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Systematic Review

Understanding Factors That Influence Pest Risk in Olive Production

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Abstract: The aim of this article was to provide a comprehensive review of the factors that influence the risk of pests in olive cultivation on a global scale. Two different analytical methods were used: a bibliometric review and a systematic review. The first method, based on the Scopus database and supported by analytical tools such as VOSviewer and Bibliometrix, allowed for the identification and analysis of 1060 publications, with a particular focus on the 445 most cited from 2014 to 2023. This bibliometric exploration highlighted the main contributions and trends in research on pest management in olive growing. On the other hand, the systematic review was carried out through a triangulation of databases, including Scopus, EBSCO, and Web of Science, following the PRISMA protocol to ensure a rigorous methodological process. A total of 27 scientific studies were selected that provided a detailed and relevant view of pest control practices. The results of this systematic analysis show the critical importance of the controlled and judicious use of pesticides in olive cultivation to prevent adverse effects on human health, biodiversity, and the environment. They also highlight the need to promote sustainable cultivation practices that reduce dependence on agrochemicals, thereby improving soil health and the quality of the harvested product.

Keywords: risk; pest; olive tree; pesticide control; climate change; SDG 13

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1. Introduction

Nowadays, various governments and international organizations are concerned with designing action plans with policies that seek the acquisition of food in favor of healthy eating. Also, the gradual increase in the world population has led to an increasing demand for agricultural products around the world, especially those of organic origin. *Olea europaea* crops are widely cultivated worldwide, but they frequently suffer from pests and diseases that reduce the quality of the harvest and, therefore, the yield of the olive tree [1]. Chemical substances known as pesticides, which according to the World Health Organization (WHO, 2022) [2] comprise more than a thousand pesticides around the world, are used to ensure that pests do not damage or destroy food. These products are used to protect crops and to increase production, as well as in public health to control vector-borne diseases and to eliminate pests. Pesticides are classified into different groups depending on the type of organism they are intended to control, including insecticides, herbicides, nematicides, fungicides, rodenticides, acaricides, molluscicides, and repellents, among others [3].

Although pesticides are considered an easy, economical, and reliable solution to maintaining high levels of agricultural productivity, excessive use of chemicals to control pests can lead to high levels of residues of these substances in food. Pesticides are a tool that allows for increased food production; however, if used excessively or inappropriately,

they can generate high levels of residues in the food consumed, which can have negative consequences for human and domestic animals' health and the environment [4–6].

Another important point is that the rapid development of insecticide resistance is severely limiting the sustainable use of various insecticides. Therefore, there is an urgent need to elucidate the biochemical and molecular mechanisms of insecticide resistance for pest management and rational use of insecticides.

In general, insects can rapidly develop resistance to insecticides through numerous mechanisms, mainly including metabolic resistance, behavioral resistance, resistance to gut commensal bacteria, and penetration resistance. Therefore, overcoming insecticide resistance problems is an urgent need for global sustainable development, and elucidating the molecular mechanisms of insecticide resistance is key to overcoming these challenges [7,8].

The variety of negative health consequences that can result from exposure to pesticides is extensive due to the great diversity of the chemicals used in them. It is common for certain pesticides to cause acute and chronic effects in exposed people, which include respiratory, immunological, central and peripheral nervous system, endocrine system, and metabolic and reproductive disorders; congenital defects; and malignant diseases such as lung, prostate, and colon cancers, as well as multiple myeloma [9–13].

Landscape structure exerts a significant influence on arthropod population dynamics, a phenomenon that is manifested in the variability observed at different landscape scales. Environmental elements, such as relief and microclimate, and biotic interactions, such as those that occur between organisms, including parasite–host dynamics, play a determining role in these dynamics. However, anthropogenic factors, including rural, urban, and industrial practices, also shape these population patterns [14–16].

In olive plantations, which tend to cover large landscapes with diverse microclimates, these interactions become more apparent, especially when they are continuous. An analysis of the adjacent land cover shows that this can significantly influence the population levels of species such as olive flies by providing food resources or habitats for their parasites and natural predators [17–20].

In addition, recent research has revealed a trade-off between changes in population density and elevation, suggesting the active movement of adult flies across the landscape over time. This pattern highlights the dispersal capacity of arthropods and the importance of considering landscape heterogeneity in integrated pest management. Understanding these dynamics is essential for implementing more effective and sustainable control strategies over time, taking into account both natural and anthropogenic variables affecting olive ecosystems [21,22].

These papers collectively emphasize the significance of sustainable agricultural practices and the contribution of integrated pest management (IPM) towards promoting sustainability. The authors of [23] highlight the necessity of enhancing agricultural extension services to foster sustainable pest management practices. The authors of [24] investigated the utilization of modeling to design pest-suppressive landscapes for promoting sustainable agriculture. Their research shows that sustainable management of insect pests at the landscape level can be achieved through native remnant management and weed removal. The author of [25] highlights the importance of transitioning from integrated pest management (IPM) to sustainable pest management (SPM) to address the challenges and gaps in pest control while promoting overall sustainable development. These findings contribute to the understanding of how various strategies and considerations can aid sustainable pest management.

In another aspect, among the products that are most frequently used in diets are those from the olive tree, with the greatest production in southern European countries, including Spain, Portugal, Greece, and Italy, which together represent approximately 70% to 75% of world olive tree production [26,27]. However, in the current literature, there is a set of studies that focus on the perception of pest risk in olive tree production, and the present study aims to provide a systematic and bibliometric review of the literature on this topic through the identification of full-text research articles published in peer-reviewed

scientific journals that compare pest risks in olive products. In this review, the advances in theoretical and empirical research that have been carried out on pesticides in the olive tree are presented to understand where the public debate on the subject is heading and which strategies should be implemented in countries where it is cultivated.

The study considers the following research questions to guide the review:

1. What types of factors influence the risk of contracting pests in olive cultivation worldwide?
2. What are the lessons learned from the different experiments and studies that have been conducted around the world to study and counteract pests that affect olive cultivation?
3. What are the possible problems associated with pests in olive cultivation and how can they be addressed?

The objective of this bibliographic review is to determine the state-of-the-art research advances in pest control in olive trees as a useful reference tool to increase awareness and to support policymakers in the adoption of measures for the appropriate preventive management of different pests in the face of global warming. The objectives of the study are as follows:

1. Identify the different types of factors that influence the risk of contracting pests in olive cultivation worldwide.
2. Evaluate success stories carried out to minimize the risk of pests in olive cultivation worldwide.
3. Evaluate which regions are the most affected by pests in olive cultivation to assess the progress in their monitoring and control.

Among the main conclusions, the importance of the variability of pest populations in agricultural systems and their impact on farmers' decision making stands out. The studies reviewed demonstrate, through the use of empirical data, that variable populations are more likely to cause performance losses. Knowing the variables that influence them contributes to generating sustainable agriculture with biological pest control that is of interest to farmers and policymakers.

2. Materials and Methods

To better comprehend the variables influencing the hazards related to pesticide use in olive farming, a bibliometric analysis is essential, utilizing software such as Vos Viewer (version 1.6.8) and Bibliometrix (version 3.0) to create network analyses that elucidate progressions in this field.

This research was conducted in two phases: the initial phase consisted of scrutinizing the bibliometric performance, while the second phase involved a systematic review using the PRISMA (see supplementary materials) methodology. The following section outlines the bibliometric and systematic review conducted.

2.1. Bibliometric Method

The development of the research began by defining the keywords and/or research equation to analyze the growth of publications, international collaborations, countries, and authors who have been analyzing pests and risks in the production of the olive tree and its derivatives. To this end, a systematic review was developed using peer-reviewed literature databases to provide a perspective on global research that has been carried out on the object of this study. Subsequently, the information was processed with two bibliometric analysis programs to analyze the quality and quantity of studies published around the world. In this sense, articles published in the identified study unit were reviewed by evaluating the documents.

For the first bibliometric review, the search was carried out only in the Scopus Database, generating filters in the search to extract the most significant data for the analysis. Exported information was analyzed, which included the titles and abstracts of each document, along

with the countries of origin of the authors and their affiliated institutions. Information on the number of annual publications, document types, citations, and journal names were also included. After obtaining the information from Scopus as a strategy, we tried to deepen the information using two free software to explore the different ways of displaying the information, as each software contains different algorithms that ensure coherence and consistency in data use. For this reason, VOSviewer was used first, as it allowed us to graphically represent the relationships between documents, authors, and key terms in a knowledge network, and through its features, to perform different analyses in order to identify patterns, trends, and areas of research emerging from the scientific literature. In the meantime, Bibliometrix was used, which is based on the R programming language and, owing to its multiple functions, allowed us to carry out a more advanced bibliometric analysis to evaluate scientific production, in this case in the field of olive tree pests.

Both VOSviewer and Bibliometrix are freely available open-source software. They facilitate the use and analysis of scientific information for the purpose of generating knowledge networks. In the context of the maps, the software VOSviewer version 1.6.8 (University of Leiden, Leiden, The Netherlands) was used to display the network of terms obtained from article titles or abstracts along with the collaboration between countries. The version of Bibliometrix used was version 3.0 by Massimo Aria and Corrado Cuccurullo [28,29].

2.1.1. Search Strategy

The search strategy was designed based on an exhaustive analysis of the systematic literature and meta-analyses relevant to the topic of study. This methodology was divided into three different phases:

1. During the first phase, specific terms were used to search for titles, using the following expression: (TITLE-ABS-KEY (olive)), which resulted in the identification of 61,966 articles.
2. In the second phase, terms related to "olive" and "pest" were introduced, applying the following expression: (TITLE-ABS-KEY (pest and olive)). This search returned a total of 1060 articles.
3. The third phase involved the application of exclusion and restriction criteria to synthesize and refine the results of the two previous phases. The time interval considered for this study spanned from 1 May 2023, to 7 May 2023, without imposing linguistic restrictions. To ensure search accuracy, double quotes ("") were used to delimit exact terms or phrases. It was decided to exclude errata and documents that had been retracted from the analysis.

As a direct consequence of this search strategy, an additional search was conducted based on article title, abstract, and keywords together. This is a reliable method because a title-only search generally produces fewer documents, including results considered false positives.

2.1.2. Search Strategy Validation

After refining the search query, the authors took precautions to eliminate any false positives. To achieve this, the 100 most cited publications were analyzed to determine if they were relevant to the searched topic. The titles and abstracts of the most cited documents were reviewed by two bibliometrics experts to confirm the absence of false positives. After confirming that there were no false positive results, the search query was considered complete. This validation method has been used in previously published bibliometric research.

To ensure the absence of false negatives, the correlation test was implemented after obtaining the search query results and before identifying the top ten active researchers. The result of the correlation test was significant ($p < 0.01$) and strong ($r = 0.96$), which is indicative of the validity of the search query. This validation method has been used in previously published bibliometric research [30–32].

The authors' approach to ensuring the accuracy of the search query was meticulous and thorough. The participation of two bibliometrics experts provides credibility to the findings, and the use of a correlation test provides additional validation. Overall, the authors' efforts have improved the quality and reliability of research and research results.

The analyses conducted for this study focused primarily on the percentage and frequency of publications. The VOSviewer program and Bibliometrix were used to generate maps of authors, co-authors, and networks of terms extracted from the titles or abstracts of the articles, as well as to visualize collaboration between countries. The purpose was to create knowledge networks based on scientific research to evaluate the progress of various research fields.

2.2. Systematic Review

For the systematic review of the literature, the guidelines established in the PRISMA statement were followed to select, review, and critically evaluate the articles published in databases. The guiding question that accompanied this search was this: What research progress has been made on the use of pesticides and risks in olive cultivation in the past two years? Next, three databases (SCOPUS, Web of Science, and EBSCO) were searched to identify eligible studies using a combination of the search terms "pest", "risk", and "olive". The search time range was from 1 May 2023, to 7 May 2023. Subsequently, a staged selection process was carried out that used the keywords "pest", which generated a total of 157,141 documents, and "pest AND risk", which generated 12,071 results. Thus, a rigorous selection was carried out to identify the 67 relevant and valid articles related to pests, risks, and olive trees. Additionally, a manual review of the reference lists of eligible articles and retrieved reviews was carried out to identify any other relevant articles.

3. Results and Discussion

3.1. Bibliometric Research Results

Below, in Table 1, the results of the bibliometric review are presented using the VOSviewer and Bibliometrix software that allow the grouping of terms into different categories, identifying 1060 publications related to pests and olive trees, mainly between the years 2014 and 2023.

(a) Author Trend Analysis

Figure 1 illustrates a visual map of research collaboration networks between authors, which used the co-authorship counting method to identify research collaboration. The unit of analysis was the authors, but a limit of 25 authors per document was established. This analysis focused on authors who have worked on the topic of pests and olive trees. According to the co-authorship analysis, author Campos topped the list with the highest number of articles (55), followed by Pereira (45), Santos (28), Mathiopoulos (24), and Petacchi (24). Figure 1 uses a colored map to indicate the density (activity) of the authors of interest; areas with warmer colors (such as yellow) indicate higher density or greater activity, while cooler areas (blue) represent lower density.

(b) Three-Field Chart

In Figure 2, a graphical analysis of three fields was carried out to establish which research keywords had been used most frequently (right) by different authors (center) and countries (left). The different elements of each field are connected with lines, and the thickness of these lines represents the strength of the relationship between the connecting elements. The study revealed the presence of five main keywords: "Biological Control", "*Olea europaea*", and "*Bactrocera oleae*", the main pest of olive cultivation [33], as well as "Olive fruit fly" and "olive". These keywords were developed by five specific authors: Campos, Pereira, Santos, Mathiopoulos, and Petacchi. You can see the visualization of the countries that have made outstanding contributions to the topic analyzed. These countries are characterized by intense scientific collaboration, as reflected in the dense connections

that link them. Among the countries with extensive collaboration are Portugal, Spain, Italy, Greece, and the United States.

Table 1. Description of the results exported from the Scopus database.

Description	Results
(1) The main information about the data	
Time frame	2014–2023
Most cited document	445
Search words:	Pest and olive
(2) Type of document	
Documents	1060
Articles	900 (85%)
Conference papers	68 (6.5%)
Review articles	48 (4.5%)
Other types of publications	44 (4%)
(3) Keywords	
Most frequent word	278
(4) Authors	
Authors	3094
Author with more than 20 documents	5

Note: Prepared based on the results of Scopus May 2023.

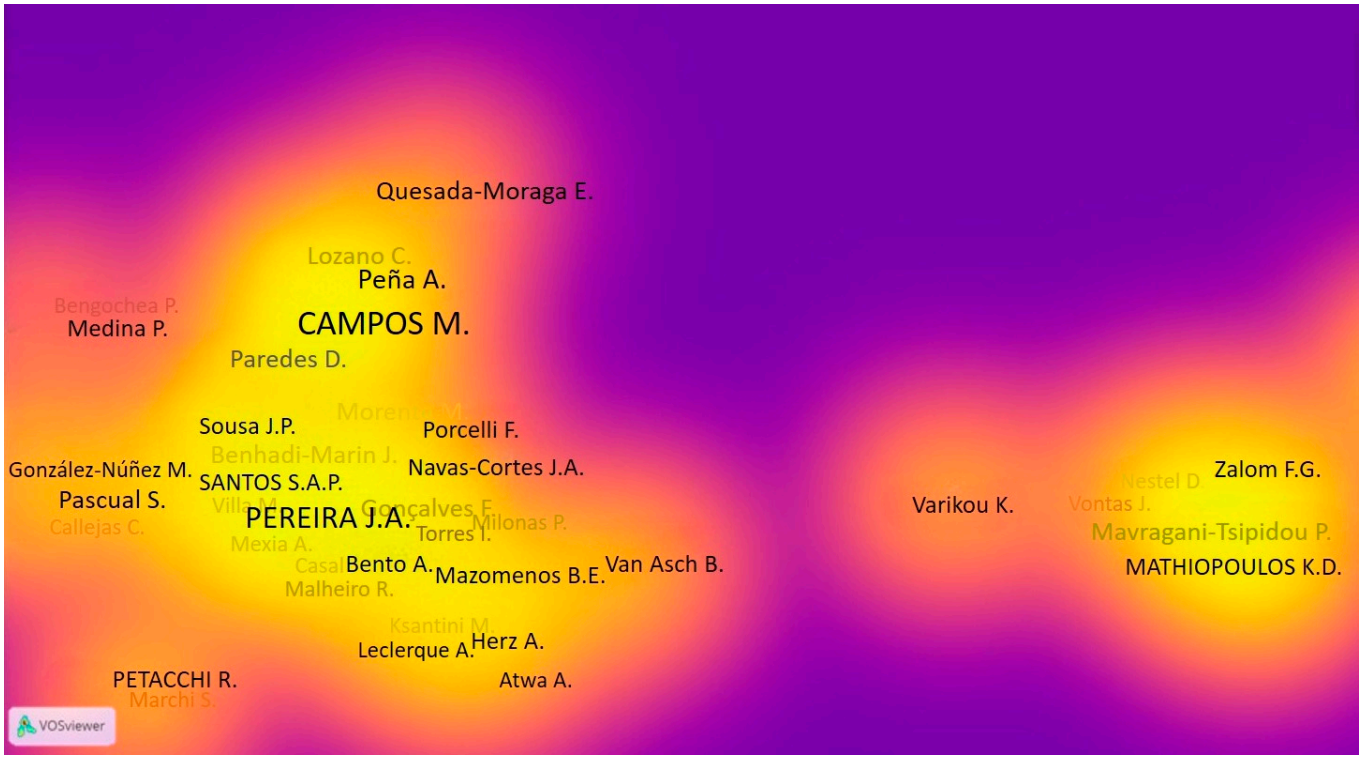

Figure 1. Author trend density map. Note: Trends of annual authors on research related to pests and densely visualized olive trees. The map was created using VOSviewer software.

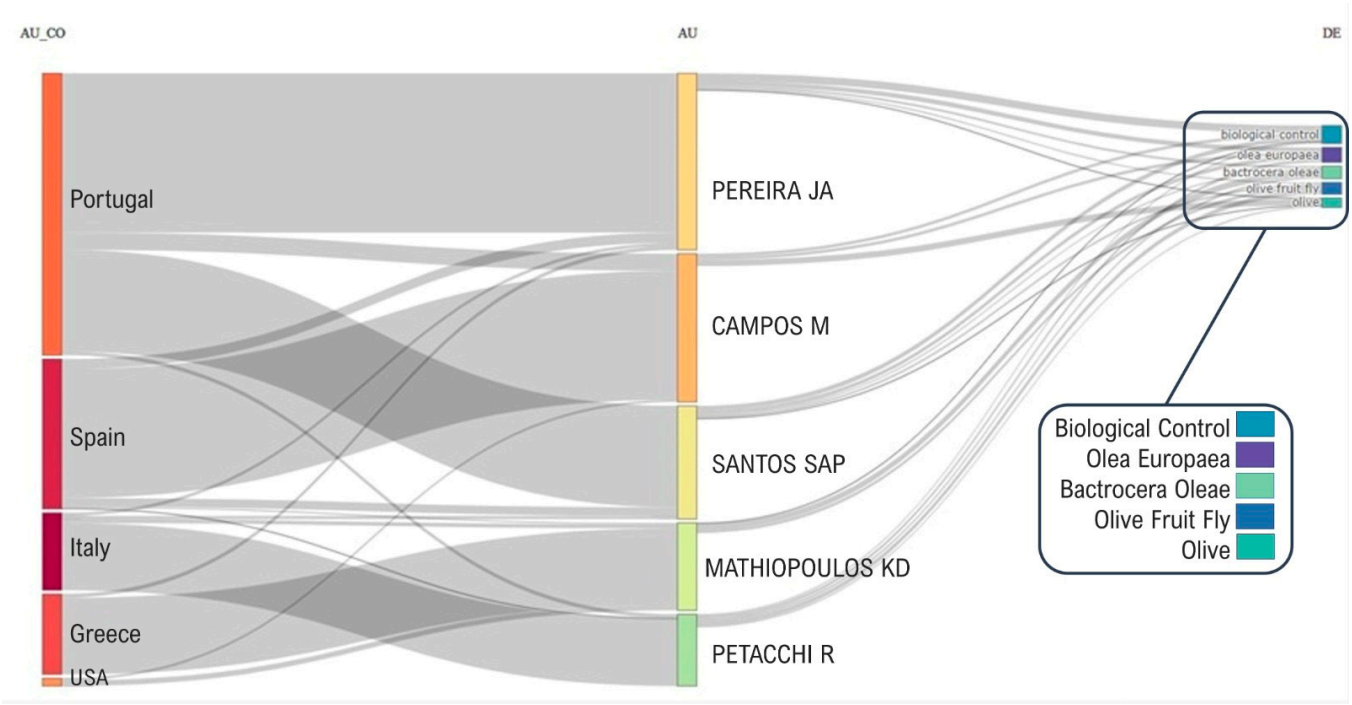

Figure 2. Three-field chart. Note: The figure shows three fields, which are the association between an author's country and a keyword. The chart was created using Bibliometrix software.

(c) Co-occurrence analysis

The co-occurrence network is generated by evaluating the number of articles in which the search terms appear simultaneously in the titles or abstracts. The objective was to identify the keywords that authors use in their articles to analyze the direction science is taking on essential topics and to monitor its progress. As shown in Figure 3, 123 keywords were selected, and it was established that the minimum number of occurrences of a keyword should be five. The most frequent terms found in the co-occurrence map include those related to (a) *Bactrocera olea* (green group), (b) the olive tree (fuchsia group), (c) olive fruit fly (yellow group), (d) integrated pest management (green group), and (e) the *Tephritidae* (brown group).

3.2. Results of the Systematic Review

The search strategy was developed based on an extensive review of the systematic literature and meta-analysis on the topic. The research strategy was based on three steps adopted from the PRISMA declaration, and the articles considered in the research were selected as follows (Figure 4):

(i) All articles were identified via a search for the variables "pest AND risk AND olive" (n = 159);
(ii) Duplicate articles were eliminated (n = 79);
(iii) Articles were selected based on inspection of title, abstracts, and keywords (n = 80); first purification (n = 67);
(iv) A search for references to selected articles was conducted (n = 27);
(v) When reviewing the selected articles, four were eliminated since they considered other study units, leaving (n = 23) articles in the systematic review that are included in the discussion of our results.

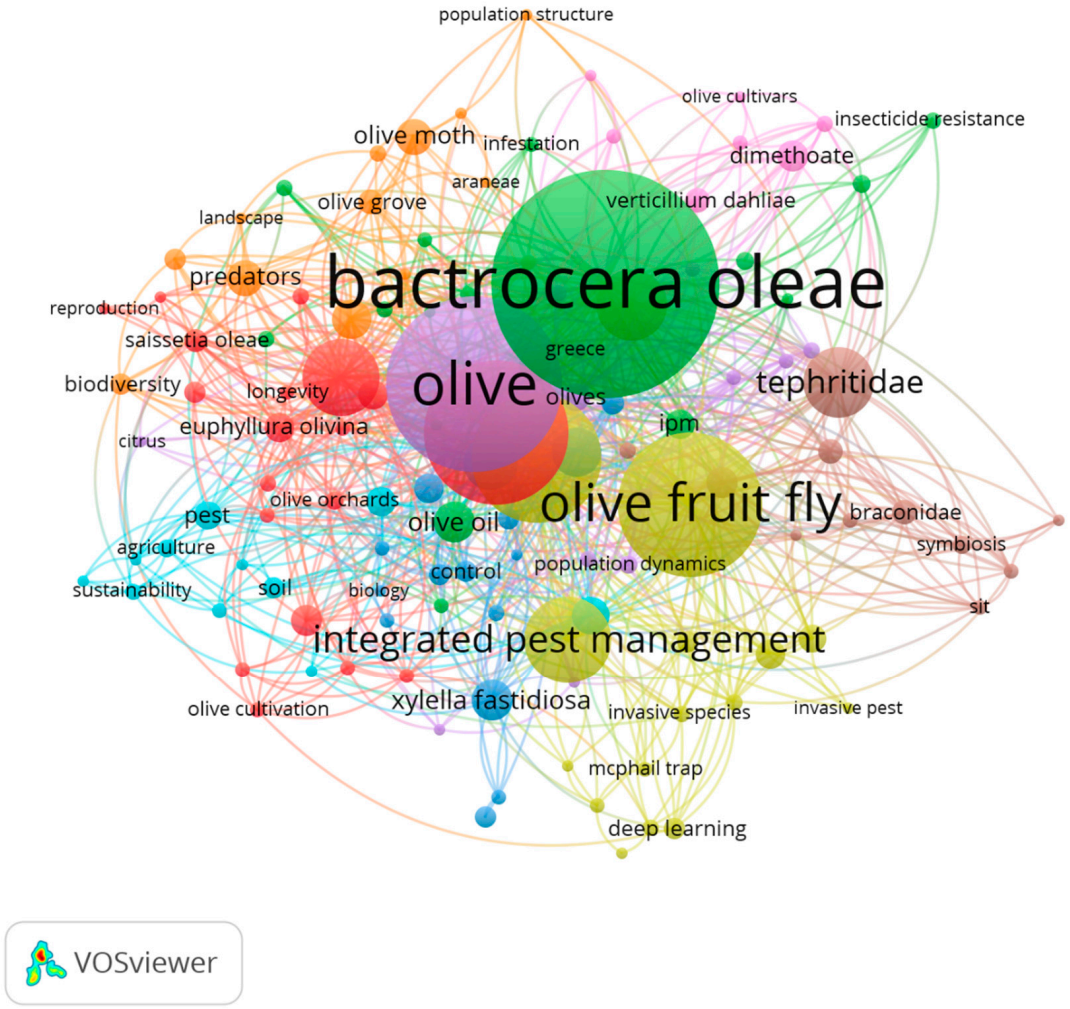

Figure 3. Co-occurrence map. A cluster map was created based on the analysis of the keyword terms that the authors use in their articles. The size of the circle on the map indicates the number of times the terms are used, while the varied colors indicate the different groups of terms. The map was created using VOSviewer software.

Table 2 below shows the identification and synthesis of the selected articles.

3.3. Discussion

The review of scientific articles made it possible to determine that there are some influential risk factors for pests in olive cultivation, which may be the climate, the variety of olive tree variety cultivated, agricultural management practices, the health status of the plants, or the presence of insect vectors, as well as the proximity to other plantations susceptible to pests. Therefore, pests can be harmful to olive cultivation because they can decrease the quality and quantity of olive production, which can negatively affect the profitability of the crop. In addition, some pests can carry diseases that can weaken or even kill olive trees.

The reviewed documents allow us to understand the use of bioinsecticides to control fungal pathogens in olive trees. The authors provide a comprehensive review of the existing literature on the topic and to present empirical data to support their conclusions. Additionally, factors that influence the effectiveness of the biological control agent are discussed, providing valuable information for farmers and other professionals interested in sustainable agriculture. An important aspect is discussions of the importance of variability in pest populations in agricultural systems, which is particularly interesting. The authors

present empirical data demonstrating that variable populations are more likely to cause significant yield losses but also occasionally create temporary windows when densities fall below insecticide spray thresholds.

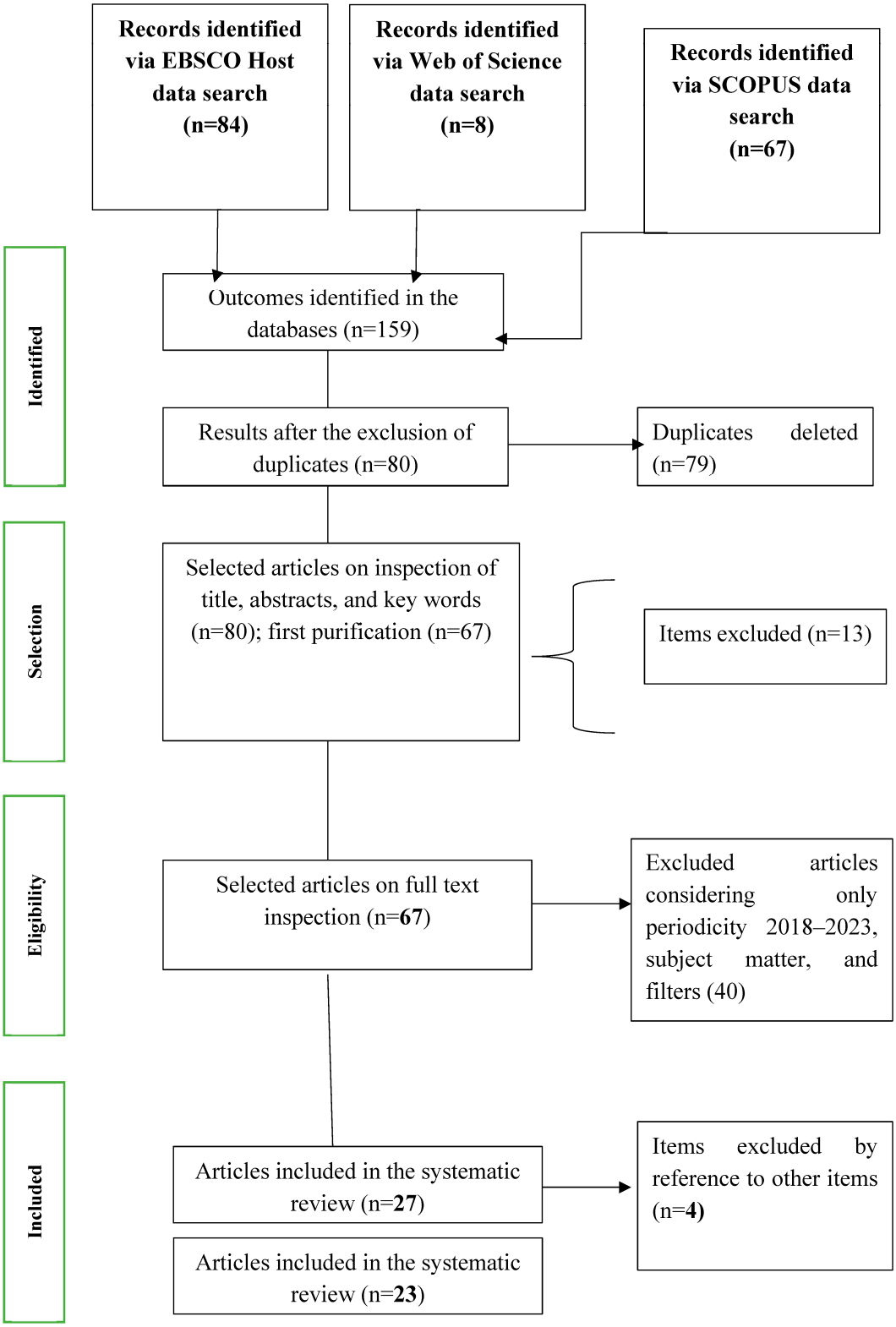

Figure 4. PRISMA flowchart: literature identification and selection process. Note: Figure 4 was prepared using the PRISMA 2020 flow chart for systematic reviews.

Table 2. Identification and synthesis of selected articles.

Title	Author	Year	Source	Area Studied	Methodology	Sample	Data Source
Persistence of Metarhizium brunneum (Ascomycota: Hypocreales) in the Soil Is Affected by Formulation Type as Shown by Strain-Specific DNA Markers	Hernández, I., Sant, C., Martínez, R., (. . .), Lara, J.M., Fernández, C. [34]	2023	*Journal of Fungi*	Agricultural Entomology Research Group Spain	Experimental	Experimental group cultivation collection	Experiment on the persistence and population dynamics of the EAMb 09/01-Su strain
Climate stressors modulate interannual olive yield at province level in Italy: A composite index approach to support crop management	Di Paola, A., Di Giuseppe, E., Gutierrez, A.P., Ponti, L., Pasqui, M. [35]	2023	*Journal of Agronomy and Crop Science*	Italy	Quantitative	Data from 2006 to 2020 (time series)	Data taken from the Italian National Statistics Institute (ISTAT)
Pest categorisation of Nipaecoccus viridis	Bragard, C., Baptista, P., Chatzivassiliou, E., (. . .), Maiorano, A., MacLeod, A. [36]	2023	*EFSA Journal*	European Commission	R. Systematic	References from 2016 to 2020	Database
Prays oleae (Bernard), its potential predators and biocontrol depend on the structure of the surrounding landscape	Pascual, S., Ortega, M., Villa, M. [37]	2022	*Biological Control*	Madrid	Quantitative	15 olives	Database
Socio-Economic Risks Posed by a New Plant Disease in the Mediterranean Basin	Cardone, G., Digiaro, M., Djelouah, K., (. . .), Lenders, A., Fucilli, V. [38]	2022	*Diversity*	Mediterranean Europe, Balkans, Middle East, and North Africa	Quantitative (evaluation–estimation)	2015–2019	Database
The causes and consequences of pest population variability in agricultural landscapes	Paredes, D., Rosenheim, J.A., Karp, D.S. [39]	2022	*Ecological Applications*	Andalusia Spain	Quantitative	2006–2018	Database
Southern Range Expansion of the Emerald Ash Borer, Agrilus planipennis, in Russia Threatens Ash and Olive Trees in the Middle East and Southern Europe	Orlova-Bienkowskaja, M.J., Bieńkowski, A.O. [40]	2022	*Forests*	Russia, Middle East, and South of Europe	Quantitative Standard detection method	100 trees per region	Database

Table 2. *Cont.*

Title	Author	Year	Source	Area Studied	Methodology	Sample	Data Source
Fungi obtained from olive twig dieback and adults of the alien pest xylosandrus compactus (eichhoff) (coleoptera curculionidae scolytinae)	Vitale, S., Toccafondi, P., Luongo, L., (. . .), Roversi, P.F., Pennacchio, F. [41]	2022	*Redia*	Italy	Quantitative	Olive seedlings	Database
Measurement of CO_2 Emissions in the Semi-Arid Region Conditions in the Soil where the Olive Plant Grows	Sakin, E., Bellitürk, K., Çelik, A. [42]	2021	*Journal of Tekirdag Agricultural Faculty*	Harran University Eyyubiye Campus Turkey	Quantitative	5 sampling zones with 3 repetitions	Database
Ecological niche models of biotic interactions predict increasing pest risk to olive cultivars with changing climate	Ashraf, U., Chaudhry, M.N., Peterson, A.T. [43]	2021	*Ecosphere*	Europe, Middle East, and Africa	Ecological niche modeling approaches	14,959 records of O. europae	Database
Potential socio-economic impact of xylella fastidiosa in the Near East and North Africa (NENA): Risk of introduction and spread, risk perception and socio-economic effects.	Cardone, G., Digiaro, M., Djelouah, K., (. . .), Rota, C., Yaseen, T. [44]	2021	*New Medit*	Algeria, Egypt, Jordan, Lebanon, Libya, Morocco, Palestine, Syria, and Tunisia	Impact evaluation, quantitative	276 questionnaires	SEM
Is *Xylella fastidiosa* a serious threat to European forests?	Desprez-Loustau, M.-L., Balci, Y., Cornara, D., (. . .), Robin, C., Jacques, M.-A. [45]	2021	*Forestry*	North America	Descriptive	-	Reports
Resource-dependent mutual association with sap-feeders and a high predation rate in the ant Crematogaster scutellaris: help or harm in olive pest control?	Frizzi, F., Masoni, A., Ottonetti, L., Tucci, L., Santini, G. [46]	2020	*BioControl*	Mediterranean	Experimental	Experiment with live prey	Observation
Distribution of *Bactrocera oleae* (Rossi, 1790) throughout the Iberian Peninsula based on a maximum entropy modelling approach	Benhadi-Marín, J., Santos, S.A.P., Baptista, P., Pereira, J.A. [9]	2020	*Annals of Applied Biology*	Iberian Peninsula	Descriptive	-	Distribution maps Entropy Mode

Table 2. *Cont.*

Title	Author	Year	Source	Area Studied	Methodology	Sample	Data Source
Impact of *Xylella fastidiosa* subspecies pauca in European olives	Schneider, K., van der Werf, W., Cendoya, M., (. . .), Vicent, A., Lansink, A.O. [47]	2020	*Proceedings of the National Academy of Sciences of the United States of America*	Italy, Greece, and Spain	Quantitative	2013	Climate suitability models
Low-cost IoT remote sensor mesh for large-scale orchard monitorization	Varandas, L., Faria, J., Gaspar, P.D., Aguiar, M.L. [48]	2020	*Journal of Sensor and Actuator Networks*	Portugal	Experimental	Sensors in plants	Remote monitoring system
Growth, DNA damage and biochemical toxicity of cyantraniliprole in earthworms (*Eisenia fetida*)	Qiao, Z., Zhang, F., Yao, X., (. . .), Zhang, J., Jiang, X. [49]	2019	*Chemosphere*	China	Experimental		Database
Favourability for the presence of wild rabbit warrens in motorway verges: Implications for the spread of a native agricultural pest species	Rouco, C., Farfán, M.Á., Olivero, J., (. . .), Villafuerte, R., Delibes-Mateos, M. [50]	2019	*Ecological Indicators*	Iberian Peninsula	Experimental	2016	Favorability function
Exposure of bombus terrestris l. to three different active ingredients and two application methods for olive pest control	Varikou, K., Garantonakis, N., Birouraki, A. [51]	2019	*Entomologia Generalis*	Greece	Experimental	Bees	Control methods
Pest categorisation of non-EU Cicadomorpha vectors of Xylella spp.	Bragard, C., Dehnen-Schmutz, K., Di Serio, F., (. . .), Czwienczek, E., MacLeod, A. [52]	2019	*EFSA Journal*	EU	Experimental	50 taxa	Secondary socioeconomic data
Landscape composition predicts the distribution of Philaenus spumarius, vector of *Xylella fastidiosa*, in olive groves	Santoiemma, G., Tamburini, G., Sanna, F., Mori, N., Marini, L. [53]	2019	*Journal of Pest Science*	Italy	Descriptive	182 olive groves	Secondary socioeconomic data

Table 2. *Cont.*

Title	Author	Year	Source	Area Studied	Methodology	Sample	Data Source
Status, sources and contamination levels of organochlorine pesticide residues in urban and agricultural areas: a preliminary review in central–southern Italian soils	Thiombane, M., Petrik, A., Di Bonito, M., (. . .), Qi, S., De Vivo, B. [54]	2018	*Environmental Science and Pollution Research*	Italy	Quantitative	148 topsoil	Secondary socioeconomic data
Updated pest categorisation of *Xylella fastidiosa*	Jeger, M., Caffier, D., Candresse, T., (. . .), Stancanelli, G., Bragard, C. [55]	2018	*EFSA Journal*	EU	Descriptive		Legal secondary data

The set of documents reviewed addresses different aspects related to the cultivation and protection of the olive tree. The first study, carried out by [34] investigated the population dynamics of the fungus *Metarhizium brunneum* in the soil when it was applied as a bioinsecticide. The study carried out by [35] examined the climatic factors that affect olive production in Italy, and in both cases, they identified how pesticides cause damage to production. In another study, ref. [52] provided information on the categorization of the pest *Nipaecoccus viridis* in the European Union [37] and analyzed the effect of landscape structure on the biological control of the olive moth, while [40] reported on the expansion of the emerald ash borer in southern Russia and its potential threat to ash and olive trees in the Middle East and Southern Europe. In another study, ref. [41] investigated the impact of the invasive species *Xylosandrus compactus* on olive trees in Italy. The authors of [42] studied the relationship between agricultural activities and climate events, and the authors of [43] assessed the impacts of climate change on the potential distributions of *Olea europaea* and *Bactrocera olea* in Europe, the Middle East, and Africa. The authors of [38,44] carried out studies on the risk of introduction and spread of *Xylella fastidiosa* in the Near East and North Africa and its potential socio-economic impacts. Finally, ref. [45] reviewed the actual and potential impacts of *X. fastidiosa* in European forests.

In many of the studies reviewed, which used experimental methods to evaluate the persistence and effectiveness of the biological control agent in commercial settings, soil samples were collected and analyzed using DNA extraction and quantification methods. In addition, climatic data and environmental parameters were analyzed to understand the factors that influence the effectiveness of the biological control agents studied [35,51,52].

The use of bioinsecticides to control pathogenic fungi in olive trees was investigated in another study. Climatic data and environmental parameters were analyzed to understand the factors that influence the effectiveness of the biological control agent. Additionally, the persistence and effectiveness of the biological control agent in commercial settings were evaluated by collecting soil samples and analyzing them using DNA extraction and quantification methods. The importance of variability in pest populations in agricultural systems and its impact on farmers' decision making were also discussed. Finally, a composite index was developed that summarizes the risk of having exceptionally low yields due to the co-occurrence of multiple stressors in olive production [53,55].

On the other hand, the documents examined through the bibliometric review in Scopus discovered the five words most frequently used in the scientific field related to the olive tree and pests. These words are (a) *Bactrocera oleae*, (b) the olive tree; (c) olive fruit fly; (d) integrated pest management; and (e) the tephritidae. Figure 5 presents a visual representation of the direction of future research using a color code to identify each term that appears in the set of publications analyzed, according to its average frequency. In this encoding, yellow represents the most recent terms, while blue corresponds to the first occurrences of the terms. Until 2016, the most frequent terms were related to "*Bactrocera oleae*, olive, olive fruit fly, and integrated pest management," as well as "*tephritidae* and pest control". Instead, research on "*Xylella fastidiosa* and *Euphyllura olivina*" is a more recent development that emerged after 2016.

Figure 6 shows that the size of the words represents the relative importance of the scientific field during each decade. Varying colors indicate different groups of terms. During the 1980s, the predominant word in science was "*Dacus Oleae*", referring to the olive fly. In the 1990s, terms such as "*Scolytidae*" and "*Bactrocera Oleae*" emerged. From the year 2000 on, "*Bactrocera Oleae*" became the dominant term in scientific research on the olive tree. Furthermore, in the last decade, the appearance of two emerging terms has been observed: "integrated pest management" and "biological control". These concepts have gained relevance in scientific research on the olive tree and represent novel approaches to addressing pest control in a more sustainable and environmentally friendly way.

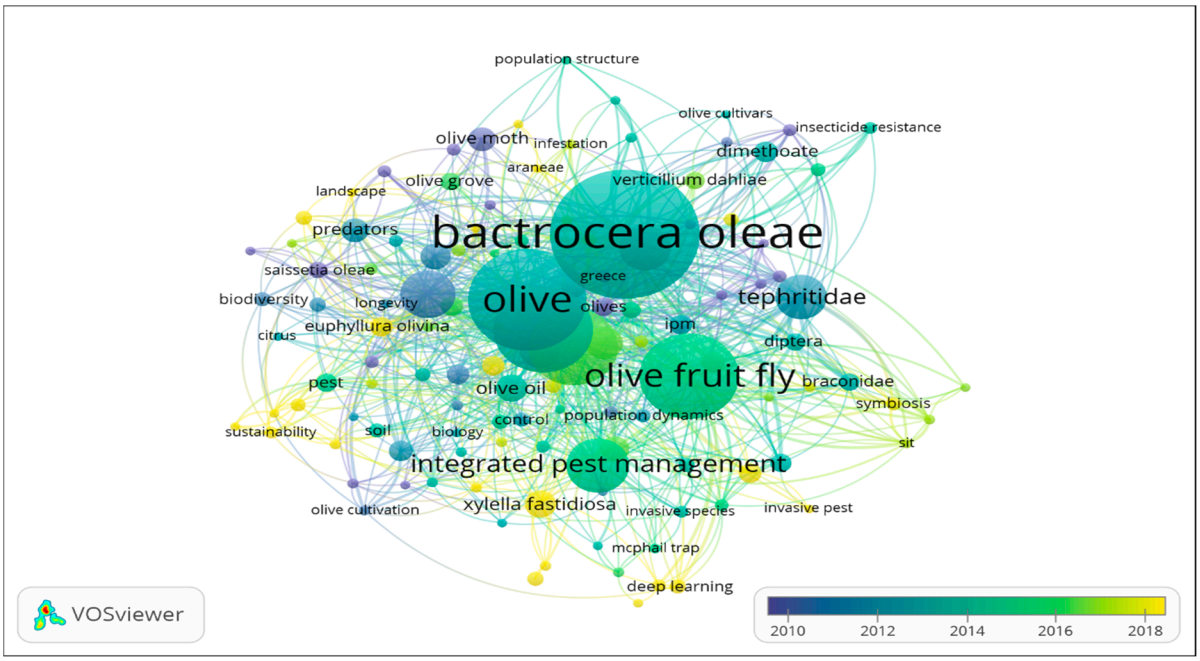

Figure 5. Analysis network visualization map. Network visualization map of the analysis of terms and keywords according to their frequency of appearance. Blue denotes earlier occurrences of the terms, and yellow denotes later occurrences. The map was created using VOSviewer software.

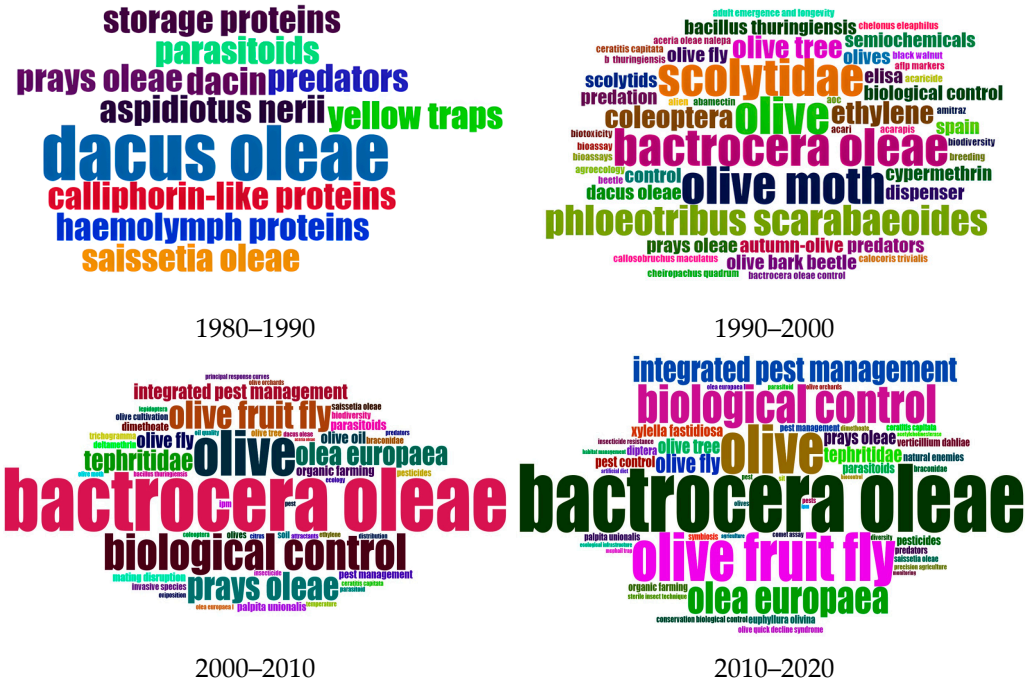

Figure 6. Analysis by decade. Note: Graphic representation of scientific advances in the study of olive trees, pest control, and risk during the past forty years. The graphic was created using Bibliometrix software.

4. Conclusions

This article presents a comprehensive analysis of the current state of knowledge on the factors influencing the risk of pests in olive cultivation worldwide. Using two complementary methodological approaches, a bibliometric review and a systematic review, a detailed evaluation of the literature available in prominent databases such as Scopus,

EBSCO, and Web of Science was carried out. The VOSviewer and Bibliometrix analysis tools, together with the PRISMA methodological framework, enabled the synthesis of data from 1060 identified publications, with a particular focus on the most cited works from 2014 to 2023.

The research results reveal a critical trend toward the need for integrated pest management practices that reduce dependence on pesticides in olive farming. The importance of this transition is underlined by the significant implications for human health, biodiversity, and environmental protection. Furthermore, this study highlights the relevance of promoting sustainable agricultural practices that not only minimize the use of pesticides but also strengthen soil health and improve the quality of the final product, in line with the Sustainable Development Goals, in particular SDG 13 on climate action.

This study is fundamental from an agronomic point of view, as it provides specific data on pest management practices in olive cultivation, which are essential for improving agricultural sustainability and crop quality. In a policy context, the results provide a sound basis for the creation of policies and regulations that promote agricultural practices that respect the environment and public health. At the environmental level, the research highlights the importance of reducing reliance on pesticides to preserve biodiversity and to protect ecosystems, as well as increasing the resilience of agriculture to the challenges of climate change. Taken together, these aspects show how the study supports the development of agricultural approaches that are sustainable, economically viable, and in line with the Sustainable Development Goals, particularly in relation to climate change.

The risk of pest infection in olive cultivation is multifactorial and complex. Studies highlighting variables such as biological control, particularly in the management of "*Bactrocera Oleae*"—the main pest of the olive tree—are crucial in understanding and mitigating these risks worldwide. Through an analysis of the scientific literature and contributions from experts in the field such as Campos, Pereira, Santos, Mathiopoulos, and Petacchi, patterns of global collaboration have been identified that are essential for progress in this area. The data visualization highlights countries such as Portugal, Spain, Italy, Greece, and the United States, which not only are at the forefront of research but also have a solid network of scientific collaboration. This type of international alliance is essential for developing effective strategies against olive pests, benefiting growers worldwide, and ensuring the sustainability of this vital crop.

Worldwide studies and experiments on pest control in olive cultivation have highlighted the urgent need to reduce the use of conventional pesticides. This is in response to the adverse effects observed, such as the development of resistance in pests, damage to beneficial species, and the problem of environmental contamination. The current trend emphasizes the adoption of an integrated pest management approach, combining cultural practices, biological control, and the use of biopesticides. These strategies aim not only to control pests effectively but also to maintain environmental sustainability and biodiversity, thus ensuring the long-term viability of olive cultivation.

The challenges posed by pests in olive growing, such as the development of resistance to pesticides and the environmental impact of these products, can be effectively addressed by implementing integrated pest management strategies. This involves a combination of techniques, including chemical rotation, the use of biological controls, and the application of biopesticides. The need to opt for more selective pesticides with less environmental impact is also emphasized, as is the promotion of organic farming practices. These measures are aimed not only at tackling the current problems of resistance and preserving the environment but also at ensuring the long-term sustainability of olive cultivation.

This study reviewed research on bibliometric indicators by processing data on their evolution using keyword search methods to evaluate scientific activity on the subject of olive cultivation and the impact of both research and sources. This review will help to facilitate improvements in the current explosion of knowledge and the compilation of bibliographic bases. Future research in olive growing and pest management is likely to

continue to focus on the long-term effects of pesticide use on human health, biodiversity, and ecosystems, as well as the development of frameworks for safer and regulated use.

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