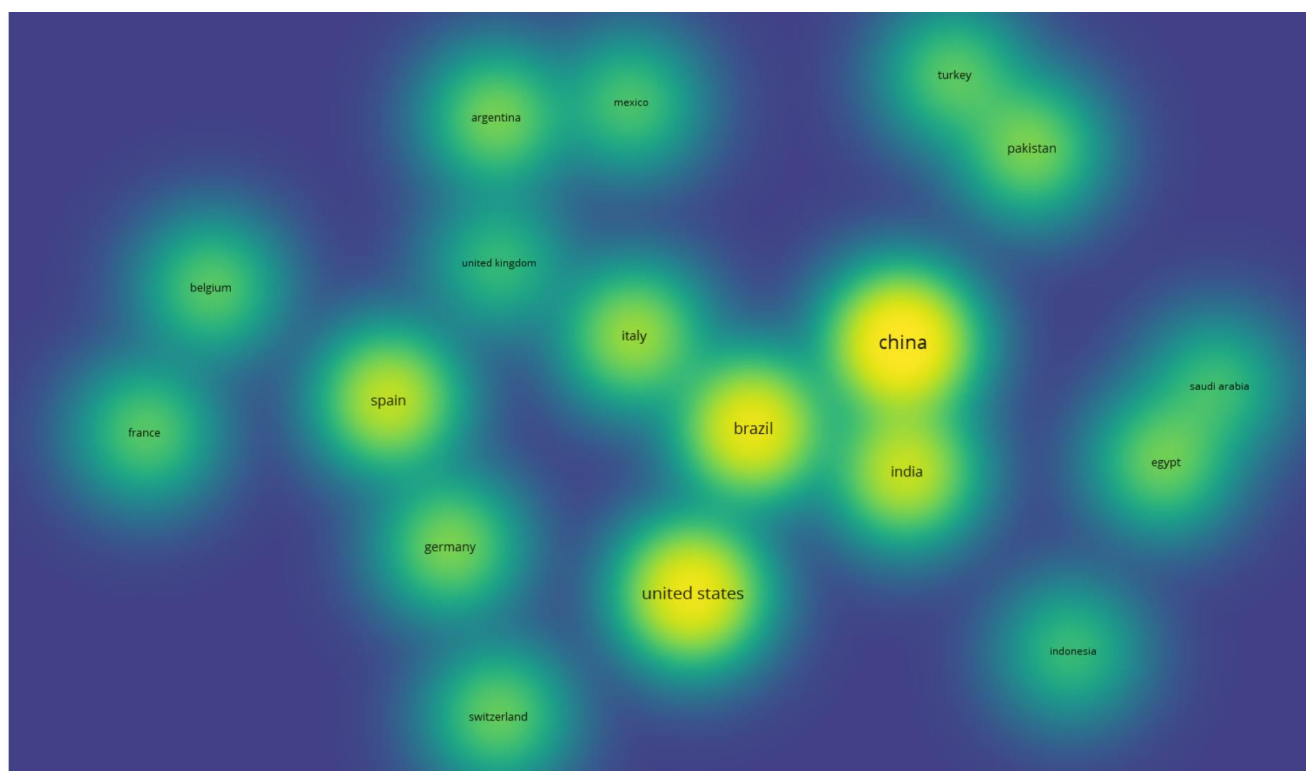
It is important to emphasize that the graph alone does not make it possible to determine which factors were responsible for the increase in publications. Nevertheless, it clearly demonstrates that the use of microorganisms for pest control is an increasingly relevant field of research.

The results therefore reveal a consistent upward trend in scientific output, reinforcing the potential of microorganisms as tools for developing more sustainable pest control strategies. This progress also highlights the importance of continuing to invest in research that evaluates their efficacy, environmental safety, and practical application in agriculture.

Figure 3 presents a geographical density visualization of scientific output, generated through country mapping. The bright yellow regions identify the principal areas of concentration and relevance in the field under study.

Figure 3

Geographical density visualization map of scientific output on the topic.



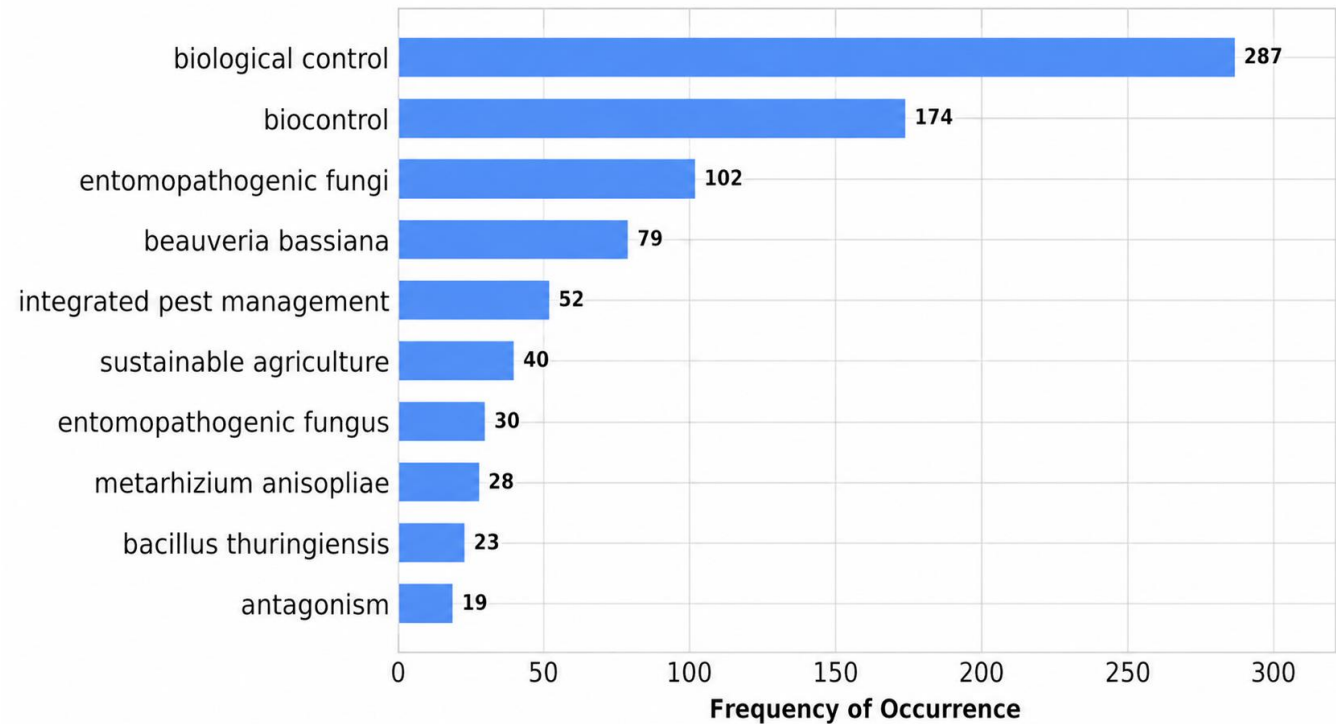
Source: Authors, 2026.

China and the United States predominate as the world’s leading centers of academic output density. Countries such as Brazil and Spain also play a central role as important bridges connecting different collaboration networks. While continental Europe forms a cohesive and well-distributed cluster, including Spain, Italy, Germany, and the United Kingdom, emerging and Middle Eastern countries such as Türkiye, Pakistan, and Egypt exhibit peripheral consolidation, indicating areas of recent expansion within the research field.

Prominent keywords

The general terms *biological control* (287) and *biocontrol* (174) exhibit clear predominance, confirming the centrality of the topic. Figure 4 illustrates the frequency of occurrence of the principal keywords identified in the literature analyzed.

Figure 4
Frequency of occurrence of the principal keywords.



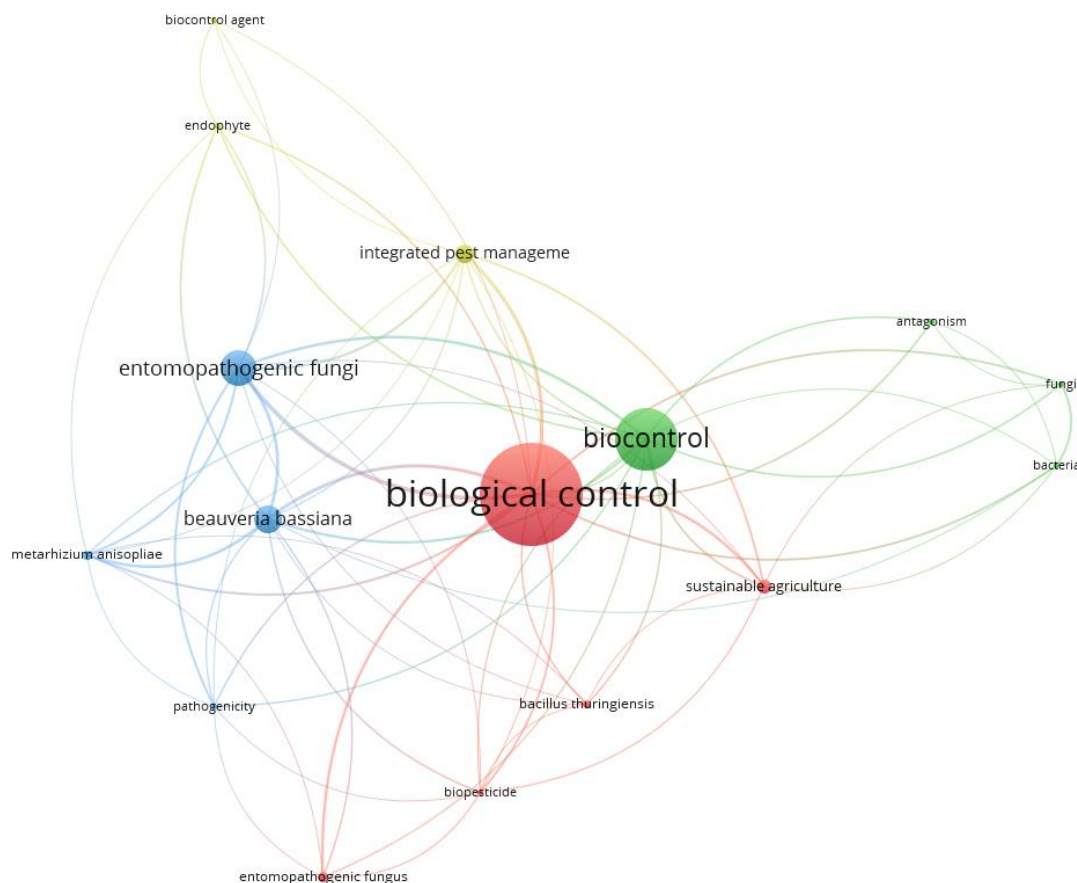
Source: Authors, 2026.

Among biological agents, entomopathogenic fungi play a particularly prominent role, standing out in both general terminology and taxonomic specification. *Beauveria bassiana* stands out as the most frequently investigated organism (79), surpassing other important control agents such as *Metarhizium anisopliae* (28) and *Bacillus thuringiensis* (23). In addition, the data reveal a strong association between the topic and applied, sustainable approaches to production, as demonstrated by the recurring concepts of *integrated pest management* (52) and *sustainable agriculture* (40), as well as mechanistic aspects such as *antagonism* (19).

VOSviewer can be used to generate a visualization of the connections among the most frequently used keywords. Figure 5 therefore shows the formation of three clusters and the relationships among them.

Figure 5

Network map of connections among the prominent keywords.



Source: Authors, 2026.

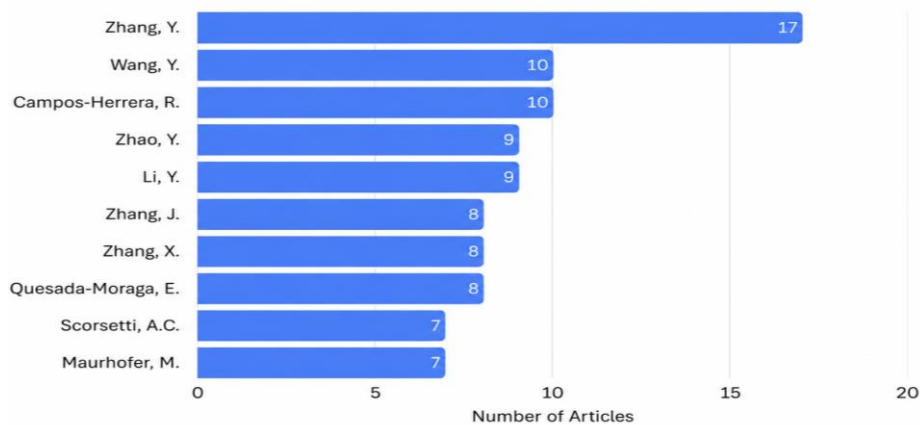
Node size reflects term frequency, while the edges indicate the strength of co-occurrence among the terms. *Biological control* and *biocontrol* act as the network’s central hubs, linking the other subfields. The mapping enabled the identification of distinct thematic clusters. The entomopathogenicity cluster, shown in blue, highlights the relevance of fungi in biocontrol, with strong links between the general term *entomopathogenic fungi* and key species such as *Beauveria bassiana* and *Metarhizium anisopliae*, which are associated with the attribute of *pathogenicity*. The inputs and sustainability cluster, shown in red, connects the practice of biological control with the development of new inputs, including *biopesticide* and *Bacillus thuringiensis*, and their role in *sustainable agriculture*. The integrated management cluster, shown in yellow, links system-level concepts such as *integrated pest management* to ecological aspects of plant-microorganism interactions, including *endophyte* and *biocontrol agent*.

Leading authors and journals

Academic leadership in the field is represented by researchers with substantial productivity and citation counts. The most productive author in the dataset is Zhang Y., with 17 publications and 446 citations, followed by Wang Y. and Campos-Herrera R., with 10 articles each, as shown in Figure 6.

Figure 6

Ranking of the 10 most productive authors.



Source: Authors, 2026.

BIBLIOMETRIC OVERVIEW OF SCIENTIFIC OUTPUT ON THE USE OF MICROORGANISMS IN THE BIOLOGICAL CONTROL OF AGRICULTURAL PESTS

However, this configuration changes when the authors are ranked by number of citations. Analysis of the most frequently cited authors reveals the presence of researchers with different levels of contribution and impact in the field of microorganism use for the control of agricultural pests. The 10 authors presented accounted for 93 documents and 2,341 citations, corresponding to an overall average of approximately 25.2 citations per document, as shown in Table 2.

Table 2

Ranking of the most frequently cited authors.

Author	Number of Articles	Citations	Average Citations
Zhang, Y.	17	446	26,24
Li, Y.	9	363	40,33
Quesada-Moraga, E.	8	343	42,88
Maurhofer, M.	7	285	40,71
Scorsetti, A.C.	7	222	31,71
Campos-Herrera, R.	10	170	17,00
Zhao, Y.	9	143	15,89
Zhang, X.	8	141	17,62
Zhang, J.	8	120	15,00
Wang, Y.	10	108	10,80

Source: Authors, 2026.

The data show substantial participation by a group of researchers in scientific output on the use of microorganisms to control agricultural pests. Among the authors analyzed, Zhang Y. exhibits the highest productivity, with 17 documents and 446 citations, standing out in terms of the number of studies published.

When the average impact of the publications is considered, the highest values belong to Quesada-Moraga E. (42.88 citations/document), Maurhofer M. (40.71), and Li Y. (40.33). Although these authors have fewer documents than Zhang Y., their studies have had a greater impact on the scientific literature.

Overall, the results demonstrate that productivity and scientific impact are not necessarily proportional. While some researchers stand out for the volume of their publications, others exert greater influence per published study.

Coauthorship relationships also form part of bibliometric analyses. The network visualization generated in VOSviewer presents the coauthorship network of the authors identified in the set of documents analyzed. The visualization shows the formation of two principal clusters, indicating different centers of scientific collaboration among the researchers, as presented in Figure 7.

Figure 7

Coauthorship network visualization map.



Source: Authors, 2026.

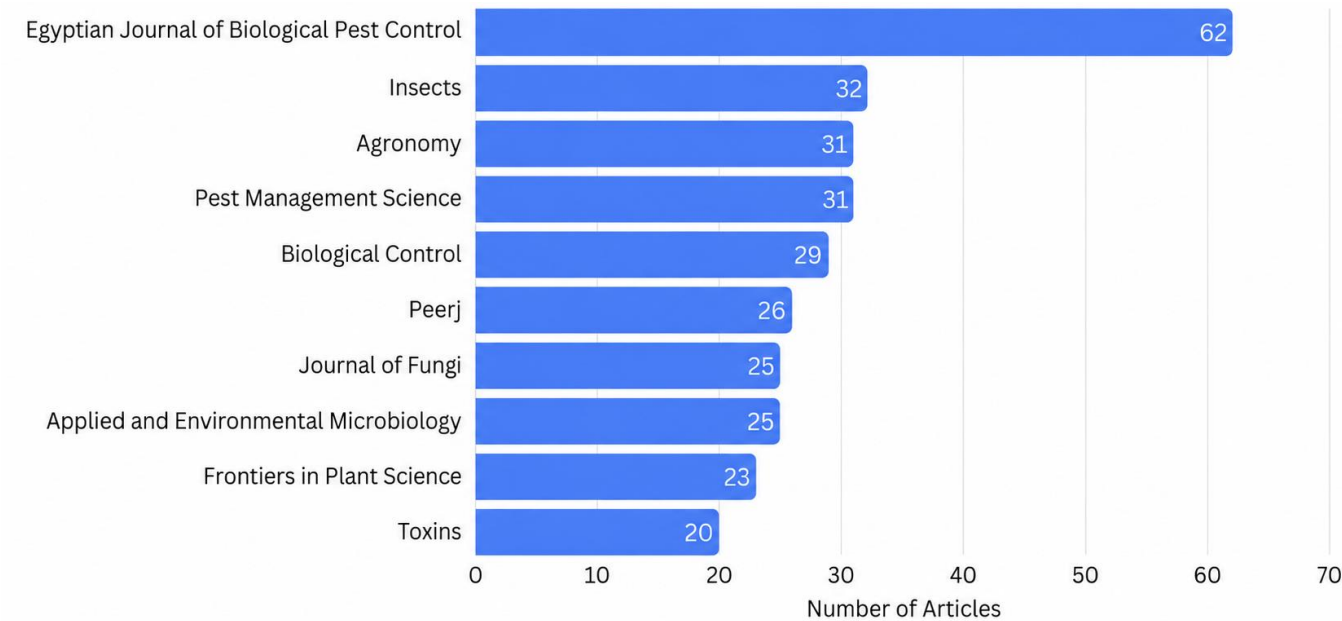
The absence of connections between the two clusters and the formation of a larger number of these networks demonstrate that no coauthorship relationships were identified between researchers belonging to different clusters within the set of documents analyzed. The network therefore reveals a relatively fragmented scientific collaboration structure, comprising groups of researchers whose work is concentrated within their own collaboration centers.

Figure 8 presents the 10 journals with the highest publication volumes on the topic investigated. The *Egyptian Journal of Biological Pest Control* clearly predominates, accounting for 62 articles and

standing out considerably from the other journals. It is followed by *Insects*, with 32 articles, and *Agronomy* and *Pest Management Science*, each with 31 published articles.

Figure 8

Ranking of the 10 journals with the most publications on the topic.



Source: Authors, 2026.

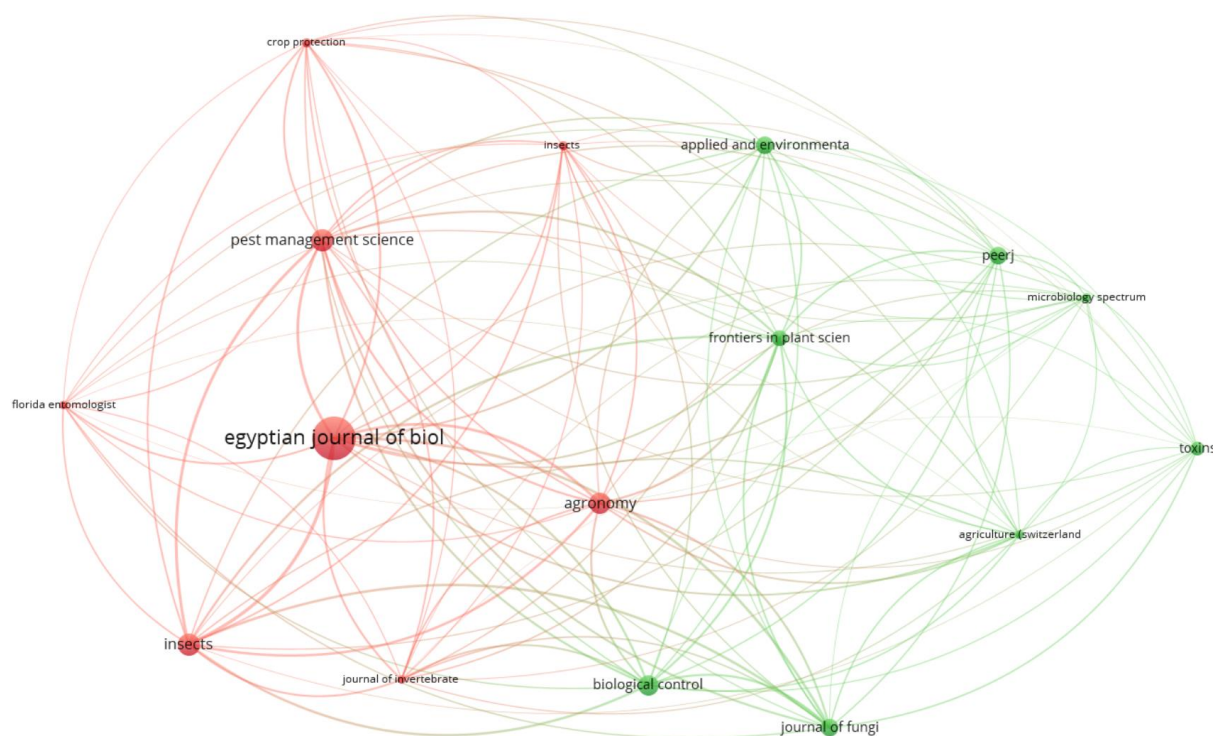
The observed distribution demonstrates that scientific output on the topic is concentrated primarily in journals directly related to biological control, entomology, pest management, agronomy, and microbiology. The prominence of the *Egyptian Journal of Biological Pest Control*, which accounted for 62 publications, demonstrates the importance of this journal as one of the primary outlets for disseminating the studies analyzed. Conversely, the presence of journals from different fields, such as *Journal of Fungi*, *Applied and Environmental Microbiology*, and *Toxins*, demonstrates the interdisciplinary nature of the topic, encompassing aspects related to microbiology, fungi, biological agents, and the production of metabolites or toxins with potential applications in the control of agricultural pests.

Figure 9 presents the relationship network among the journals that stood out in the scientific output analyzed, which was also produced using VOSviewer. Two principal clusters, identified by the

colors red and green, can be observed, demonstrating different centers of relationships among the journals.

Figure 9

Network map of relationships among the journals.



Source: Authors, 2026.

The red cluster primarily comprises journals related to the management and control of agricultural pests, with the *Egyptian Journal of Biological Pest Control* standing out as one of the network's central nodes because of its larger size and the number of connections established. *Pest Management Science*, *Insects*, *Agronomy*, *Crop Protection*, and *Florida Entomologist* also occupy prominent positions within this cluster. The proximity and number of links among these journals indicate a strong thematic association with studies focusing on pest control, crop protection, and agricultural entomology. The green cluster, in turn, is more strongly associated with biological control, microbiology, and plant sciences, comprising journals such as *Applied and Environmental Microbiology*, *Frontiers in Plant Science*, *PeerJ*,

Biological Control, *Journal of Fungi*, *Toxins*, and *Microbiology Spectrum*. The presence of these journals highlights the role of microbiological and biotechnological approaches in research on the biological control of pests.

CONCLUSION

The bibliometric analysis provided a comprehensive overview of the conceptual, intellectual, and dissemination structure of research on biological control. The results reveal that the field is organized around the sustainable pest management paradigm, fundamentally based on the use of entomopathogenic microorganisms.

From a conceptual perspective, the general terms *biological control* and *biocontrol* constitute the principal organizing axes of scientific output. Analysis of the keyword networks demonstrated that the literature is structured into three integrated domains: entomopathogenicity, with *Beauveria bassiana* playing a particularly prominent role compared with the other agents; the development of biotechnological inputs, including *biopesticides* and *Bacillus thuringiensis*, for sustainable agriculture; and integrated pest management, which connects systemic ecological approaches with plant-microorganism interactions.

Regarding the authorship structure, the data demonstrated that publication volume and scientific impact follow distinct dynamics. Although researchers such as Zhang Y. lead in terms of publication volume, authors such as Quesada-Moraga E., Maurhofer M., and Li Y. stand out for having the highest citation rates per document, indicating the substantial impact of their publications. In addition, analysis of the coauthorship network revealed a relatively fragmented scientific community characterized by isolated centers of collaboration, with no direct interconnections between the principal clusters.

Finally, the dissemination of scientific knowledge on the topic is both highly concentrated and interdisciplinary. The *Egyptian Journal of Biological Pest Control* stands out as the principal outlet in terms of published article volume and as a central node in the citation and academic relationship network.

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The coexistence of two large clusters of journals, one focused on entomology and applied plant protection and the other on microbiology, biotechnology, and plant sciences, reaffirms the field's transdisciplinary character, as it continuously moves from biotechnological and microbiological laboratory research to direct field application.

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