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Bibliometric Analysis of Plant Disease

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ABSTRACT

Plant diseases pose a severe problem in terms of agricultural production, global food security, and sustainable agriculture. The current research seeks to understand the development, research trends, intellectual structure, and new topics of plant disease studies via the bibliometric analysis method. The papers devoted to plant disease research have been studied using several bibliometric techniques such as citation analysis, co-authorship analysis, keyword co-occurrence analysis, thematic evolution analysis, and density visualization. It appears that plant disease studies have greatly grown in size and become a multidisciplinary field covering plant pathology, microbiology, molecular biology, biological control, and agricultural engineering. The highly cited papers show the relevance of the research in such areas as plant-pathogen interactions, mechanisms of disease resistance, sustainable disease management, and artificial intelligence applications to disease detection. According to the results of the keyword analysis, the research is being changed from a biological to a technological one with deep learning, machine learning, image processing, and automated disease diagnosis gaining their popularity. The analysis of cooperation reveals that China, India, and the USA are playing the leading roles in plant disease research in the global scientific network. The current research gives the understanding of the evolution of plant disease research and shows the future directions of plant disease studies with an emphasis on the application of artificial intelligence and molecular approaches.

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1. INTRODUCTION

The issue of plant diseases poses one of the biggest obstacles in terms of agricultural productivity and sustainable agriculture in the world. With increasing demand for food due to population increase, climatic changes, and modifications in agricultural practices, there has been more pressure put upon the production of crops in the world [1], [2]. Plant diseases, which may come in the form of fungi, bacteria, viruses, nematodes, or any other infectious disease-causing organisms, contribute to yield loss and reduce quality in agricultural products. According to the Food and Agriculture Organization, the importance of plant health has been highlighted as it forms an integral part of food security because the pest and disease losses of crops pose a risk to food supplies [3], [4].

In the past, management of plant diseases has largely involved chemical controls involving the use of synthetic insecticides and fungicides. While such techniques have been used in reducing losses from plants, the reliance on chemicals has been blamed for causing environmental damage, development of pesticide resistance, and health risk for people [5]. The development of pathogen resistance has made conventional methods ineffective, leading scientists to adopt new methods such as biological controls, integrated pest management, resistant plant species, precision farming, and molecular based detection of disease [6]. In addition, biotechnology, remote sensing, artificial intelligence, and genomics have created new frontiers for plant disease management and diagnosis [7]. This has led to an increase in scientific literature focusing on different aspects of plant diseases.

The intricacies of plant diseases research have led to inter-disciplinary collaboration of researchers from different scientific backgrounds like plant pathology, microbiology, biotechnology, agricultural engineering, environmental science, and computational science. The current trends in plant diseases research tend to involve various research perspectives like pathogen identification, host-pathogen interaction, disease epidemiology, disease prediction due to climatic factors, and digital agricultural tools. For instance, there has been increasing interest in machine learning and deep learning methodologies in the context of their application to automate the process of disease recognition through image analysis and predictive modeling [8]. Likewise, developments in molecular science have increased our knowledge about the evolution of pathogens and processes that contribute to resistance in plants. It is therefore necessary to map the evolution of scientific knowledge in the field of plant diseases due to its increasing interconnectedness.

The use of bibliometric analysis is a valuable methodological technique to study the growth, spread, and intellectual organization of scientific literature in a particular field of research. In contrast to conventional literature review which mostly involves the qualitative evaluation of certain publications, bibliometric analysis is based on the use of quantitative tools to evaluate numerous academic papers through various parameters such as publications, citations, author productivity, cooperation of institutions, key term association, and theme evolution [9]. With the help of bibliometric analysis, scholars are able to find leading contributors, research areas, analyze collaboration networks, and find out knowledge gaps which will further be useful for the future research. Thus, the range of applicability of bibliometric analysis includes various fields such as medicine, environmental sciences, biotechnology, and agriculture.

Bibliometric analysis becomes especially relevant in the study of plant disease research as the area has grown significantly due to various new problems such as climate change, globalization, pathogen relocation, and innovation in technology. Previous studies have been done about specific topics within plant pathology research like fungal diseases, biological control, or detection techniques; however, it is still needed to conduct a more general study of plant disease research in order to get a clear idea of where this area is now standing. Bibliometric analysis helps us understand how the development of plant disease research has changed over the years and gives us insight on current trends, changes in methods used, geographical contribution to the field, and future directions that may be worth exploring. Also, bibliometric analysis can help determine connections between the keywords and research clusters, thus showing how traditional plant pathology has merged with modern concepts like artificial intelligence, genomics, sustainability, and precision agriculture.

Despite the considerable increase in research related to plant diseases in the last few decades, there exists a challenge in understanding the structure of accumulated knowledge due to the sheer number and variety of scientific publications in this sphere. Researchers and stakeholders may find it hard to determine the key works, emerging topics, collaboration networks, and untapped research domains because of the fragmented character of the literature in the field. Previously performed review studies were mostly focused on particular pathogens, crops, or techniques; thus, little is known about the evolution of research on plant diseases as such. For that reason, a thorough bibliometric analysis is needed.

This research will involve the undertaking of bibliometric analysis on the subject of plant diseases. The publication trends, citation performances, key authors, key countries, key institutions, key journals, key words, and thematic development in the scientific literature on plant disease will be analyzed in order to understand the development of plant disease studies over time and find out any new direction that could be useful in the future.

2. METHODS

In the course of this study, a bibliometric analysis technique was used to analyze the evolution and trends in the area of plant disease research. The bibliometric analysis technique was selected since it allows conducting quantitative analysis of the scientific literature through productivity, citation analysis, networks of collaboration, and development of themes within a particular research area [9]. Data collection was done with the help of the Scopus database since it is characterized by the wide variety of peer-reviewed scientific literature and is reliable for bibliometric analysis. For finding publications on the topic, the following keywords were used: "plant disease," "crop disease," "plant pathogen," and similar ones. It should be noted that the search was limited to research articles and review papers from scientific journals; conference proceedings, book chapters, and other documents were not taken into consideration.

The retrieved literature sources were then exported in an appropriate bibliographic format, including crucial data such as titles of the articles, their authors, affiliation, year of publication, abstracts, keywords, citations, and references. The gathered dataset was filtered to eliminate duplicates and irrelevant documents that were not related to the research area. Finally, the obtained dataset was analyzed using bibliometric analysis indicators such as annual increase in publications, citation analysis, highly productive authors, dominant countries, institutions, and journals. In addition, science mapping was performed to establish connections between publications, authors, countries, and keywords.

Bibliometric analysis was carried out through VOSviewer, which are software used to create visualization networks and thematic analysis. The creation of co-authorship networks, citation networks, and keyword co-occurrence maps was done by use of VOSviewer software while bibliometric descriptive analysis and thematic evolution were done by use of Bibliometrix software. Thematic analysis of research trends was done by the use of keyword co-occurrence analysis to help in identifying research clusters and trends that emerge from the frequency and relationships among the keywords. Thematic mapping analysis was also performed to categorize the research themes according to their level of development.

3. RESULT AND DISCUSSION

3.1 Co-Author Analysis

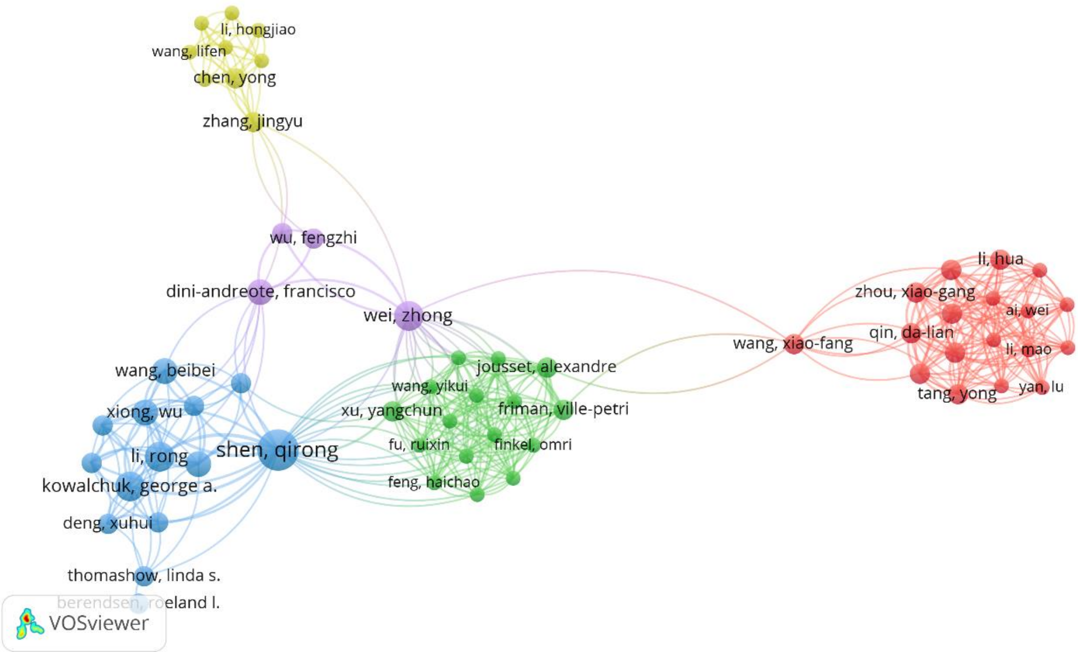

Figure 1. Author Visualization
Source: Data Analysis

Figure 1 highlights the pattern of intellectual collaboration in the field of plant diseases. The network can be seen to consist of many clusters, thereby signifying the presence of various research groups that have a unique pattern of collaborations. The biggest blue cluster, which revolves around Shen, Qirong, is one of the most prominent author nodes in terms of size and connectivity. The cluster consists of authors such as Li, Rong; Xiong, Wu; Wang, Beibei; Kowalchuk, George A.; and Deng, Xuhui, thus suggesting that there has been a lot of collaboration on topics related to plant-microbe interactions, microbial ecology, and biological plant disease management techniques. The green cluster, consisting of authors such as Triman, Ville-Petri; Jousset, Alexandre; Xu, Yangchun; and Fu, Yixin, signifies another group that collaborates on microbial communities, beneficial microbes, and biological methods.

The cluster on the right side with authors like Li, Hua; Ai, Wei; Li, Mao; Tang, Yong; and Yan, Lu, forms an extremely connected research cluster with a rather independent collaborative structure. The presence of bridging authors like Wang, Xiao-Fang and Wei, Zhong, shows their important contribution to connecting various scientific communities. The entire network suggests that the study of plant diseases has progressed through several collaborative networks, and not just through one dominating network. This shows that the present research in the field of plant diseases consists of varied themes like pathogens identification, microbial control, biological control, and disease management strategies.

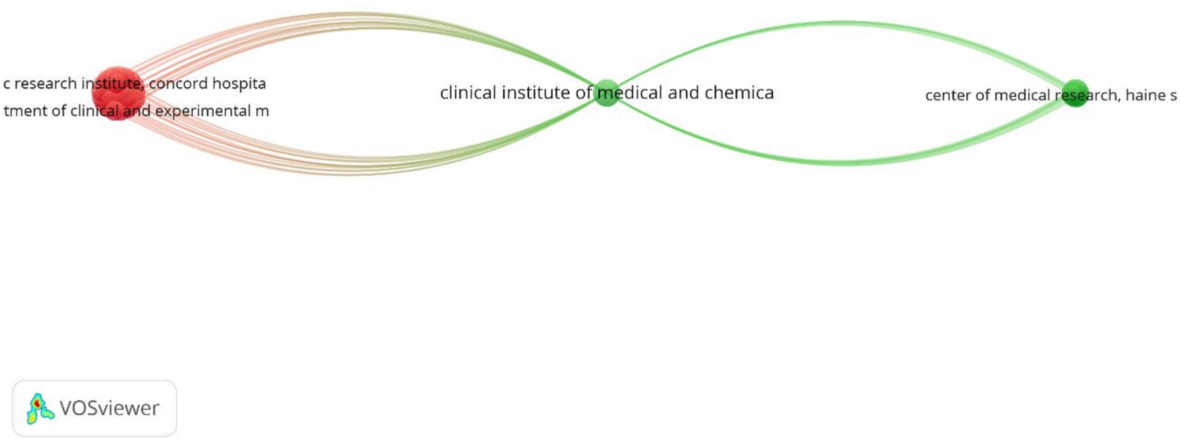

Figure 2. Institution Visualization
Source: Data Analysis

Figure 2 presents a limited yet interrelated pattern of research collaboration between various institutions undertaking research related to plant diseases. From the network presented in Figure 2, it is clear that Clinical Institute of Medical and Chemical Research acts as an intermediary institution because of its large node compared to other nodes, as well as its linkage between different institutional categories. This institution connects the Research Institute, Concord Hospital, and the Department of Clinical and Experimental Medicine on one side to the Center of Medical Research, Hainan on the other side. From this, it is clear that this institution plays a crucial role in facilitating the process of knowledge transfer as well as collaborative research activities. The thick lines connecting the nodes indicate multiple collaborations in terms of co-authorship relations. However, from the number of nodes present in the figure, it is clear that the collaboration between institutions in this field of research is still limited.

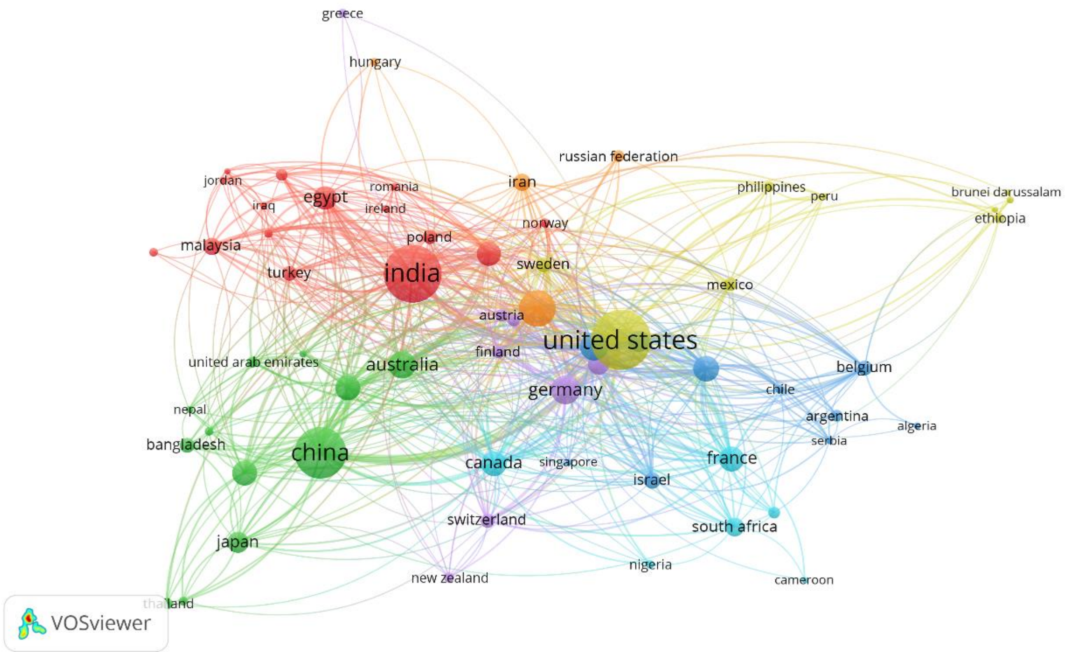

Figure 3. Country Visualization
Source: Data Analysis

The global cooperation network in research in plant diseases is illustrated in Figure 3. The network reveals that research activities are conducted in many countries and that several countries serve as major contributors and collaboration centers. India, China, and the USA come out as the major nodes because of the large size of their nodes, which indicates high publication and influence among the research community. India has many ties with countries such as Egypt, Malaysia, Turkey, Iran, Poland, and others. Thus, India has many collaborations at an international level. China is also one of the major contributors and collaborators in research, having many ties with Japan, Australia, Bangladesh, Thailand, and other Asian countries. Similarly, the USA acts as another hub of research collaborations with strong ties with several European countries such as Germany, France, Belgium, Canada, and others.

It can be observed that there are several regions which are collaborating with one another through the network structure. Green cluster consists of several Asian-Pacific countries with leadership from China, along with Japan, Australia, and neighboring countries. The red cluster is mainly consisting of India along with other countries from Asia, Middle East, and Europe, depicting the growing role of India in international plant disease research. Blue cluster is representing the collaboration of Western countries, consisting mainly of the US, France, Germany, Canada, and Belgium. At the same time, there are some smaller clusters including Iran, Mexico, Peru, Ethiopia, and Brunei Darussalam, indicating the emerging research collaboration. Several lines connecting various clusters show the increasing globalization and interdisciplinary aspect of plant disease research, implying that knowledge sharing is taking place in various geographic regions. At the same time, the intensity of collaboration still seems to be limited to a few countries only.

3.2 Citation Analysis

Table 1. Top Cited Literature

Citations	Authors and Year	Title

4650	[10]	The effects of plant flavonoids on mammalian cells: Implications for inflammation, heart disease, and cancer
4575	[11]	Using deep learning for image-based plant disease detection
4196	[12]	Plant polyphenols as dietary antioxidants in human health and disease
3121	[13]	Deep learning models for plant disease detection and diagnosis
2191	[14]	Use of plant growth-promoting bacteria for biocontrol of plant diseases: Principles, mechanisms of action, and future prospects
2105	[15]	Plant essential oils for pest and disease management
2056	[16]	Bacillus lipopeptides: versatile weapons for plant disease biocontrol
1806	[17]	Deep Neural Networks Based Recognition of Plant Diseases by Leaf Image Classification
1644	[18]	Hormone crosstalk in plant disease and defense: More than just JASMONATE-SALICYLATE antagonism
1573	[19]	Plant disease: A threat to global food security

Source: Scopus 2026

The most important scientific publications in terms of the plant disease study citation rate and, consequently, the major scientific achievements in this sphere are summarized in Table 1. The article with the highest number of citations is the work by [10] "The effects of plant flavonoids on mammalian cells: Implications for inflammation, heart disease, and cancer" with 4,650 citations. This information reveals the crucial role of plant-based substances and their biological functions in broader biomedical research. Nevertheless, there is an increasing number of highly cited articles concerning the application of modern approaches to plant diseases' identification and control. For instance, the works by [11] "A review of deep learning methods and applications" and [13] "Applications of artificial intelligence for plant disease detection" gained 4,575 and 3,121 citations, respectively, showing the increasing role of deep learning and artificial intelligence in automatic plant disease detection through imaging technology. Another group of the most highly cited papers concerns the application of biological means of disease control in the form of plant growth-promoting bacteria [14], essential oils [15], and Bacillus lipopeptides [16]. Also, works concerning the immune system of plants, especially its hormonal regulation [18], and global implications of plant diseases on food security [20] can be pointed out.

3.3 Keyword Co-Occurrence

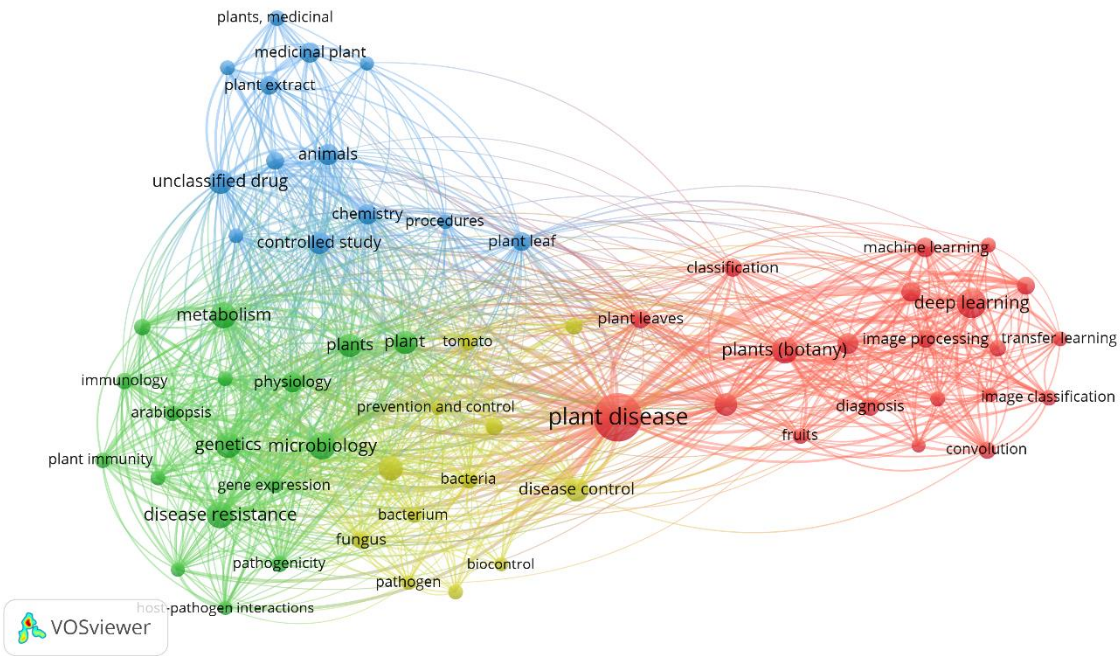

Figure 4. Network Visualization
Source: Data Analysis

Figure 4 shows the theoretical framework and research areas within plant disease research. The network consists of a number of interrelated clusters, showing that the research into plant disease has emerged from various scientific viewpoints, such as the use of artificial intelligence to detect the disease, plant pathology, molecular mechanisms, and sustainable disease control. The central location of the keyword "plant disease," together with its large node size, signifies that it is the main research area that links various research areas together. The strong connections between "plant disease" and other keywords show that present-day research is highly multidisciplinary in nature.

The red cluster depicts the newly emerging technology dimension of plant disease studies, especially concerning machine learning, deep learning, image processing, image classification, convolutional neural network, and diagnosis. This is due to the increasing use of artificial intelligence technology in agriculture where researchers employ images for detecting, classifying and improving the accuracy of early detection of symptoms of disease. The terms like "deep learning" and "machine learning" reveal a high connectivity with "plant leaves" and "classification," implying that the study of images of plant leaves is increasingly used as an approach to automated diagnosis of plant diseases.

The green cluster shows biological and molecular research associated with plant-pathogen interactions, disease resistance, and plant immunity. The keywords “genetics,” “microbiology,” “gene expression,” “pathogenicity,” “disease resistance,” and “host-pathogen interactions” confirm that scientists are still researching the mechanisms involved in the plant response to pathogens and disease development. It is evident that there is an emphasis on research into molecular mechanisms necessary to breed resistant crops and improve strategies of disease management. The relationship of the cluster to the main keyword “plant disease” proves that biological mechanisms play a crucial role in preventing and managing diseases.

The yellow cluster is concerned with managing diseases in plants and biological control methods. Usage of keywords like “bacteria,” “fungus,” “pathogen,” “biocontrol,” “disease control,” and “prevention and control” implies an emphasis on sustainable techniques that can reduce the negative effects of disease. This cluster shows the rising interest in using environmental-friendly techniques such as biocontrol agents and microorganisms as opposed to chemical pesticides. The strong connection between this cluster and the green biological cluster indicates that an understanding of the interaction between the microbes and pathogens is crucial in devising sustainable control measures.

Blue cluster denotes scientific studies concerning plant-based chemicals, medicinal plants, and biochemical characteristics, such as “plant extract,” “medicinal plant,” “chemistry procedures,” “metabolism,” and “plant leaf.” This theme points out the exploration of bioactive substances and their possible uses for disease prevention and plant protection, among others.

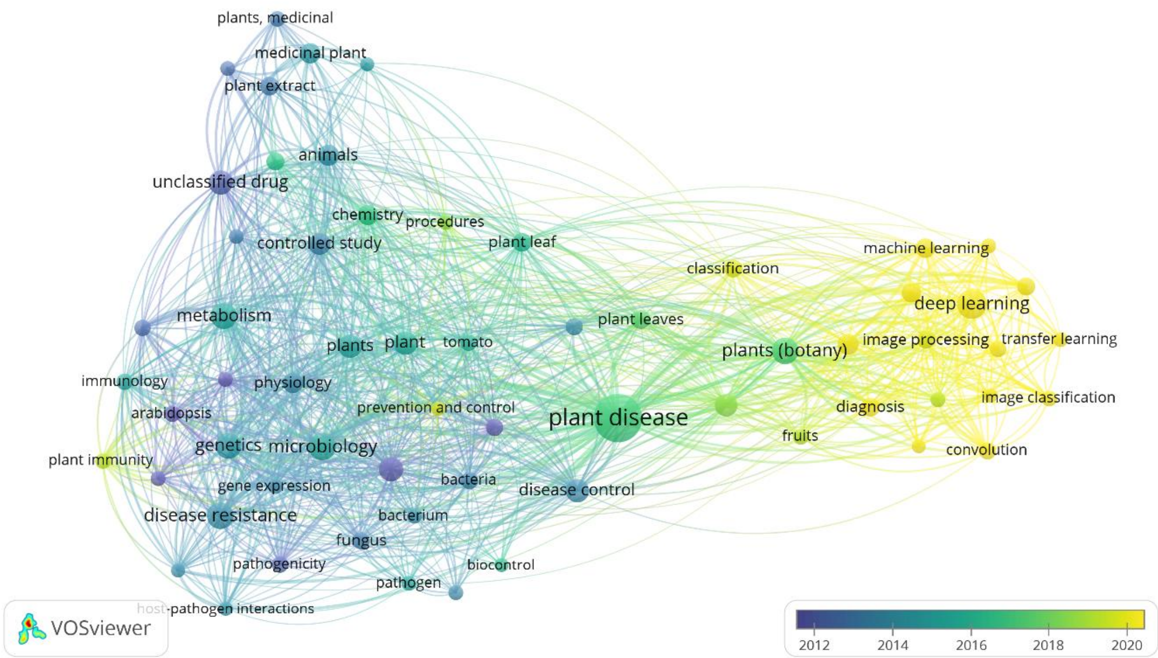

Figure 5. Overlay Visualization
Source: Data Analysis

Figure 5 shows the temporal dynamics of the major topics in the research on plant diseases using the pattern of keyword appearance. The color scale denotes the average publication time span, where dark blue corresponds to the older topic (about 2012-2014), and green and yellow denote the relatively recent topic (about 2018-2020). The central keyword “plant disease” marks the major topic in the research connecting all the science fields. The coloring suggests that earlier publications mostly deal with the biological aspect, pathogen interaction, and disease resistance, and the relatively recent ones involve technology, especially artificial intelligence, and disease diagnostics.

The first phase of research is denoted by the blue colored keywords like "genetics," "microbiology," "gene expression," "disease resistance," "pathogenicity," "host-pathogen interactions," and "plant immunity." These topics signify the fact that the focus of the initial research was on comprehending the biological aspects of plant diseases through the behavior of pathogens, molecular response, and defense mechanism of plants. Bacterial and fungal interactions were also common topics of the first phase of research.

The recent research direction is characterized by keywords that are highlighted in yellow color such as "deep learning," "machine learning," "image processing," "image classification," "classification," and "diagnosis." Such emerging research topics clearly show how artificial intelligence and computer vision technologies are becoming increasingly integrated into the study of plant diseases. This change in the research themes proves that contemporary research trends are shifting away from conventional pathogen detection methods towards developing an automated, fast, and non-invasive method of detecting plant diseases using images of plant leaves. The entire timeline of research shows a shift from basic research of plant pathology to advanced technological approaches in which artificial intelligence is a prominent emerging trend.

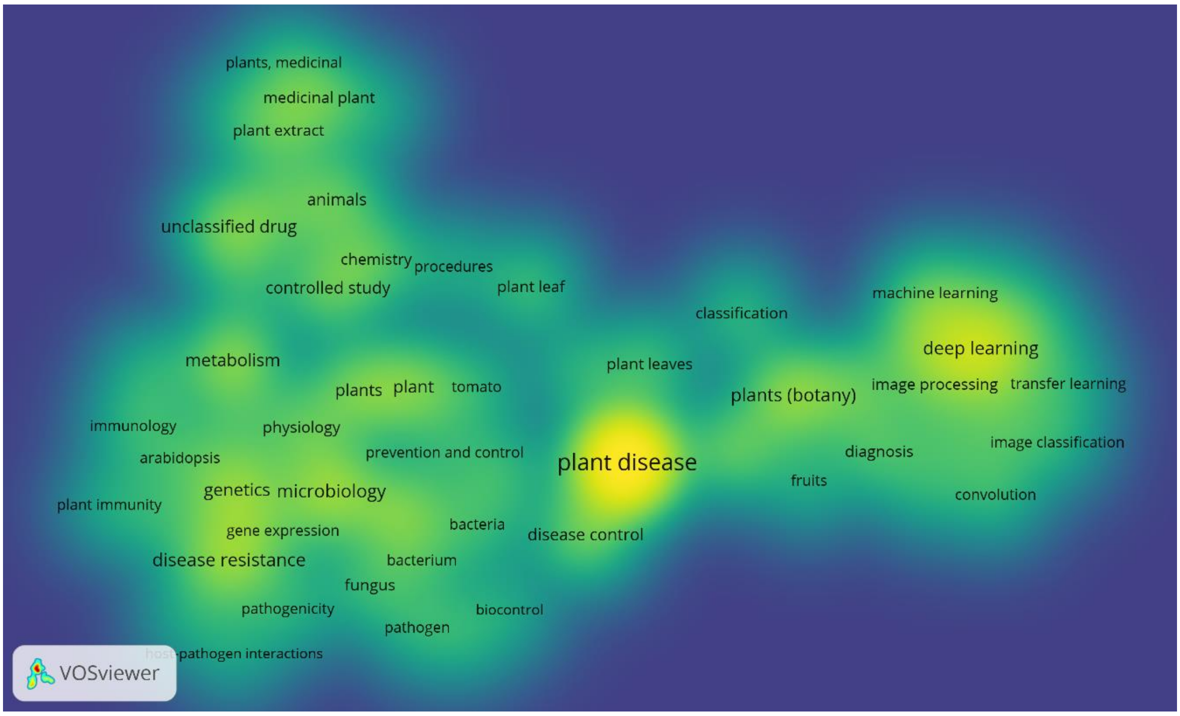

Figure 6. Density Visualization
Source: Data Analysis

Figure 6 depicts the level of significance and density of research topics in plant disease literature. The region with the highest density is the one that centers on the keyword "plant disease," suggesting that it is the core of the research field and the most common topic of discussion among researchers. The core topic is highly related to different fields, including plant disease control, plant leaves, pathogens, bacteria, fungi, and biological mechanisms of the plant. The dense regions around "genetics," "microbiology," "gene expression," "disease resistance," and "pathogenicity" demonstrate the importance of basic biological and molecular investigations within the research field of plant diseases.

The visualization also emphasizes the development of high-density zones related to the application of technology-based approaches, especially in terms of the use of "deep learning," "machine learning," "image processing," "image classification," and "diagnosis." These subjects exhibit active research interests and prove the growing importance of artificial intelligence and computer vision as effective tools in automatic disease diagnosis of plants. In comparison with the traditional biological-based approaches, these technology-based areas can be considered new ones for future research on more accurate, faster, and efficient disease recognition. Some other moderately dense areas include plant extract, medicinal plants, metabolism, and biocontrol.

DISCUSSION

In the bibliometric analysis of plant disease research, it becomes clear that this research area has become an interdisciplinary research area consisting of plant pathology, microbiology, molecular biology, biotechnology, and agricultural technology. An analysis of the trends of publication, collaboration networks, and keywords shows that plant disease is one of the scientific issues that has been of great importance because it affects the productivity of crops and sustainable agriculture. The influence of citations in important papers can be attributed to two fundamental areas of research: knowledge of biological processes involved in plant diseases and approaches to manage plant diseases. Important papers published in the past focused on the processes of defense of plants against pathogens, biological control, and the use of natural compounds to inhibit diseases.

Development of research topics highlights an important shift from traditional plant pathology to technology-oriented researches. The use of terms such as deep learning, machine learning, image processing, and image classification shows an increasing trend in applying artificial intelligence in the process of diagnosing diseases in plants. The reason for this is that there is an increasing need for fast, accurate, and non-destructive methods of detecting diseases in order to be able to apply precision agriculture. Researches that have been done earlier and were based on visually recognizing symptoms through observations by humans have gradually evolved towards more automated approaches using convolutional neural networks and computer vision. The high citation rate of articles that deal with the application of deep learning to detect diseases in plants clearly proves that artificial intelligence has become one of the most influential new trends in this field.

Moreover, the analysis of collaboration and themes clearly indicates that there is global distribution of plant disease studies but at the same time they are dominated by advanced countries, organizations, and researchers. China, India, and the United States act as main centers for research because of high publishing activities and broad international collaborative network. But the presence of several regional clusters clearly indicates growing international collaboration and sharing of knowledge among different research groups. Future studies must enhance international collaboration by combining expertise from plant sciences, data sciences, environmental sciences, and agricultural engineering.

4. CONCLUSION

This bibliometric analysis offers an insight into the development, intellectual structure, and trends emerging in the field of plant disease research. It is evident from the results that plant disease research has emerged as a multidisciplinary research field including biological science, agricultural technology, microbiology, molecular science, and artificial intelligence. The highly cited publications analysis has revealed that earlier researches were more inclined towards studying plant-pathogen interaction, disease resistance, and biological control of diseases whereas current research is moving towards using technology-based solutions such as deep learning, machine learning, and disease detection using images. Collaboration network analysis has revealed that global research on this topic is led by the world's leading countries such as China, India, and USA, which are the major contributor countries and centers for international collaborations. Moreover, keyword evolution analysis shows that the field of plant disease has shifted from classical disease detection to intelligent and sustainable disease detection techniques using data. It is apparent that the future of plant disease research will lie in the fusion of technological advances with biological knowledge.

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