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Bibliometric Analysis of Pest Management

Loso Judijanto
IPOSS Jakarta, Indonesia

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ABSTRACT

Pest management research has gained a considerable importance among scholars because of growing problems associated with agricultural efficiency, environmental sustainability, development of pesticide resistance, and food safety issues. In this paper, the objective is to investigate the growth, intellectual structure, collaborations, and future trends of global pest management research with the help of bibliometric analysis. The data used in the current study are obtained from scientific publications indexed in an international academic database and analyzed through VOSviewer in order to identify authorship networks, co-occurrence of keywords, citation structure, and time-related developments of the research. The results of the study show that pest management research is highly concentrated around certain topics that include pest control, pest management, biological control, insect control, pesticide application, and integrated pest management (IPM). The citation analysis proves that important studies have been involved in the process of change from traditional chemical pest management towards ecological and sustainable pest management strategies including habitat management, biopesticides, conservation of natural enemies, and biological control. The collaborations analysis proves that such countries as the USA, China, India, Australia, and several European countries are actively participating in knowledge production on the global scale but there are still opportunities for enhancing research cooperation between countries. Finally, the analysis of keyword evolution suggests that the attention of researchers focuses on sustainability, invasive species management, biotechnology, and ecological pest management techniques.

Corresponding Author:

Name: Loso Judijanto
Institution: IPOSS Jakarta
Email: losojudijantobumn@gmail.com

1. INTRODUCTION

Pest management is arguably one of the key aspects of sustainability within agriculture since there is still a threat posed by pests, pathogens, and many other types of destructive organisms to global food security, agricultural productivity, and environmental stability. Rising demands on food production due to the population growth, climatic variations, and changing land use practices have made the problem more complicated than ever [1], [2]. Pests of agriculture cause substantial crop losses around the world, which leads to reduced quantity and quality of agricultural products. According to the Food and Agriculture Organization, pests and

diseases are some of the key factors limiting global crop production and causing considerable economic implications [3], [4]. Thus, pest management has become crucial in terms of agricultural productivity and sustainability.

Throughout history, pest control has mainly been based on chemical pest control practices through excessive usage of synthetic pesticides. Even though synthetic pesticides have helped increase yields from agriculture considerably, misuse and overuse of these chemicals have led to many ecological and human health problems such as pesticide resistance, decrease in biodiversity, degradation of soils, and pollution of water resources [5], [6]. Resistance development in pests against chemical pesticides has not only decreased efficiency of chemical control measures but also created new obstacles to the sustainability of agriculture. This situation has motivated scholars and practitioners to create new pest control systems based on ecological principles, innovative technology, and interdisciplinarity. Integrated Pest Management (IPM) can be identified as one of the most notable systems of pest management using biological, cultural, monitoring systems, and selective pesticides for pest control [7].

There have been many developments in sustainable pest management through advancements in biological sciences, information technology, and data-based agriculture. Some of the recent developments include biological control, precision agriculture, remote sensing, artificial intelligence, molecular approaches, and decision-support tools, which provide more accurate ways of detecting pests and making interventions. The use of such technological developments has made it possible to shift pest management from being reactive to being proactive and predictive [7], [8]. In addition, pest management is now multi-dimensional due to climate change as factors such as changes in temperature, precipitation, and disturbances in ecosystems affect pests' distribution and occurrence [9]. Hence, pest management has become multidisciplinary involving agriculture, ecology, biotechnology, environmental science, and information technologies.

Increased complexity of issues related to pest management has brought about rapid growth in scientific articles published in different fields of research. Researchers from all over the world have analyzed a number of issues related to pest management, such as biological control, insecticide resistance, sustainable agriculture, precision farming, pest prediction, and ecosystem-based management. Growth of the amount of scientific literature is both an opportunity and a challenge to comprehend the evolution of the entire field. Though many articles have contributed greatly to the field, the fragmented character of research output makes it challenging to detect research trends, significant contributions, collaborative networks, and emerging topics. Bibliometric analysis is an effective methodological tool that helps to overcome this challenge through quantitative analysis of scientific publications and identification of intellectual structure and evolution of a research field [10].

The use of bibliometric analysis has grown significantly in agricultural and environmental sciences owing to its ability to help researchers analyze publication trends, citation performance, research collaborations, and theme emergence. Bibliometric research through methods like citation analysis, co-authorship analysis, keyword co-occurrence analysis, and science mapping provides comprehensive insight into the way scientific knowledge evolves over time. In relation to pest management, bibliometric analysis can help reveal major themes in research, prominent authors and institutions, methodology changes, and areas that could be researched further. Bibliometric analysis becomes especially useful as pest management research is an evolving area which is affected by technology changes, environmental issues, and agriculture trends.

Despite the intense interest in pest management research from scholars in different fields, the overall scope, knowledge structure, and trends of development of this domain have not been well explored. Current studies mainly concentrate on certain

subfields of pest management research like pesticide resistance, biological control, integrated pest management, and precision agriculture without giving a general picture of development of global research in this area. The lack of systematic analysis of publication trends, major research contributions, collaboration patterns, and research trend evolution prevents the recognition of gaps and formulation of research directions. That is why the need for bibliometric analysis appears in order to assess the development of pest management research.

The purpose of this research is to analyze the literature in pest management through bibliometrics by analyzing the trends in publications, citation structures, influential authors, international collaborations, and new research trends. This research is intended to utilize bibliometric methods in order to have a comprehensive picture on the evolution of pest management knowledge, to pinpoint significant intellectual achievements in this research area, and point out possible avenues for further research. It is hoped that the results will help advance research on sustainable pest management by giving a systematic review of the scientific developments.

2. METHODS

In this paper, bibliometric analysis methodology was adopted to study the evolution, structure, and development of research on pest management. The choice of bibliometric analysis methodology was due to its ability to conduct the quantification of scientific publications using statistical and visualization methods, thus making it possible for scientists to find out publication trends, significant studies, collaboration, and new research topics within a certain field of knowledge [10]. The bibliometric analysis was carried out in accordance with the methodology that involved data gathering, performance analysis, and science mapping, thus giving an overall view of global research on pest management. This analysis was based on scientific publications on pest management without limiting the scope of the research to a particular agricultural system or location.

The bibliographic data were sourced from the Scopus database, the choice of which is justified by its wide coverage of peer-reviewed scientific literature and applicability in bibliometric analyses (Baas et al., 2020). The keywords used for the search included such phrases as “pest management,” “integrated pest management,” “biological control,” and others relevant to the research topic. The search was performed with the use of title, abstract and keyword fields in order to retrieve the documents that have direct connection to the topic. The screening of the retrieved records was conducted according to the inclusion/exclusion criteria, which included the document type, relevancy and completeness of bibliographic information.

The data collected were analyzed with the help of Bibliometrix using the R programming platform and VOSviewer software to conduct descriptive and network analysis. The bibliometric performance analysis was done to study the growth of publications, citation impact, productive authors, influential journals, and leading countries involved in pest management studies. Moreover, science mapping tools were used, which included the analysis of keywords co-occurrence, co-authorship analysis, and citation network analysis to recognize the conceptual structure, collaborative networks, and key research clusters of pest management [11].

3. RESULT AND DISCUSSION

3.1 Co-Author Analysis

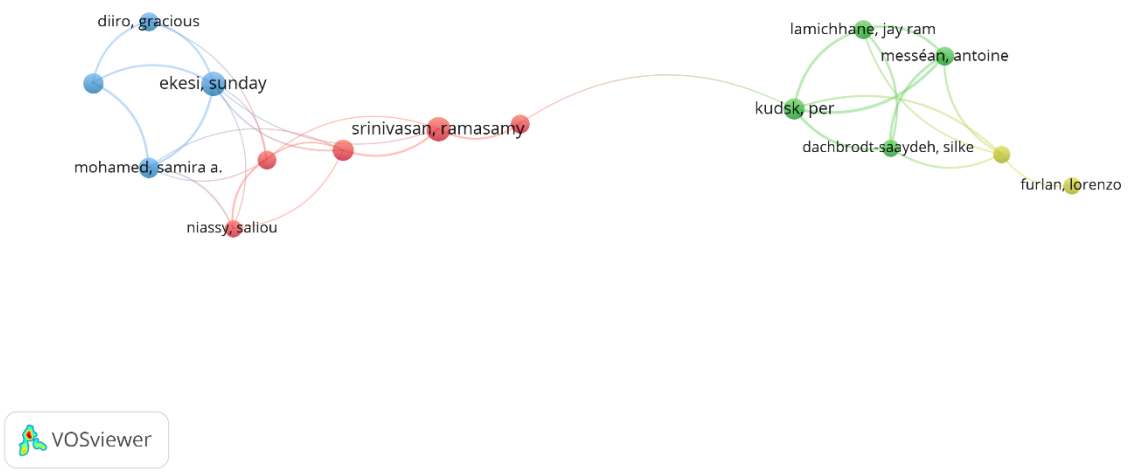

Figure 1. Author Visualization
Source: Data Analysis

The author collaboration network in pest management research is shown in Figure 1. According to the figure, scientific collaboration can be represented in several relatively small clusters, which means that research in this sphere is carried out by certain research groups and not in a well-connected global scientific community. The left part of the map shows the biggest collaboration cluster, where authors like Ekesi Sunday, Mohamed Samira A., Diiro Gracious, Niasse Salifou, and Srinivasan Ramasamy are presented. These authors have relatively intensive cooperation relations between each other, which means that there is an active research group working on similar themes in pest management, including agricultural pest control and biological management.

Another independent collaborative group can be seen on the right side of the map, including researchers like Lamichhane Jay Ram, Messaian Antoine, Kudsk Per, Dachbrodt-Saaydeh Silke, and Furlan Lorenzo. This collaboration group indicates the existence of another research group that has its own collaboration style. It may be concerned with pesticide management, integrated pest management, and regulation of the crop protection process. The fact that there are not many links between the two major collaboration groups means that collaboration among various research communities is still rather low. It implies the possibility for further research development by increasing international and interdisciplinary collaboration.

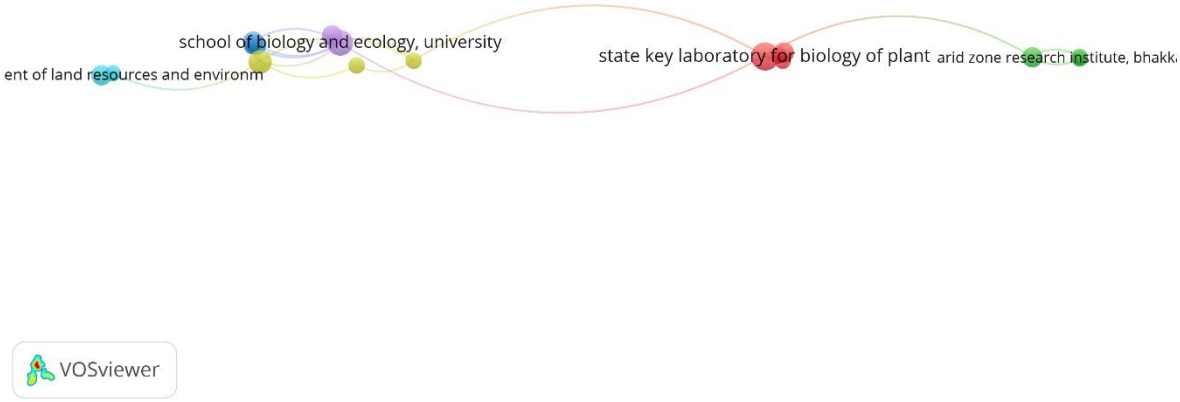

Figure 2. Institution Visualization
Source: Data Analysis

Figure 2 provides information about the network analysis of institutional collaboration in pest management research. From the diagram, one can understand that collaboration in pest management research among various institutions is low and confined to some clusters. It can be clearly observed from the diagram that the most noticeable collaboration between two institutions exists between State Key Laboratory for Biology of Plant Diseases and Insect Pests and Arid Zone Research Institute, as both these institutions are involved in research concerning the subject of pest management in agriculture and plant protection. The other collaboration cluster includes School of Biology and Ecology, University, collaborating with institutions engaged in land resource and environmental research.

Nonetheless, the comparatively low number of nodes and the relatively low level of connectedness indicate that institutional cooperation in the study of pests is not cohesive. This network is indicative of the presence of research centers focused on their own scientific fields, although international cooperation among institutions in terms of the study of pests does not seem to be sufficiently developed. Future studies may take advantage of international institutional cooperation and bring into play knowledge from such areas as plant pathology, ecology, environmental science, and agricultural technology.

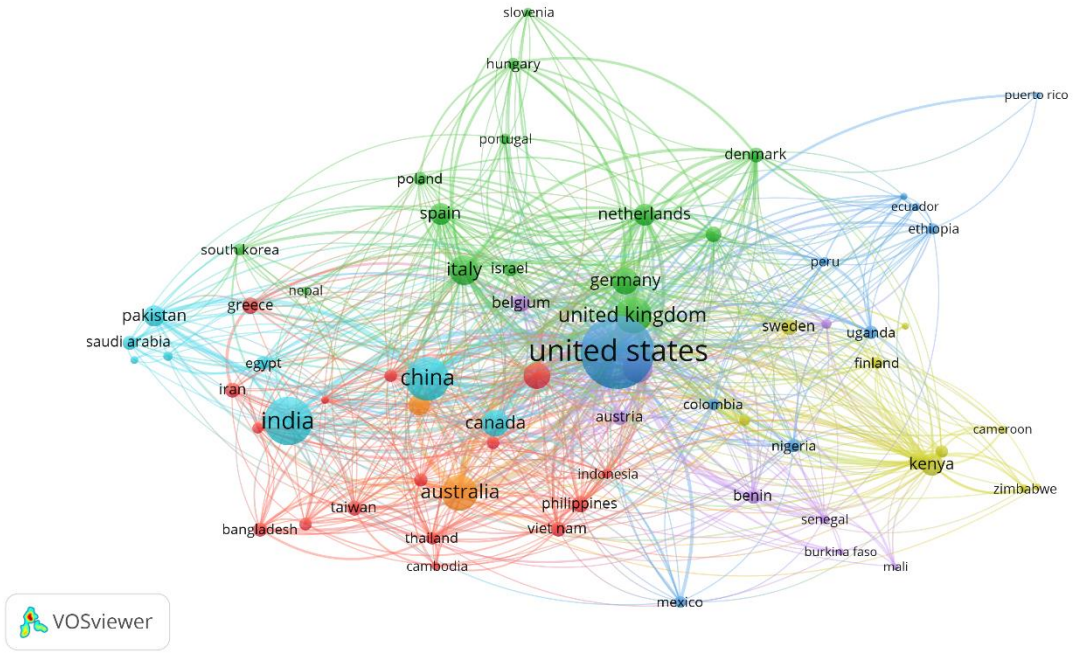

Figure 3. Country Visualization
Source: Data Analysis

Figure 3 shows the international cooperation network for research on pest management. The network clearly highlights the extent of connectivity in the global research landscape, involving many countries, with the United States being the largest and most influential country due to its size and high interconnectivity with other countries. This shows that the United States is an important country in the area of pest management research through international cooperation. Other highly connected countries include China, India, Australia, United Kingdom, Germany, Italy, and Canada, which are some of the important research centers contributing greatly to the creation of knowledge in the area.

3.2 Citation Analysis

Table 1. Top Cited Literature

Citations	Authors and Year	Title
2486	[12]	Habitat management to conserve natural enemies of arthropod pests in agriculture
2105	[13]	Plant essential oils for pest and disease management
1343	[14]	The use of push-pull strategies in integrated pest management
951	[15]	Sex pheromones and their impact on pest management
870	[16]	Eight principles of integrated pest management
723	[17]	The development, regulation and use of biopesticides for integrated pest management
673	[18]	Pesticide-Induced Stress in Arthropod Pests for Optimized Integrated Pest Management Programs
665	[19]	Sterile insect technique: Principles and practice in area-wide integrated pest management
647	[20]	Integrated pest management: good intentions, hard realities. A review
642	[21]	A review of the invasion of Drosophila suzukii in Europe and a draft research agenda for integrated pest management

Source: Scopus 2026

The most cited publications in the area of pest management research can be seen in Table 1 below. From the findings, highly cited publications are mainly concerned with research into sustainable or integrated pest management (IPM) approaches. In this respect, the most cited paper, namely "Habitat Management to Conserve Natural Enemies of Arthropod Pests in Agriculture" by [12], was cited 2,486 times. This reflects the significance attached to ecological methods of boosting the number of natural enemies of pests as an alternative to chemical pest management approaches. Furthermore, [22] made significant contributions in plant essential oils in his research. Other papers stress innovation in IPM approaches such as push–pull approaches [14], pheromone-based pest management [15], biopesticides [17] and sterile insect techniques [23].

This citation trend highlights the evident development from traditional pest control methodologies towards environmentally-friendly, integrated, and technology-enabled ones. The recently cited literature like IPM methodology by [24], stress caused by pesticides by [25], and problems of IPM implementation by [26] show that more and more scientific effort is devoted to reduction of the pesticide use and increasing agricultural sustainability. Also, the inclusion of literature about invasive pests like Drosophila suzukii by [21] points at the broadening research scope related to globalization and ecological change.

3.3 Keyword Co-Occurrence

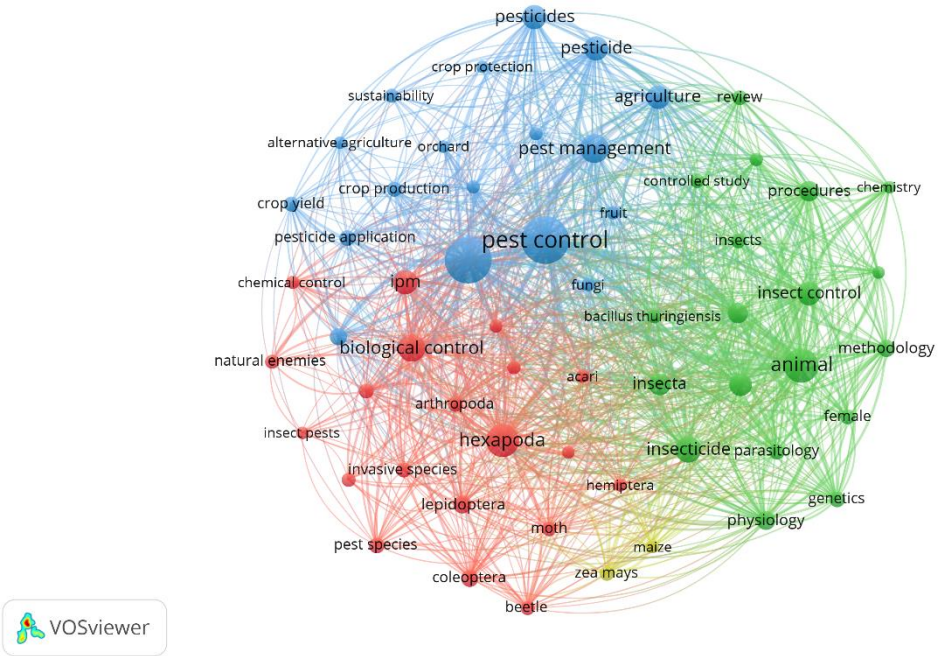

Figure 4. Network Visualization
Source: Data Analysis

Figure 4 depicts the network of co-occurrences of keywords in pest management research, highlighting major research topics, conceptual relations, and development trends of the field. This network includes a number of interrelated clusters, where the larger size of the nodes denotes high-frequency keywords in the literature, whereas the lines linking different nodes show the intensity of the relationship between the keywords. The centrality of the node "pest control" highlights its significance as a dominant keyword and core topic linking various directions of research. Keywords like "pest management," "pesticide," "insect control," and "biological control," which cluster around "pest control," highlight the development of pest control research through the interaction of chemical, ecological, and integrated management.

Blue cluster focuses mainly on the research associated with agricultural production, pesticides usage, and sustainable pest management. The presence of such keywords as “pesticides,” “pesticide,” “crop protection,” “crop production,” “agriculture,” and “sustainability” demonstrates high relevance of chemical control means in the field of agriculture. Nevertheless, the relationship of these keywords with such concepts as “alternative agriculture,” “orchard,” and “natural enemies” testifies to the current trend towards development of other ways of managing the pests instead of using chemicals.

The green cluster is concerned with research involving biological features of pests, insects, ecology of insects, and biological control techniques. Some of the keywords that fall under this cluster are “insects,” “animal,” “insect control,” “insecticide,” “genetics,” “physiology,” and “Bacillus thuringiensis.” This shows that there is much interest in the biology of pests, insect behavior, microorganisms, and genetics in order to devise a more effective pest control strategy. Inclusion of Bacillus thuringiensis shows that there is an interest in developing a biological alternative to chemical insecticides.

The second cluster colored in red denotes the research area associated with biological control, diversity of pest species, and ecological interactions. Key terms like “biological control,” “natural enemies,” “arthropoda,” “hexapoda,” “lepidoptera,” “coleoptera,” and “invasive species” clearly show that there is a significant concentration of studies concerning pest classification, ecological interactions, and pest control by means of biological entities. It becomes clear from this cluster that more and more studies are being conducted on pest management using ecological approaches, which include predator-prey relationships and conservation of natural pests' enemies. Invasive species also indicate increasing concern about global environmental change and the spreading of pests geographically.

The keyword network analysis suggests that pest management studies have evolved into a multi-disciplinary area which combines agriculture, ecology, biotechnology, and sustainable science. The interconnections between pesticide studies, biological control, and IPM point towards a change in approach from the chemical-based methods towards sustainable and adaptive methods. Possible future research areas will be directed at enhancing IPM by means of advanced technologies and biological methods for precision agriculture and other environmentally friendly methods.

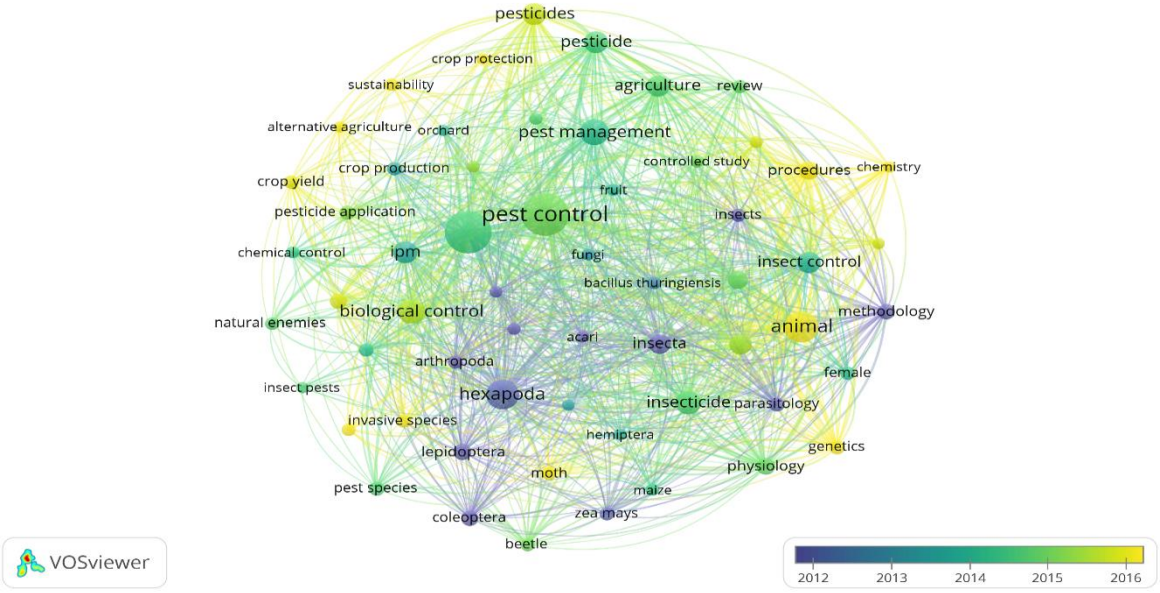

Figure 5. Overlay Visualization
Source: Data Analysis

Keywords' trend development in pest management research is shown in Figure 5 with colors reflecting the average publication year for earlier keywords (from blue to purple) to recent trends (from orange to yellow). The network shows that "pest control," "pest management," "biological control," and "insect control" have been core topics in scientific research over the years. Highly connected keywords are the core keywords representing core ideas in scientific research involving agriculture protection, insect biology, pesticides use, and pest management.

The themes from the earlier studies that are denoted in blue and green represent topics related to basic studies in taxonomy of pests, biology of insects, and methods of biological control. Words like "hexapoda," "coleoptera," "lepidoptera," "arthropoda," "natural enemies," and "Bacillus thuringiensis" show that the previous studies were primarily concentrated on the study of the features of pests and their interaction, as well as the development of biological means of pest suppression.

The emerging trends in research, which can be seen from the use of yellow-color coded words, suggest growing interest in sustainability of agriculture, pesticides, and IPM. Words like "sustainability," "crop protection," "pesticides," "insecticide," "genetics," "methodology," and "invasive species" show that current research tends to focus on environmental issues, improve the efficiency of pest control, and utilize more sophisticated management methods. The emergence of new topics shows that the contemporary research on pest management is going to move beyond conventional pest eradication to an integrated and environmentally friendly approach.

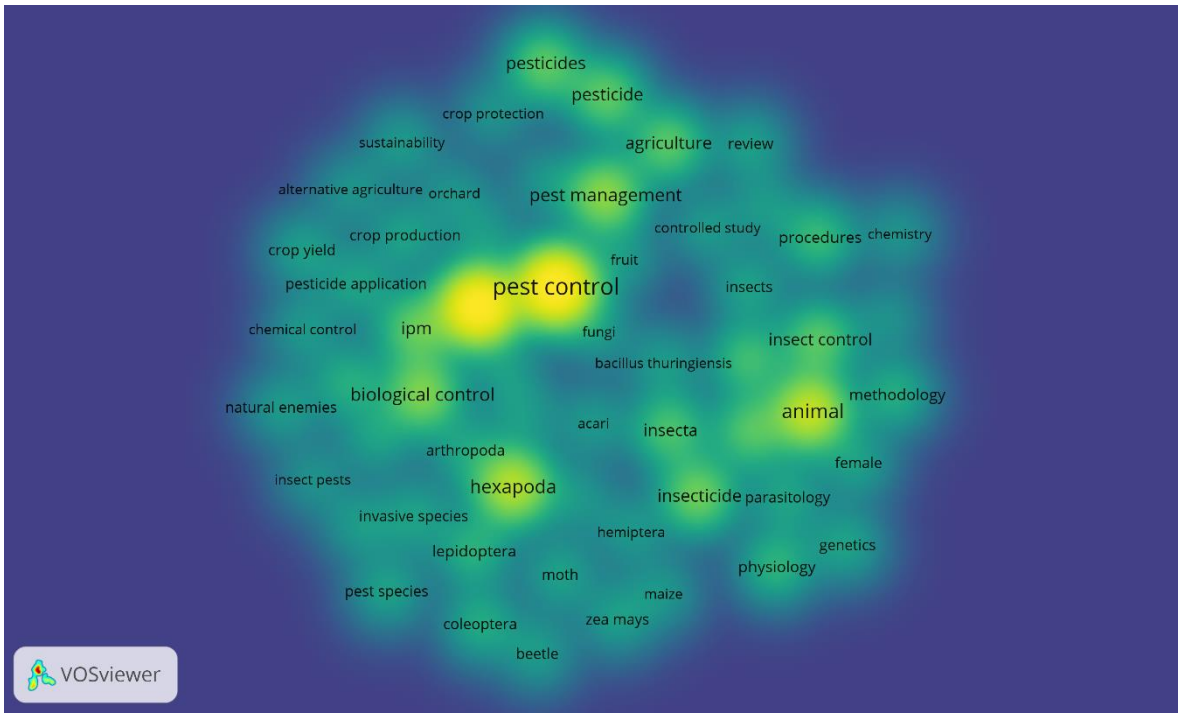

Figure 6. Density Visualization
Source: Data Analysis

Figure 6 illustrates the frequency and strength of keyword presence in the field of pest management research. The gradient color scale signifies the level of research density where the yellow part denotes keywords with high frequency and strong co-occurrence links. Green and blue parts signify low research density. From the visualization above, it can be noted that "pest control" is the dominant research subject since it lies in the high-density region, suggesting that it is the central keyword which unites different themes in pest management research. Other highly dense keywords include "pest

management," "animal," "biological control," and "hexapoda."

The density distribution also shows how diverse the research paths can be in the domain. The keywords related to chemical control and pesticide usage, "pesticides," "pesticide," "insecticide," and "crop protection" are still relevant and important fields of study, implying ongoing research in the area of suppressing pests in agriculture. On the other hand, the inclusion of keywords like "biological control," "natural enemies," "Bacillus thuringiensis," "sustainability," and "integrated pest management (IPM)" suggests growing interest in environmentally friendly approaches.

Discussion

The results of the bibliometric analysis reveal that the topic of pest management research has evolved into a complex multidisciplinary research area comprising agriculture, ecology, biotechnology, and environmental sustainability. The trends in publications and keywords show that pest control, pest management, biological control, and insect control are the key topics that continuously define scientific discourse. Such a central position of the key words reveals the continuous relevance of managing pest populations to ensure agricultural production. The conclusion can be drawn that the research on pest management goes beyond the elimination of pest species but focuses on ecological interactions and sustainable agricultural production systems.

The citation analysis reveals that influential studies in pest management have largely contributed to the transition from conventional chemical approaches toward integrated and environmentally friendly strategies. Highly cited literature emphasizes habitat management, natural enemy conservation, plant-derived pesticides, push–pull strategies, pheromone applications, biopesticides, and integrated pest management (IPM). This intellectual development indicates a paradigm shift in which researchers increasingly recognize the limitations of excessive pesticide dependence, including resistance development, environmental contamination, and negative impacts on non-target organisms. Therefore, contemporary pest management research focuses on combining multiple control approaches, including biological agents, ecological engineering, and precision-based interventions, to achieve effective and sustainable pest suppression.

Analysis of the collaboration and country networks show that there is widespread distribution of research on pest management across the world. However, research on pest management continues to be affected by certain dominant research centers including the United States, China, India, Australia, and other countries in Europe. These countries act as key players in the collaboration and production of scientific knowledge in the field of pest management. The analysis reveals that collaboration between certain regions in the network is still low, especially collaboration between research countries that produce a lot of scientific knowledge and developing agricultural regions.

The results of keyword evolution and density analysis further point towards the future of pest management research with respect to sustainability, biological innovations, and integrated efforts. The emerging topics of sustainability, invasive pests, genetics, biopesticides, and integrated pest management suggest that future research will definitely address minimizing the impact on the environment while ensuring productive agriculture. The growing trend of combining ecological information, molecular tools, and innovations indicates that the future of pest management research will be about shifting from reactive pest control strategies to more preventive and adaptive ones.

4. CONCLUSION

This bibliometric study provides a comprehensive overview of the development, intellectual structure, and emerging trends in global pest management research. The findings demonstrate that pest management has evolved from a primarily chemical-based

control approach toward a more integrated and sustainable research domain involving biological control, ecological management, biotechnology, and environmentally responsible agricultural practices. The analysis identifies pest control, pest management, biological control, and insect control as the central research themes that connect various scientific areas. Highly cited literature further confirms the significant contribution of integrated pest management, natural enemy conservation, biopesticides, and alternative control strategies in shaping the current direction of the field. The collaboration analysis highlights the important role of leading countries and institutions in advancing pest management knowledge, although opportunities remain to strengthen international cooperation across regions. Furthermore, the temporal and density analyses indicate that future research is increasingly oriented toward sustainability, precision agriculture, invasive species management, and innovative biological solutions.

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