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Literature Review Study of Google Scholar Indexed Articles on Mycorrhiza in Plant Disease Control

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ABSTRACT. Mycorrhiza is a fungus that is symbiotic with plant roots, has great potential in biological control of plant diseases. The purpose of this literature review study is to examine in depth the role of mycorrhiza in plant disease control based on scientific articles indexed on Google Scholar. This study used the Systematic Literature Review (SLR) method to collect data from 100 relevant scientific articles, indexed on Google Scholar, with a range of years 2010-2024. The data was analyzed using VOSviewer software to map the relationship between keywords. The results of network, overlay and density visualization using VOSviewer showed that mycorrhiza, particularly arbuscular mycorrhizal fungi (AMF), have a central role in plant disease control through symbiotic interactions with roots and soil microorganisms. The network visualization highlights the close relationship between keywords such as "plant," "fungi," and "soil microorganism," while the overlay visualization reveals recent research trends focusing on plant growth and protection against pathogens. The density map visualization emphasized that topics such as root health, symbiosis, and soil microorganism management were the main focus. Overall, this study confirms the importance of mycorrhizae in supporting sustainable agriculture, with great potential to increase crop productivity and reduce reliance on chemical pesticides.

Keywords: *Mycorrhiza, Plant disease control, Arbuscular Mycorrhizal Fungi (AMF), Sustainable agriculture, VOSviewer bibliometric analysis*

INTRODUCTION

Arbuscular mycorrhizae fungi (AMF) are the symbiotic fungi that predominate in the roots and soils of agricultural crop plants. The AMF forms beneficial symbioses in most terrestrial ecosystems and crop production systems (Singh, et al., 2019). Arbuscular mycorrhizal fungi (AMF) are symbiotic organisms that form close relationships with their host plants through the development of intracellular structures, namely arbuscules, within root cortical cells. AMF plays an important role in natural ecosystems, providing various ecological benefits such as enhancing the uptake and transfer of essential nutrients, influencing the composition of fungal and bacterial communities in the soil, and improving soil texture and structure. In addition, AMF strengthens plant resistance to salinity, drought, temperature extremes, pathogens, pests and weeds. AMF also supports plant defense mechanisms through the production of antimicrobial compounds, induction of defense-related biomolecules, and activation of resistance genes (Bhupenchandra, et al., 2024). The symbiotic association between plants and mycorrhizal fungi has been shown to significantly reduce the severity of diseases caused by fungi, nematodes, and bacteria, especially in crops vulnerable to these pathogens.

Microbial communities play a pivotal role in the functioning of plants by influencing their physiology and development. While many members of the rhizosphere microbiome are

beneficial to plant growth, also plant pathogenic microorganisms colonize the rhizosphere striving to break through the protective microbial shield and to overcome the innate plant defense mechanisms in order to cause disease (Rodrigo, et al., 2013). Arbuscular mycorrhizal fungi (AMF) are the most common, have the largest biomass and the most significant group of beneficial fungi in mycorrhiza, with specific antagonistic or inhibitory effects against soil-borne pathogens (Allsup, et al., 2021, Gabriele, et al., 2009). Studies have shown that AMF can regulate the formation of secondary metabolites in host plants by changing the morphology or anatomical structure of plant roots, improve the physical and chemical properties of the rhizosphere environment, compete with pathogens for photosynthetic products and infection space, and activate disease resistance and defense systems in plants (Aseel, 2029). AMF can reduce damage caused by fungi, nematodes, bacteria, and other pathogens on *Cucumis sativus, Fragaria ananassa, Lycopersicon esculentum, Citrus reticulata, Olea europaea, Medicago truncatula, Cucumis melo, Zea mays, Solanum tuberosum, Musa nan,* and other crops, and can also reduce the use of pesticides (Razak, 2021; Begum, et al, 2019; Lee, et al, 2013; Gianinazzi, et al., 2010; Allsup, et al., 2021, Li, et al., 2018).

The effectiveness of mycorrhizal fungi in disease control can vary depending on factors such as the type of pathogen, the fungal species involved, and environmental conditions. However, in most cases, their application has been associated with improved plant vigor and reduced disease incidence in a wide range of crops, including tomatoes, wheat, and potatoes This has led to growing interest in integrating mycorrhizal fungi into disease management strategies as part of integrated pest management (IPM) programs, which aim to reduce the reliance on chemical treatments.

Based on the description above, mycorrhiza as plant disease control, the author intends to examine how mycorrhiza can be used in plant disease control through a literature review study on articles indexed on Google Scholar. Mycorrhiza, which is a symbiosis between fungi and plant roots, is known to have great potential in increasing plant resistance to pathogen attack. Therefore, a deeper understanding of the mechanism of action of mycorrhiza in plant disease control needs to be studied further. In this review, the authors will collect and analyze various relevant research results to understand the role of mycorrhiza in improving plant health and reducing disease attacks.

This literature review study aims to explore the scientific evidence supporting the use of mycorrhiza as a biological control agent. Based on previous research, mycorrhiza has been proven to protect plants from various types of soil pathogens, such as wilt-causing fungi, *Fusarium, Pythium,* and *Rhizoctonia*. One of the mechanisms carried out by mycorrhiza is competition with pathogens for space and nutrients in the rhizosphere, which directly reduces the ability of pathogens to attack plants. Other studies have shown that mycorrhiza can also stimulate the plant defense system through the activation of plant immune responses, which allows plants to be more resistant to pathogen infection.

The problem raised in this review is to explore the extent to which mycorrhiza can play a role in plant disease control, especially in soils with commonly found pathogens. This literature review is expected to provide a clear picture of the effectiveness of mycorrhiza in overcoming plant disease problems that often occur in food crops and horticulture. The author also hopes that the results of this review will enrich the understanding of the application of mycorrhiza as an alternative to disease control in a more sustainable agricultural system.

Through this literature review, the author hopes to provide greater insight into the potential of mycorrhiza in plant disease control and how this technology can be practically

applied in the field. With a deeper understanding of mycorrhizal interactions with pathogens, it is hoped that innovative solutions can be created in the management of plant diseases that are environmentally friendly, reduce dependence on chemical pesticides, and support more sustainable agriculture in the future.

MATERIALS AND METHODS

This research method uses a literature review approach with a focus on publications indexed in Google Scholar (GS) that are relevant to the use of mycorrhiza in plant disease control. Data searches were conducted using the Publish or Perish tool on February 18, 2024 with a publication time span between 2010 and 2024. The keywords used in the search included "Mycorrhiza, Plant Disease Control, Fungal Symbiosis, Soil Microbial Management, Crop Protection," which resulted in 100 articles related to this research topic. The data obtained were then analyzed and visualized using VOSviewer software, which allows mapping and bibliographic analysis based on co-occurrence with all keywords analysis type and full-counting method. Determining a minimum of five occurrences for each keyword helps to clarify the main trends in related research.

Bibliometric analysis using VOSviewer aims to identify the interrelationships between different topics covered in the literature on mycorrhiza as a plant disease control agent. Using co-occurrence visualization, this tool provides a clear picture of how keywords related to mycorrhiza and plant disease control are interconnected in the context of existing publications. In addition, the mapping of relevant articles based on predefined criteria allows researchers to focus on more specific and relevant topics. The article selection process was carried out with inclusion criteria, namely articles published in google scholar indexed journals, and containing relevant keywords.

The selected articles were then analyzed using the VOSviewer matrix analysis system to identify important patterns that emerged in the studies. This selection process and matrix analysis enabled the authors to obtain relevant and quality articles, resulting in in-depth conclusions on the role of mycorrhiza in plant disease control. This method is expected to provide a comprehensive and structured insight into the use of mycorrhiza in a more sustainable agricultural context.

RESULTS AND DISCUSSION

Network Visualization

This network visualization provides an overview of the relationships and interrelationships of terms relevant to research on Arbuscular Mycorrhizal Fungi (AMF) and their role in plant disease control, soil health and plant growth. These terms are grouped into three main clusters that represent specific themes: mycorrhizal symbiosis, crop protection, and the role of soil microorganisms. Arbuscular Mycorrhizal Fungi (AMF) take center stage in this map, highlighting their significant role in supporting soil and plant ecosystems through symbiotic relationships. These clusters show the linkages between mycorrhizae and important aspects such as root protection from pathogens, enhanced nutrient uptake by plants, and interactions with other microorganisms in the soil. As such, this map not only provides deep insights into the conceptual structure of existing research, but also shows the potential contribution of mycorrhiza in sustainable approaches to crop and soil management. Analysis of results based on network visualization of bibliometric data obtained as follows in Figure 1.

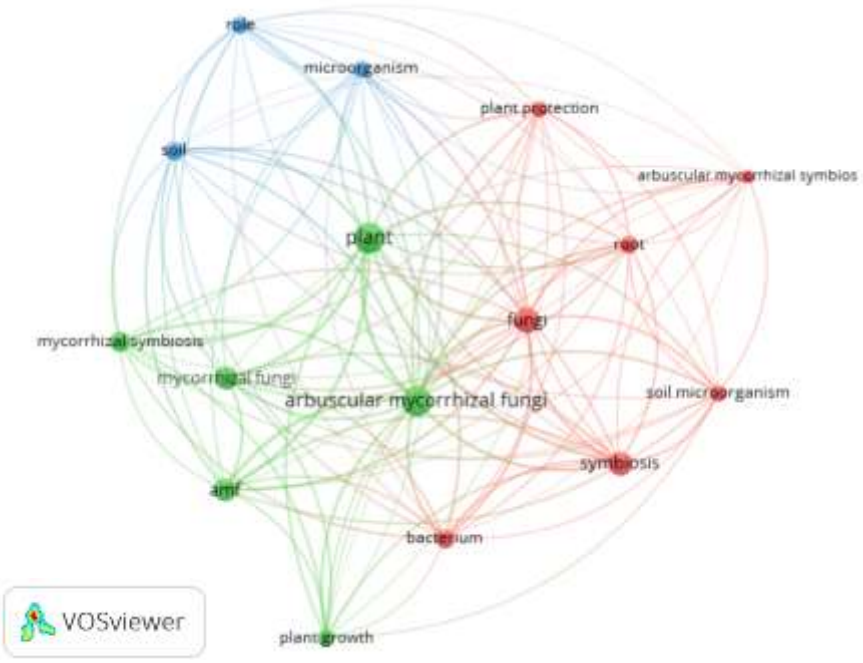


Figure 1.Network Visualization Map (Source processed: VOSviewer, 2024)

Main Keyword Linkages. The network visualization shows a close relationship between several main keywords such as arbuscular mycorrhizal fungi, plant protection, symbiosis, and soil microorganism. This indicates that research on mycorrhizae often focuses on the role of these symbionts in enhancing plant protection through interactions with soil microorganisms. These keywords are at the core of discussions in research related to mycorrhiza and plant disease control.

Main Clusters in the Study. Three main clusters were identified in the visualization. Cluster 1 (red) includes topics such as arbuscular mycorrhizal symbiosis, fungi, plant protection and roots. This cluster highlights the major role of arbuscular fungal symbionts in protecting plants from pathogens through symbiotic relationships at the root. This cluster reflects the large focus on the biological benefits of mycorrhizal fungi to agricultural systems.

Cluster Two: Plant Growth and AMF. The second cluster (green) displays the relationship between arbuscular mycorrhizal fungi (AMF), mycorrhizal fungi, plant growth, and mycorrhizal symbiosis. The main focus of this cluster is the role of mycorrhizae in enhancing plant growth. This relationship is supported by studies showing that AMF helps plants increase uptake of nutrients such as phosphorus, thus contributing to plant protection indirectly.

Third Cluster: Soil Microorganisms and Their Role. The third cluster (blue) includes keywords such as microorganism, soil, and role. It shows the interconnectedness of soil microorganisms and their contribution to supporting a healthy soil ecosystem. Mycorrhizae interact closely with other soil microorganisms to create a favorable environment for plants.

Relationship between Symbiosis and Plant Protection. Keywords such as symbiosis and plant protection often appear together in visualizations. This shows that research on mycorrhizae is not only focused on nutritional aspects, but also on how the symbiont relationship with plants protects plants from pathogens through biological mechanisms.

The Role of Mycorrhizae in Soil Pathogen Management. This visualization also highlights how AMF is connected to the term soil microorganism. This shows that one of the main roles of mycorrhiza is in the control of diseases caused by soil pathogens. This function is important in the context of biologically managing plant diseases without reliance on chemical pesticides.

Benefits to the Plant Root System. The term root, which is closely linked to arbuscular mycorrhizal fungi, indicates the important role of mycorrhizae in improving the health of plant root systems. Mycorrhizae are known to form external structures that improve the ability of roots to absorb nutrients and water, while providing protection against pathogen attack.

Sustainable Approaches in Agriculture. The link between plant protection and soil microorganisms highlights the relevance of using mycorrhizae in sustainable agricultural approaches. Research shows that mycorrhizae help create a balance of soil microbiota, which naturally reduces the prevalence of pathogens.

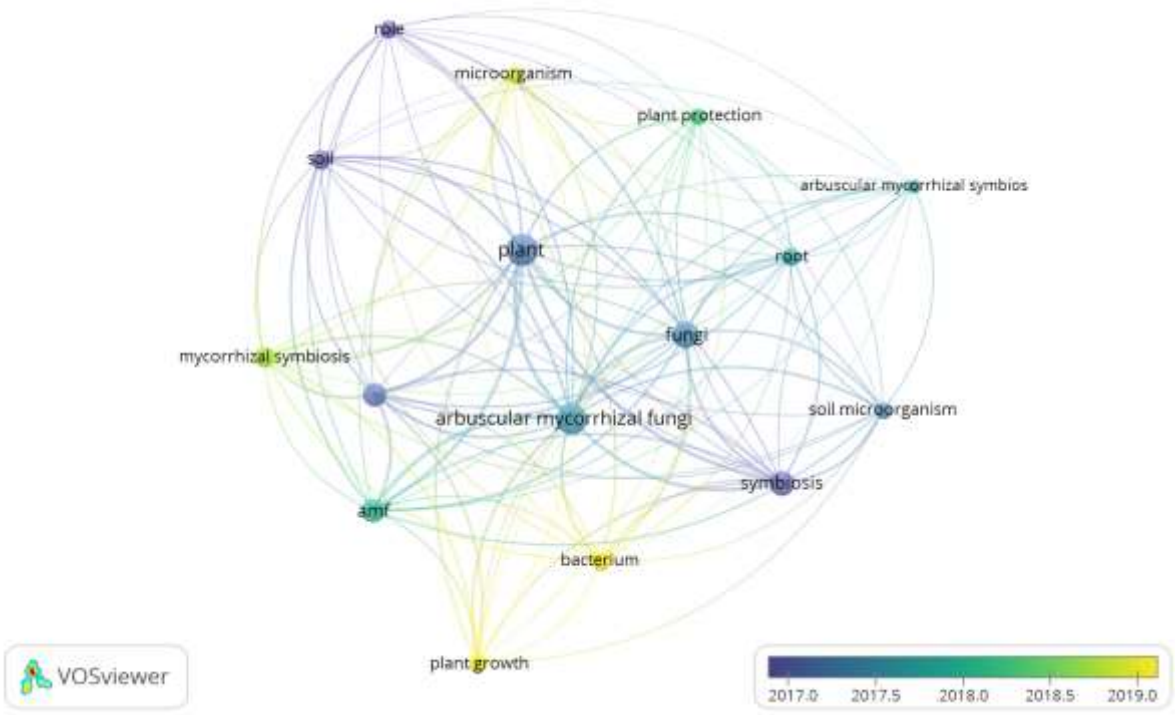
Visualization as a Tool to Find Research Patterns. This bibliometric visualization also helps identify research trends in the use of mycorrhiza for plant disease control. By using co-occurrence analysis, researchers can understand key areas that have received attention in previous research, as well as identify potential future research.

Based on the patterns identified, future research could focus on developing practical applications of mycorrhiza for specific crops, as well as further exploration of the interactions between mycorrhiza and soil microorganisms in the context of plant disease control. This opens up opportunities to develop new technologies based on soil ecosystems.

The visualization results show that mycorrhiza plays an important role in plant disease management, both directly through protection against pathogens, and indirectly through improved root health and interactions with soil microorganisms. Further research is needed to fully utilize this potential in agricultural systems.

Overlay Visualization

This Map Overlay Visualization provides an overview of keyword relationships in research related to plants, microorganisms, and fungi, as well as their temporal trends from 2017 to 2019. The map shows the close relationship between key topics such as "plant," "fungi," "soil microorganism," and "arbuscular mycorrhizal fungi," reflecting the research focus on symbiotic relationships between plants and soil organisms. In addition, the color distribution on the map shows the development of research themes over time, with topics such as "plant growth" and "bacterium" receiving greater attention in recent years. As such, the map not only highlights the conceptual connections between keywords, but also provides insight into priorities and trends within this field of research.



Map Overlay Visualization (Source processed: VOSviewer, 2024)

Dominance of Relationships between Keywords. The Overlay Visualization map shows that "plant" is at the center of the network, being the main topic with strong relationships to other keywords such as "fungi," "root," and "soil microorganism." This suggests that plant research is the main focus in this domain, with related studies on other organism interactions.

The Role of Fungi and Soil Microorganisms. Keywords such as "fungi," "arbuscular mycorrhizal fungi," and "soil microorganisms" have a close connection with "plant." This reflects the research interest in the symbiotic relationship between plants and microorganisms, especially in the context of plant growth and soil health. This reflects the research interest in the symbiotic relationship between plants and microorganisms, especially in the context of plant growth and soil health.

Arbuscular Mycorrhizal Fungi (AMF) as the Main Focus. The keyword "arbuscular mycorrhizal fungi" and its abbreviation, "amf," appear as important entities in this map. This topic highlights the focus on the role of mycorrhizal fungi in assisting nutrient uptake by plants, demonstrating their biological significance in plant ecosystems.

Temporal Trends of Keywords. The gradient colors used on the map show the change in research time, from 2017 (blue color) to 2019 (yellow color). Keywords such as "plant growth" and "bacterium" are more dominant in the latter period, reflecting the increased attention to this topic in recent years.

Symbiotic Relationships and Plant Growth. The connection between "symbiosis," "mycorrhizal symbiosis," and "plant growth" suggests that research exploring symbiotic

relationships has a direct impact on increasing yield and plant health. This is relevant in the context of sustainable agriculture and ecosystem improvement.

Plant Protection. The keyword "plant protection" also has significant connections. It includes studies that focus on how microorganisms and fungi help plants deal with pathogens or environmental stress, such as drought or nutrient deficiencies.

The Role of Roots in Plant Ecosystems. The keyword "root" suggests important connections with fungi, microorganisms, and plants. It reflects research interest in the function of roots as a major gateway for nutrient uptake and a place of interaction with soil organisms.

Collaboration of Microorganisms and Bacteria. The presence of keywords such as "bacterium" alongside "microorganism" suggests that soil bacteria are also an important component in plant ecosystem relationships, especially in facilitating plant growth through nitrogen fixation or decomposition of organic matter.

Multidisciplinary Research Linkages. The map shows that research involving plant-soil organism relationships is multidisciplinary, incorporating aspects of ecology, biology and agriculture. This shows how important cross-disciplinary collaboration is to understand the complexity of organism interactions.

Implications for Sustainable Agriculture Development. The research represented in this map has direct applications in the development of sustainable agriculture. Studies focusing on the symbiosis of plants and soil organisms can provide natural solutions to increase crop productivity while maintaining ecosystem health.

Density Visualization

This Density Visualization map provides an overview of the density distribution of keywords in research related to plant relationships with soil organisms, such as fungi, microorganisms, and roots. The bright yellow color signifies areas with the highest research density, indicating that topics such as "plant," "fungi," and "arbuscular mycorrhizal fungi" are the main focus. This visualization also reflects the relevance of research themes such as symbiosis, plant growth, and plant protection in agrarian ecosystems. By showing the interaction and intensity of the topics under study, the map is an important tool for understanding research priorities in soil biology and sustainable agriculture.

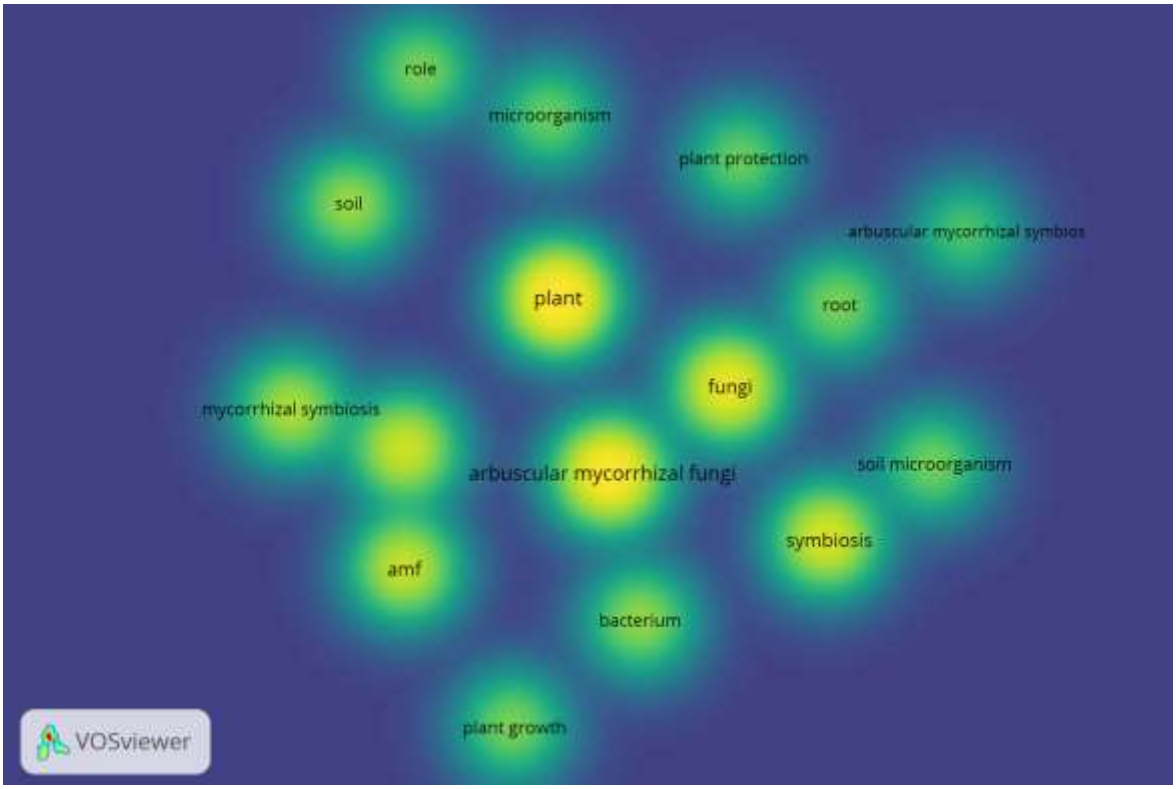


Figure 3. Density Visualization map (Source processed: VOSviewer, 2024)

Center of Density on the Keyword "Plant". The keyword "plant" has the highest density, which can be seen from the intensity of the very bright yellow color around it. This shows that plants are the main center of attention in this study, with strong connections to other aspects such as fungi, roots, and soil microorganisms.

Significant Associations with "Fungi" and "Arbuscular Mycorrhizal Fungi". High densities were also seen around the keywords "fungi" and "arbuscular mycorrhizal fungi," indicating that fungi, particularly mycorrhizae, play an important role in plant ecosystems. This confirms the relevance of fungi as symbiotic mediators for improving plant health and productivity.

The Role of Soil Microorganisms. The keywords "soil microorganism" and "microorganism" also have a high density, indicating research attention on the important role of microorganisms in supporting plant life, whether through nutrient uptake, pathogen control, or symbiotic interactions.

Roots as a Center for Biological Interactions. "Roots" are seen to have a high density, reflecting their important role as the main site of interaction between plants and microorganisms. This study focuses on how roots are the starting point for processes such as nutrient uptake and plant growth.

Relationship with Plant Growth. The keyword "plant growth" has a fairly high density, indicating great interest in research linking soil microorganisms and fungi with efforts to improve plant growth. This topic is particularly relevant for practical applications in sustainable agriculture.

Importance of Symbiosis in Plant Ecosystems. The high density around "symbiosis" and "mycorrhizal symbiosis" indicates that symbiosis between plants and soil organisms is a central theme in this study. This emphasizes the importance of mutualistic relationships in supporting plant resilience and productivity.

Topic Plant Protection. The keyword "plant protection" appeared with medium density, highlighting the important role of fungi and microorganisms in protecting plants from biotic and abiotic stress, including diseases and adverse environmental conditions.

Research Trends on Microorganisms and Bacteria. "Microorganism" and "bacterium" show significant density, reflecting recent research trends on the role of microbes, especially bacteria, in supporting agricultural systems through mechanisms such as biofertilization and biocontrol.

The Role of AMF in Plant Ecosystems. The abbreviation "amf" (arbuscular mycorrhizal fungi) indicates a fairly high density, underscoring the role of these fungi in enhancing the uptake of phosphorus and other nutrients by plants. This is particularly relevant in research focused on improving nutrient efficiency on farms.

Overall, this visualization shows that research focusing on the relationship between plants and soil organisms has great potential to support agricultural sustainability. By understanding these interactions, strategies can be developed to naturally increase crop productivity while maintaining healthy soil ecosystems.

CONCLUSION

Network, overlay, and density visualizations using VOSviewer show that mycorrhizae, particularly arbuscular mycorrhizal fungi (AMF), have a central role in plant disease control through symbiotic interactions with roots and soil microorganisms. The network visualization highlights the close relationship between keywords such as "plant," "fungi," and "soil microorganism," while the overlay visualization reveals recent research trends focusing on plant growth and protection against pathogens. The density map visualization emphasized that topics such as root health, symbiosis, and soil microorganism management were the main focus. Overall, this study confirms the importance of mycorrhizae in supporting sustainable agriculture, with great potential to increase crop productivity and reduce reliance on chemical pesticides.

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