Telaah Sistematik

A bibliometric Analysis of Biopesticides in Mosquitoe Control : Current Trends and Future Prospects

A bibliometric Analysis of Biopesticides in Mosquitoe Control : Current Trends and Future Prospects

Mirnawati Dewi[1*], Fandi Tuju[1] , Wahyu Anggar Wanto[1]

[1] Biology Study Program, Faculty of Mathematics and Natural Science, Palangka Raya University, Central Kalimantan 73111, Indonesia

Kutipan: Dewi M., Tuju F., Wanto WA. A bibliometric Analysis of Biopesticides in Mosquitoe Control : Current Trends and Future Prospects ASP. Juni 2025: 16(1): 22–32

Editor: M. Nirwan
Diterima: 26 November 2024
Revisi: 8 Mei 2025
Layak Terbit: 17 Juli 2025

Catatan Penerbit: Aspirator tetap netral dalam hal klaim yurisdiksi di peta yang diterbitkan dan afiliasi kelembagaan.

Abstract. *Mosquitoes are insects that play a role in the balance of the ecosystem. However, some species of mosquitoes are detrimental because they act as disease carriers (vectors) for humans and animals. The increasing mosquito population is feared to have the potential to become a vector, prompting various efforts to reduce the population, including the use of biopesticides. This article aims to analyze and visualize the research trends on b biopesticides in mosquito control over the past 19 years and to identify potential research topics related to biopesticides for future studies. The methodology used in this article involves a literature review conducted through Publish or Perish and bibliometric analysis using the VOSviewer databases, which collectively encompass 1000 papers. Assessing scientific research progress is crucial for formulating goals and rationalizing future efforts. Based on the results of the bibliometric analysis, biopesticides derived from Bacillus thuringiensis, as well as bacteria, fungi, and other types of microbes, have the potential to be researched and developed as mosquito vector control biopesticide products. Microbial pesticides obtained from actinomycetes, Bacillus thuringiensis (Bt), B. sphaericus (Bs), Lysinibacillus sphaericusand, Saccharopolyspora spinosa, Wolbachia and many other microorganisms are reported as environmentally friendly alternatives for mosquito control.*

Keywords: *Bibliometric analysis, Biopesticide, Mosquito, Control*

Abstrak. *Nyamuk merupakan serangga yang memiliki peranan terhadap keseimbangan ekosistem. Namun sebagian spesies nyamuk merugikan karena berperan sebagai pembawa penyakit (vektor) bagi manusia dan hewan. Populasi nyamuk yang meningkat dikhawatirkan berpotensi sebagai vektor sehingga berbagai upaya yang dilakukan untuk menurunkan populasinya diantaranya yaitu biopestisida. Artikel ini bertujuan untuk menganalisis kemudian mevisualisasikan tren penelitian tentang biopestisida pada pengendalian nyamuk dalam 19 tahun terakhir, dan mengidentifikasi topik penelitian potensial terkait biopestisida pengendalian nyamuk pada penelitian mendatang. Metode pada artikel ini menggunakan tinjaun pustakan melalui Publish or Perish dan analisis bibliometrik menggunakan basis data serta VOSviewer yang mengumpulkan 1000 paper. Penilaian kemajuan penelitian ilmiah sangat penting untuk menyusun tujuan dan rasionalisasi di masa mendatang. Berdasarkan hasil analisis bibliometrik bahwa biopestisida yang berasal dari Bacillus thuringiensis, bakteri, jamur dan jenis mikroba lain berpontesi untuk diteliti dan dikembangkan sebagai produk bioepstisida pengendalian vektor nyamuk. Biopestisida mikroba yang diperoleh dari actinomycetes, Bacillus thuringiensis (Bt), B. sphaericus (Bs), Lysinibacillus sphaericusand, Saccharopolyspora spinosa, Wolbachia dan banyak mikroorganisme lainnya dilaporkan sebagai alternatif yang ramah lingkungan untuk pengendalian nyamuk.*

Kata Kunci: *Analisis bibliometrik, Biopestisida, nyamuk, pengendalian*

*Korespondensi Penulis
Email:mirnawatidewi22@mipa.upr.ac.id
Telp: +6285241077910

INTRODUCTION

The increase in human population worldwide has resulted in increased mobility for human activities. As a result, the spread of vector-borne and zoonotic diseases has also increased, including malaria and dengue fever transmitted by mosquitoes. Mosquitoes are insects, some species of which act as vectors of disease in humans and animals. The main strategy to control mosquito populations to date still relies on chemical control using synthetic pesticides. However, the use of these chemicals can be ecologically harmful as they can persist in soil and water for years, accumulate in the food chain, and cause further damage. These effects can be exacerbated by the leaching of synthetic pesticides into the aquatic environment which can cause adverse effects to aquatic organisms and species that use them as a food source[1–4]. In addition, the use of insecticides that work through a similar mechanism may cause some populations to become resistant [5]. It is known that exposure to insecticides from synthetic compounds is unavoidable [6–8]. Exposure to insecticides commonly leads to oxidative stress and physiological disorders, including Parkinson's disease, Alzheimer's disease, heart disease, and stroke as well as various respiratory and reproductive disorders[9].

So the application of these chemicals around the environment of residential areas can cause humans who live around the area to be exposed to disease. One type of insecticide that is widely used in the environment and households to control pest populations is Organophosphorus Insecticides (OP). However, this insecticide causes toxic effects on humans [10]. Another alternative to vector control is biological control using biological pesticides and plant-based pesticides called biopesticides, which is a possible way to minimize pollution and nuisance associated with the use of synthetic chemicals that greatly reduce their negative impact on the environment[11]. Biopesticides, defined as certain types of pesticides derived from natural sources such as plants, bacteria, fungi, animals, biological agents and some minerals, are potential alternative pesticides and are receiving increasing attention. However, there are several limitations that restrict the widespread use of such biopesticides. These limitations include cost, difficulty in production, and scarcity of appropriate biopesticide formulations. One thing is clear, however, that biopesticides have a promising future as they offer several advantages over conventional pesticides, including reduced environmental impact, minimal residue levels, biodegradability and target-specific mode of action [12,13] . The use of biopesticides in pest or vector management is a dynamic and growing field of research, characterized by continuous advances in technology, formulations, and application strategies [14].

To gain insight into the current status and prospects of biopesticides in vector control, this review uses a bibliometric analysis approach to systematically analyze the scientific literature on this topic. Bibliometric analysis provides a quantitative framework for assessing publication trends, identifying research focal points, mapping citation networks, and evaluating the impact of scientific contributions within a given field [14]. By synthesizing the collective knowledge and research efforts in biopesticides for mosquito vector control, this review aims to provide insights for researchers, policy makers, and practitioners seeking to improve the sustainability and cohesiveness of biopesticide research.

MATERIALS AND METHODS

This review used a descriptive quantitative systematic literature review (SLR) method.) Bibliometric analysis was used to analyze research on biopesticides for vector control. Data were collected by searching for articles in the google scholar database (Figure 1). The search was limited to articles published in the last twenty-two years (2002 to 2024). Data collected included original research articles, reviews, editorials and other relevant publications. The analysis focused on the annual number of publications, as well as details about the authors and their affiliations as indexed in the google scholar database. In addition, network maps were created to visualize the relationship between keywords and authors. Publish or Perish (PoP) and VOSviewer software were then used for bibliometric mapping and visualization to reveal patterns in this dataset. Following Amik Krismawati's [14] methodological framework and Niknejad, Nazari [15], This approach allows for the systematic evaluation of data, helping to identify key trends, leading authors, and emerging topics in biopesticide research for vector control. The reason for using data from google scholar is because google scholar provides extensive data and easy access and is free. In addition, the ability to identify from various sources so that the data obtained is more complete.

Publish or Perish (PoP).	Sources database	Keyword
	Google scholar	"Mosquito, "biopestisida""

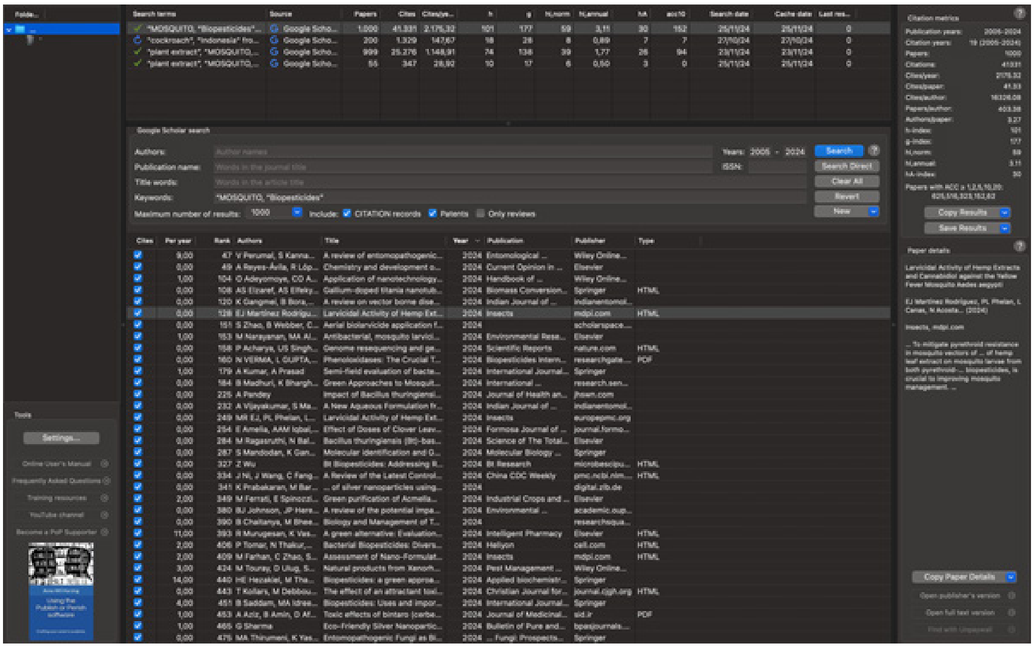

Figure 1. Source from Google Scholar using Publish or Perish Source: primary data processed by the author (2024)

RESULT

Data analysis

Analyze and visualize the data collected in this study to identify patterns, enhance insights, and present findings[14]. This study uses analytical techniques and visualization tools to explore bibliometric data collected from selected articles on vector control bipesticides. Through careful analysis and visualization, this study aims to shed light on important trends, relationships and characteristics in the scientific literature. It provides insights for researchers, policy makers, and practitioners who seek to improve the sustainability and cohesiveness of this research.

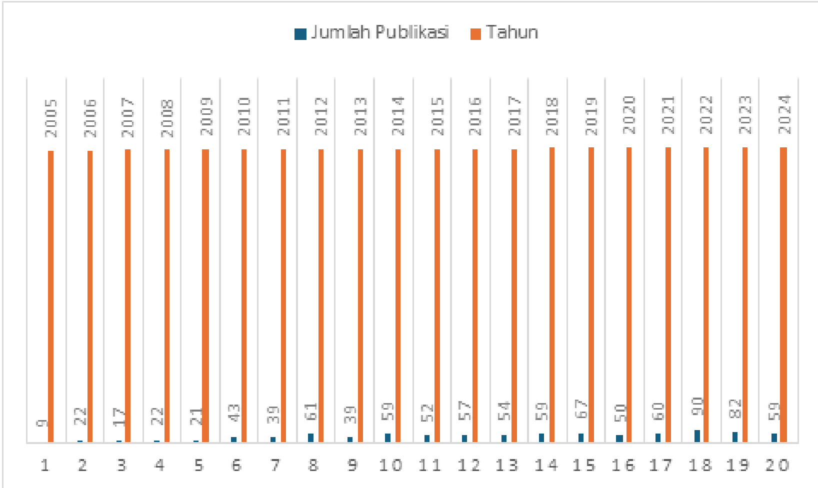

Figure 2. Annual publication results Biopesticides in vector/pest control Source: primary data processed by the author (2024)

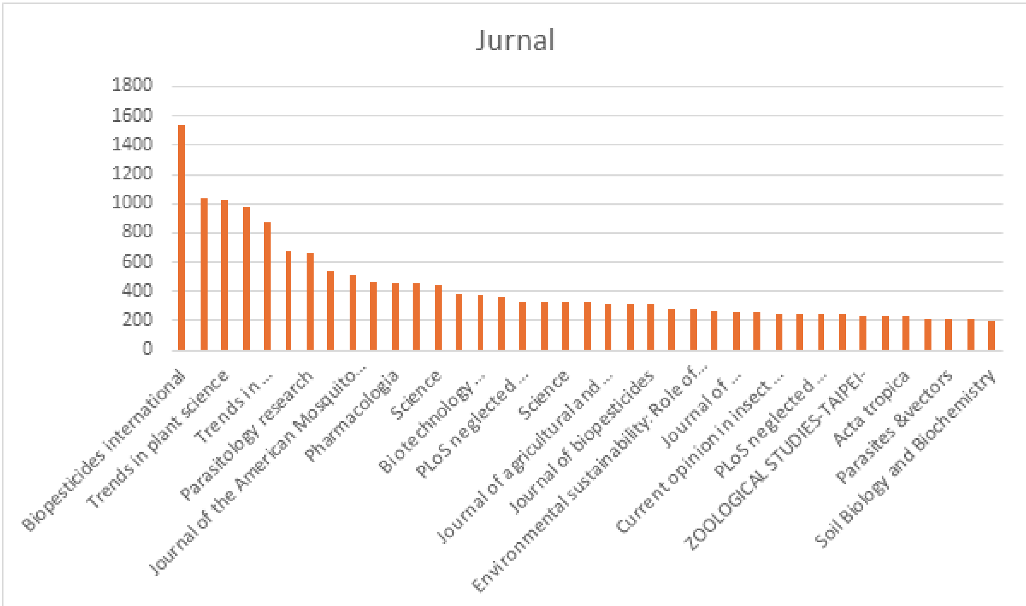

Figure 3. Top journals with the most citations related to biopesticides Source: primary data processed by the author (2024)

Science Mapping

Network Visualization

In this review, there are three visualizations, namely network visualization, overlay visualization, and density visualization that represent research data. The three visualizations using the keel device are vosviewer meta-analysis which includes meta-analysis with bibliometric methods Figure 4.

Overlay Visualization

The visualization of overlay frames on the potential of biopesticides in mosquito vector control shown in the figure below illustrates the relationship between words in a certain range of years (Figure 5).

Table 1. Identification of the most cited publications and 39 most cited articles in the context of biopesticides in mosquito vector control.

No	Penulis	Judul	Tahun	Total Sitasi
1	O Koul, S Walia, GS Dhaliwal	Essential oils as green pesticides: potential and constraints	2008	1533
2	D Chandler, AS Bailey, GM Tatchell...	The development, regulation and use of biopesticides for integrated pest management	2011	1040
3	R Pavela, G Benelli	Essential oils as ecofriendly biopesticides? Challenges and constraints	2016	1025
4	A Ghosh, N Chowdhury, G Chandra	Plant extracts as potential mosquito larvicides	2012	977
5	T Glare, J Caradus, W Gelernter, T Jackson...	Have biopesticides come of age?	2012	874
6	L Alphey, M Benedict, R Bellini, GG Clark...	Sterile-insect methods for control of mosquito-borne diseases: an analysis	2010	676
7	G Benelli	Research in mosquito control: current challenges for a brighter future	2015	663
8	Iturbe-Ormaetxe, T Walker, SL O'Neil	Wolbachia and the biological control of mosquito-borne disease	2011	541
9	LA Lacey	Bacillus thuringiensis serovariety israelensis and Bacillus sphaericus for mosquito control	2007	517
10	G Benelli, CL Jeffries, T Walker	Biological control of mosquito vectors: past, present, and future	2016	469
11	HF Khater	Prospects of botanical biopesticides in insect pest management	2012	457
12	Y Thakore	The biopesticide market for global agricultural use	2006	456
13	S Blanford, BHK Chan, N Jenkins, D Sim, RJ Turner...	Fungal pathogen reduces potential for malaria transmission	2005	447
14	MB Thomas, AF Read	Can fungal biopesticides control malaria?	2007	390
15	B Szewczyk, L Hoyos-Carvajal, M Paluszek...	Baculoviruses—re-emerging biopesticides	2006	375
16	SK Brar, M Verma, RD Tyagi, JR Valéro	Recent advances in downstream processing and formulations of Bacillus thuringiensis based biopesticides	2006	368
17	NL Achee, JP Grieco, H Vatandoost...	Alternative strategies for mosquito-borne arbovirus control	2019	332
18	J Kumar, A Ramlal, D Mallick, V Mishra	An overview of some biopesticides and their importance in plant protection for commercial acceptance	2021	324
19	W Fang, J Vega-Rodríguez, AK Ghosh...	Development of transgenic fungi that kill human malaria parasites in mosquitoes	2011	323
20	RS Lees, JRL Gilles, J Hendrichs, MJB Vreysen...	Back to the future: the sterile insect technique against mosquito disease vectors	2015	322
21	JN Seiber, J Coats, SO Duke...	Biopesticides: state of the art and future opportunitie	2014	316
22	N Komalamisra, Y Trongtokit, Y Rongsriyam...	Screening for larvicidal activity in some Thai plants against four mosquito vector species	2005	315
23	NK Dubey, B Srivastava, A Kumar	Current status of plant products as botanical pesticides in storage pest management	2008	312
24	MB Isman	A renaissance for botanical insecticides?	2015	281
25	S Senthil-Nathan	A review of biopesticides and their mode of action against insect pests	2014	280
26	TGT Jaenson, K Pålsson...	Evaluation of extracts and oils of mosquito (Diptera: Culicidae) repellent plants from Sweden and Guinea-Bissau	2006	270
27	Boonserm, M Mo, C Angsuthanasomba	Structure of the Functional Form of the Mosquito Larvicidal Cry4Aa Toxin from Bacillus thuringiensis at a 2.8-Angstrom Resolution	2006	261
28	ABB Wilke, MT Marrelli	Paratransgenesis: a promising new strategy for mosquito vector control	2015	253
29	NJ Dennison, N Jupatanakul, G Dimopoulos	The mosquito microbiota influences vector competence for human pathogens	2014	251
30	LB Carrington, CP Simmons	Human to mosquito transmission of dengue viruses	2014	246
31	L O'Connor, C Plichart, AC Sang...	Open Release of Male Mosquitoes Infected with a Wolbachia Biopesticide: Field Performance and Infection Containment	2012	245
32	S Arthurs, SK Dara	Microbial biopesticides for invertebrate pests and their markets in the United States	2019	244
33	R Kumar, JS Hwang	Larvicidal efficiency of aquatic predators: a perspective for mosquito biocontrol	2006	234
34	VK Dua, AC Pandey, K Raghavendra, A Gupta...	Larvicidal activity of neem oil (Azadirachta indica) formulation against mosquitoes	2009	232
35	R Pavela, F Maggi, R Iannarelli, G Benelli	Plant extracts for developing mosquito larvicides: From laboratory to the field, with insights on the modes of action	2019	229
36	L Ruiu	Microbial biopesticides in agroecosystems	2018	211
37	T Bukhari, W Takken, CJM Koenraadt	Development of Metarhizium anisopliae and Beauveria bassiana formulations for control of malaria mosquito larvae	2011	209
38	AFV Howard, G Zhou, FX Omlin	Malaria mosquito control using edible fish in western Kenya: preliminary findings of a controlled study	2007	207
39	RK Hynes, SM Boyetchko	Research initiatives in the art and science of biopesticide formulations	2006	204

Source: primary data processed by the author (2024)

Density Visualization

Science mapping in bibliometric analysis provides a visual representation of the density of a research topic through the density visualization feature in VOSviewer(12). Furthermore, the visualization of biopesticides in mosquito vector control can be seen in the Figure. 6

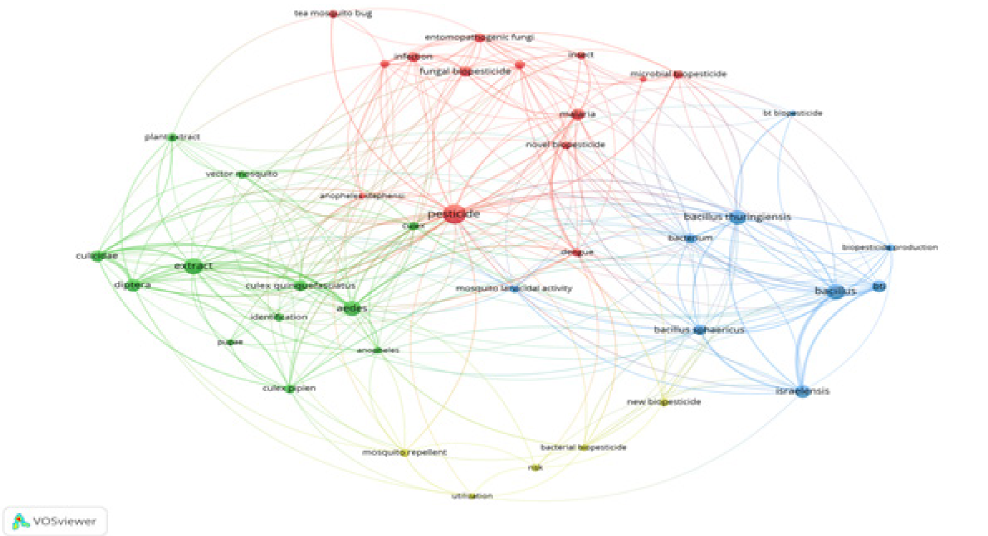

Figure 4. Network Visualization
Source: primary data processed by the author (2024)

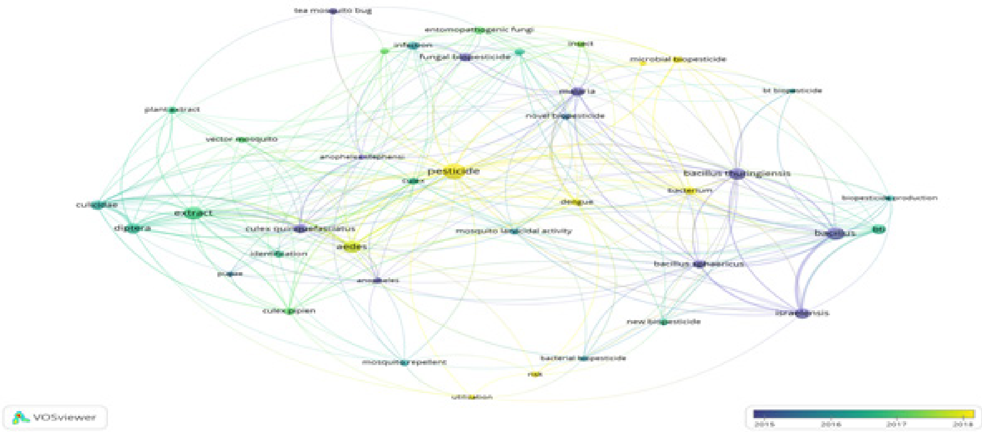

Figure 5. Overlay Visualization
Source: primary data processed by the author (2024)

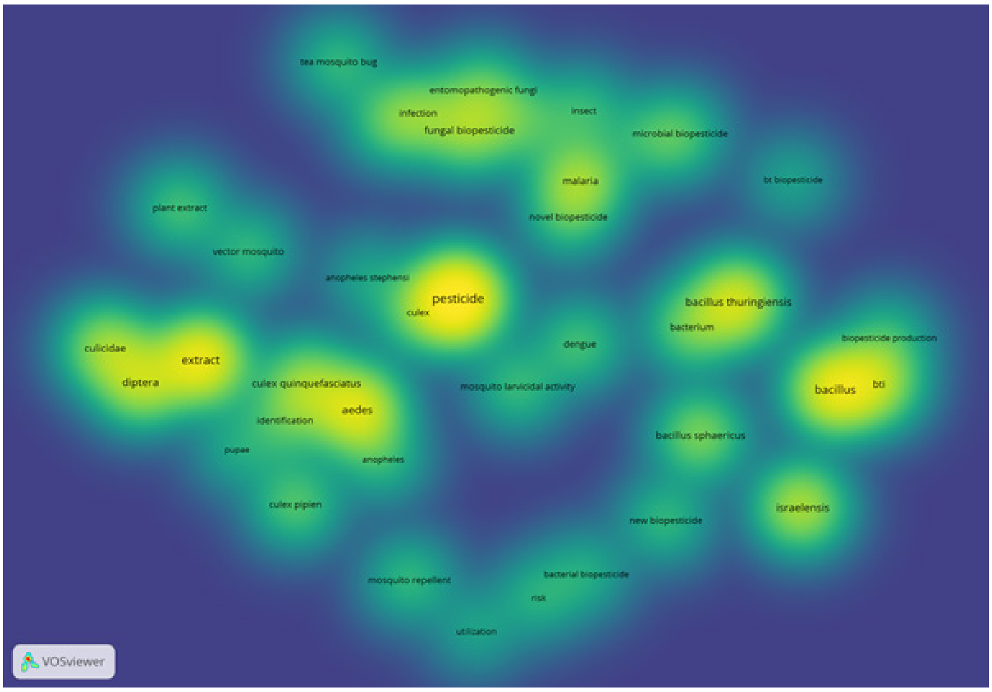

Figure 6. Density Visualization
Source: primary data processed by the author (2024)

DISCUSSION

Bibliometric Analysis

To assess the growth and evolution of research on bioepsticides for vector control, it is important to know and understand the annual output of scientific publications. In identifying patterns of research activity, including periods of expansion, stagnation or decline can be tracked based on the number of publications over several consecutive years. Furthermore, analysis of annual results enables identification of trends, such as the emergence of new research topics, shifts in research focus, and responses to evolving challenges and priorities in bipesticide research for vector control.

Figure 2 presents the results of annual publications on biopesticides in vector control from 2005 to 2024. However, some articles were not included in the data analysis because they did not include the year of publication. The graph provides a visual representation of the number of scientific publications released each year, which provides insight into the temporal trends and dynamics of research activity in the field of pest control science. A detailed examination of the graph reveals fluctuations in publication output over the 19 years, reflecting varying levels of scientific interest and productivity in biopesticides for vector control. For example, there are peaks in publication output observed in certain years, such as 2019, 2022, and 2023, indicating periods of increased research activity. Conversely, in the number of publications seen in years such as 2005 and 2007, which indicates a relatively lower level of scientific output during the period. Figure 3 visualizes the global distribution of journals with the most citations for research on biopesticides.

Overall, Table 1 provides a comprehensive overview of the global distribution of scientific publications on biopesticides in vector control. This analysis offers knowledge about research activities that contribute to a deeper understanding of the global research landscape in biopesticides for vector control.

Based on Figure 3 above, it can be seen that the network visualization illustrates the number as well as the relationship between keywords from 1000 articles. Circles of different colors reflect the keywords in the research data, while the size of the circles indicates the frequency present in the data [16]. From Figure 4, it can be seen that there are two keywords with the highest frequency, namely “pesticide”, “fungi biopesticide” and “malaria”. These three keywords are interconnected with other subtopics or keywords, as shown by the connecting lines between the various keywords. In the context of “biopesticide fungi”, there are several related keywords such as use, entamaphotegic fungi, and insect. Similarly, the topic “malaria” is related to various subtopics such as microbial pesticides, insects, and others. These two keywords show that beopesticides are often utilized by researchers in mosquito vector control testing.

When analyzing Figure 5, it can be seen that research trends on the potential use of biopesticides in mosquito vector control from 2005 to 2024 are marked in purple, green, and yellow. The color analysis of the overlay visualization shows that the brighter the color, the more recent the journal is; conversely, the darker the color, the older the publication. In the visual, the words “pesticide” and “bacillus” are far away from each other and have a larger size than other words.

The density or visualization of density is shown by the color of the dot which reflects the number of items at any given moment. Therefore, the brighter the color of the dot, the more publications related to the item or topic relevant to the research being conducted. In Figure 6, it can be seen that there are two most prominent dots, namely: pesticides and bacillus. This is in line with the visualization of the number of frequency distributions of topics that most often appear in the overlay visualization, namely the number of items related to pesticides and bacillus. Meanwhile, the other highest density value is found in the keywords pesticide while biopesticide production, microbial biopesticide, new biopesticide which is marked with a fainter greenish yellow color. Thus, it can be clarified that biopesticides for mosquito vector control still have the potential for research and development of biopesticide products in the future.

Potential of Biopesticides

Due to the weaknesses of synthetic pesticides, alternative means of pest and/or vector control are being encouraged, namely the use of biopesticides. [17,18.] Biopesticides are an effective and safer way to control pests, have less impact on the environment compared to synthetic pesticides, and are target-specific, thus preventing bioaccumulation. [19,20]. Biopesticides are made from natural materials, such as plants, microbes, and nanoparticles of biological origin, making them a sustainable way to control pests or vectors.[21].

Various studies have shown that biopesticides are environmentally friendly, have low toxicity, are biodegradable, and are specific in their action with little or no negative impact on non-target organisms [22]. Unlike biopesticides, conventional pesticides are a major source of environmental pollution, promoting pest resistance with high post-harvest contamination and bioaccumulation in food crops [23]. Microbial pesticides obtained from actinomycetes, *Bacillus thuringiensis* (Bt), *B. sphaericus* (Bs), *Lysinibacillus sphaericusand*, *Saccharopolyspora spinosa*, *Wolbachia* and many other microorganisms are reported as environmentally friendly alternatives for mosquito control [22,24]. In addition, some plants have potential as phytopesticides in mosquito control, namely *Cyperus esculentus* can inhibit the larvicidal activity of *Aedes aegypti* and *Culex quinquefasciatus* (Diptera: Culicidae) [25]. Meanwhile Cola Gigantea, Malacantha Alnifolia and Croton Zambesicus as Phytoinsecticides against Malaria Vector Anopheles Stephensi (Diptera: Culicidae). Essential Oil of Matricaria chamomilla and its Components (E)-β-Farnesene, Germacrene D, and α-Bisabolol Oxide A have the potential to inhibit Malari vectors and Zika Virus Vectors [26].

Future Prospects

Cases of infectious and zoonotic diseases are still encountered worldwide, but the advent of synthetic pesticides has helped suppress mosquito populations, reducing cases of infectious and zoonotic diseases. However, the negative impacts of synthetic pesticides limit their use, thus, encouraging the use of biological pesticides [27]. Since biopesticides have proven to be a good alternative to chemical pesticides, it would be imperative to explore them for maximum use in mosquito vector population control. The demand and availability of biopesticides are very low, discouraging their producers and users, respectively. Therefore, providing grants or capital to researchers, entrepreneurs, producers and marketers will help increase the production and availability of biopesticides.

The shelf life of biopesticides is short, as they require special temperatures and conditions to survive during transportation and storage. Therefore, further research to uncover mechanisms to make biopesticides more stable and increase their shelf life would be helpful in improving their efficiency.

The fact that biopesticides have no residual effects on the environment can be both an advantage and a disadvantage. Therefore, further research should be conducted to combine plant-based and biological pesticides and other sustainable methods, which can be used to improve the resistance of biopesticides in the environment. Therefore, it is important to conduct further research on the compatibility of various biopesticides. Awareness about the use and health effects of biopesticides on humans will also help to promote good environment and health. Due to the many challenges still faced with the use of biopesticides.

CONCLUSION

Based on the above discussion, there is an overview of the potential of biopesticide research in mosquito vector control. This picture was revealed through bibliometric analysis using PoP and Vosviewer methods. The results of this analysis also indicate that future research in biopesticides for mosquito vector control should prioritize improving formulation techniques to increase efficacy and stability, especially under variable environmental conditions.

AUTHOR'S CONTRIBUTION

All the authors in this article, Mirnawati Dewi and Fandi Tuju, have equal contributions. Details of each author's contribution can be seen in the following details:

Contribution Role	Contributor
Concept, Data processing and analysis	Mirnawati Dewi
Editing and translating	Fandi Tuju
Review, Proofreading and layouting	Wahyu Anggar Wanto

REFERENCE

1. Dewi M, Kristin J. Penerapan Kecerdasan Buatan dalam Penelitian Demam Berdarah: Analisis Bibliometrik. Jurnal Surya Medika [Internet]. 2025 Apr 25;11(2):222–7. Available from: https://journal.umpr.ac.id/index.php/jsm/article/view/9755
2. Ireland D, Rabeler C, Gong TX, Collins EMS. Bioactivation and detoxification of organophosphorus pesticides in freshwater planarians shares similarities with humans. Arch Toxicol. 2022;96(12).
3. Leonel Javeres MN, Habib R, Judith N, Iqbal M, Nepovimova E, Kuca K, et al. Analysis of PON1 gene polymorphisms (rs662 and rs854560) and inflammatory markers in organophosphate pesticides exposed cohorts from two distinct populations. Environ Res. 2020;191.
4. Sarwar M, Rasool B. Seasonal Prevalence and Phenomenal Biology as Tools for Dengue Mosquito Aedes aegypti (Linnaeus) (Diptera: Culicidae) Management. Brazilian Archives of Biology and Technology. 2022;65.
5. Richardson EB, Troczka BJ, Gutbrod O, Davies TGE, Nauen R. Diamide resistance: 10 years of lessons from lepidopteran pests. Vol. 93, Journal of Pest Science. 2020.
6. Said M. An Overview of Impact of Agrochemicals on Human Health and Natural Environment. Scientific Research Communications. 2023;3(2).
7. Kollars T, Carder M, Debboun M, McPhatter L. The effect of an attractant toxic sugar bait (ATSB) incorporating Bacillus thuringiensis israelensis and methoprene on mosquito populations. Christian Journal for Global Health.

2024;11(1).

8. Mohaddab M, El Goumi Y, Gallo M, Montesano D, Zengin G, Bouyahya A, et al. Biotechnology and In Vitro Culture as an Alternative System for Secondary Metabolite Production. Vol. 27, Molecules. 2022.
9. Algharably EA, Di Consiglio E, Testai E, Pistollato F, Bal-Price A, Najjar A, et al. Prediction of in vivo prenatal chlorpyrifos exposure leading to developmental neurotoxicity in humans based on in vitro toxicity data by quantitative in vitro–in vivo extrapolation. Front Pharmacol. 2023;14.
10. Mostafalou S, Abdollahi M. The susceptibility of humans to neurodegenerative and neurodevelopmental toxicities caused by organophosphorus pesticides. Vol. 97, Archives of Toxicology. 2023.
11. Gois MFB, Fernández-Pato A, Huss A, Gacesa R, Wijmenga C, Weersma RK, et al. Impact of occupational pesticide exposure on the human gut microbiome. Front Microbiol. 2023;14.
12. Ayilara MS, Adeleke BS, Akinola SA, Fayose CA, Adeyemi UT, Gbadegesin LA, et al. Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides. Vol. 14, Frontiers in Microbiology. 2023.
13. Khursheed A, Rather MA, Jain V, Wani AR, Rasool S, Nazir R, et al. Plant based natural products as potential ecofriendly and safer biopesticides: A comprehensive overview of their advantages over conventional pesticides, limitations and regulatory aspects. Vol. 173, Microbial Pathogenesis. 2022.
14. Krismawati A, Yustisia Y, Arifin Z, Purbiati T, Rachmawati D, Latifah E, et al. A bibliometric analysis of biopesticides in corn pest management: Current trends and future prospects. Vol. 10, Heliyon. Elsevier Ltd; 2024.
15. Niknejad N, Nazari B, Foroutani S, Hussin AR bin C. A bibliometric analysis of green technologies applied to water and wastewater treatment. Environmental Science and Pollution Research. 2023;30(28).
16. Averta SO, Putri RA, Malika FF, Fajar MA, Rienovita E. Potensi Pemanfaatan Aplikasi Canva Sebagai Alat Kreatifitas Guru Dalam Mendesain Media Pembelajaran Interaktif : Analisis Bibliometrik Dengan Metode Prisma. Edutech. 2024 Jun 3;23(2):189–201.
17. Ojuederie OB, Chukwuneme CF, Samuel O, Modupe Ayilara O, Adegboyega TT, Babalola OO. Contribution of Microbial Inoculants in Sustainable Maintenance of Human Health, including Test Methods and Evaluation of Safety of Microbial Pesticide Microorganisms. In: Biopesticides: Botanicals and Microorganisms for Improving Agriculture and Human Health. 2021.
18. Ayilara MS, Adeleke BS, Akinola SA, Fayose CA, Adeyemi UT, Gbadegesin LA, et al. Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides. Vol. 14, Frontiers in Microbiology. Frontiers Media SA; 2023.
19. Saberi F, Marzban R, Ardjmand M, Pajoum Shariati F, Tavakoli O. Optimization of culture media to enhance the ability of local Bacillus thuringiensis var. tenebrionis. Journal of the Saudi Society of Agricultural Sciences. 2020;19(7).
20. Wanasiri N, McGovern RJ, Cheewangkoon R, To-Anun C. Efficiency of antifungal compounds against powdery mildew disease of rose (Podosphaera pannosa). International Journal of Agricultural Technology. 2020;16(1).
21. Tudi M, Li H, Li H, Wang L, Lyu J, Yang L, et al. Exposure Routes and Health Risks Associated with Pesticide Application. Vol. 10, Toxics. 2022.
22. Daraban GM, Hlihor RM, Suteu D. Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health.

Vol. 11, Toxics. 2023.

23. Fenibo EO, Ijoma GN, Matambo T. Biopesticides in Sustainable Agriculture: A Critical Sustainable Development Driver Governed by Green Chemistry Principles. Front Sustain Food Syst. 2021;5.
24. Elzaref AS, Elfeky AS, El-Adawy HA, Awad MA, El-Bahy ZM. Gallium-doped titania nanotubes as advanced photocatalysts and biopesticides: a path to water purification and vector control. Biomass Convers Biorefin [Internet]. 2024 Nov 20; Available from: https://link.springer.com/10.1007/s13399-024-06334-2
25. Avicor SW, Wajidi MFF, Achoribo ES, Ong MT, Hamzah SN. Tiger nut (Cyperus esculentus) as a potential phytoinsecticide: Larvicidal activity of crude extracts on aedes aegypti and culex quinquefasciatus (diptera: Culicidae). Trop Biomed. 2021;38(2):186–91.
26. Al-Ghanim KA, Krishnappa K, Pandiyan J, Nicoletti M, Gurunathan B, Govindarajan M. Insecticidal Potential of Matricaria chamomilla's Essential Oil and Its Components (E)-β-Farnesene, Germacrene D, and α-Bisabolol Oxide A against Agricultural Pests, Malaria, and Zika Virus Vectors. Agriculture (Switzerland). 2023 Apr 1;13(4).
27. Katak R de M, Cintra AM, Burini BC, Marinotti O, Souza-Neto JA, Rocha EM. Biotechnological Potential of Microorganisms for Mosquito Population Control and Reduction in Vector Competence. Vol. 14, Insects. 2023.