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Role of Vesicular Arbuscular Mycorrhiza (VAM) Fungi in Plant Disease Management

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Arbuscular Vesicular Mycorrhiza (AVM), also known as arbuscular mycorrhizal fungi (AMF), play a crucial role in sustainable plant disease management by forming symbiotic associations with plant roots. These fungi enhance nutrient uptake, particularly phosphorus and micronutrients, thereby improving plant growth and physiological resilience. Beyond nutrition, AVM contribute to disease suppression through multiple mechanisms, including induced systemic resistance, competition with pathogens, and modification of rhizosphere microbial communities. They also strengthen physical root barriers and enhance the production of defense-related compounds. AVM are effective against a wide range of soil-borne pathogens, nematodes, and even foliar diseases by triggering systemic plant immunity. Furthermore, their synergistic interaction with other biocontrol agents enhances overall disease control. As eco-friendly alternatives to chemical inputs, AVM play a significant role in improving soil health, reducing environmental risks, and promoting sustainable agriculture, making them integral components of integrated disease management strategies.

Keywords: Arbuscular mycorrhiza, VAM, plant disease management, induced systemic resistance, rhizosphere, biocontrol, sustainable agriculture, soil health

Introduction

Arbuscular vesicular mycorrhiza (AVM), also known as arbuscular mycorrhizal fungi (AMF), are beneficial soil microorganisms that establish symbiotic associations with the roots of approximately 80–90% of terrestrial plant species. These fungi form specialized structures within root cortical cells, facilitating efficient exchange of nutrients between the host plant and the fungus. In this mutualistic relationship, plants supply carbohydrates to the fungi, while AMF enhance the uptake of essential nutrients, particularly phosphorus, along with micronutrients such as zinc and copper. As a result, AMF significantly improve plant growth, vigor, and productivity.

In addition to their role in nutrient acquisition, AMF contribute to enhanced plant tolerance against a wide range of biotic and abiotic stresses. They help plants withstand adverse environmental conditions such as drought, salinity, and heavy metal toxicity by improving water relations, maintaining ionic balance, and enhancing antioxidant defense systems. At the same time, AMF play an important role in protecting plants against soil-borne pathogens, thereby contributing to improved plant health.

In the context of sustainable agriculture, AMF are increasingly recognized as environmentally friendly tools for plant disease management. Unlike chemical pesticides, they do not pose risks to the environment or human health and support long-term soil fertility and ecosystem stability. Their ability to establish symbiosis with a wide variety of crops makes them suitable for diverse agricultural systems.

Recent studies have demonstrated that the role of AMF extends beyond nutrient uptake. They actively modulate plant immune responses by inducing systemic resistance and priming defense-related pathways, which enhances the plant's ability to respond more effectively to pathogen attack. Additionally, AMF influence the composition and activity of rhizosphere microbial communities by promoting beneficial microorganisms and suppressing pathogenic populations. These interactions create a more balanced and disease-suppressive soil environment.

Furthermore, AMF contribute to disease suppression through multiple mechanisms, including improved plant nutrition, competition with pathogens for space and resources, enhancement of physical barriers such as thicker root cell walls, and production of bioactive compounds. The integration of these mechanisms leads to a reduced incidence and severity of plant diseases.

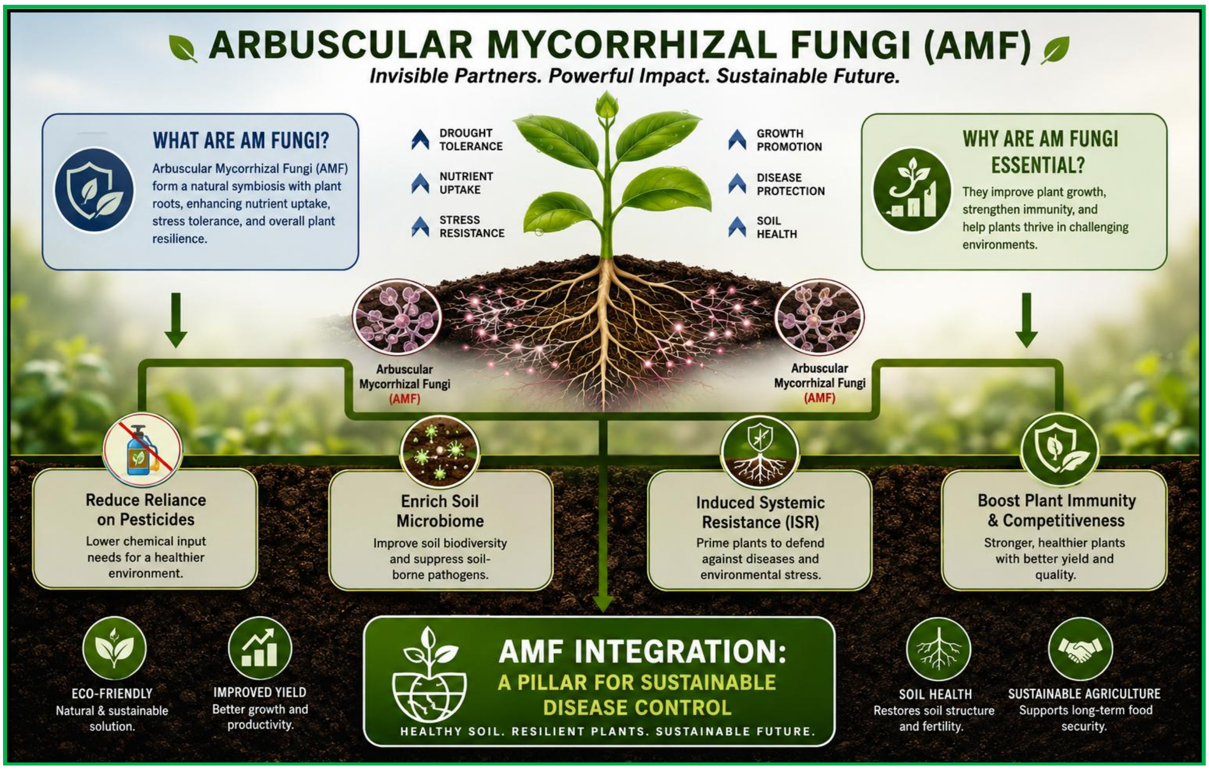

Fig 1: Overview of the Arbuscular Vesicular Mycorrhiza (AVM) fungi

Overall, the multifunctional nature of AMF makes them indispensable components of integrated disease management strategies. Their combined effects on plant nutrition, stress tolerance, immune modulation, and rhizosphere interactions highlight their potential as sustainable alternatives to conventional disease control methods. As research continues to advance, the application of AMF in agriculture is expected to play a crucial role in achieving resilient and eco-friendly crop production systems (Umer *et al*., 2025; Wang & Chen, 2024).

Mechanisms of Disease Suppression by AVM

Improved Nutritional Status

Arbuscular vesicular mycorrhiza (AVM) play a significant role in enhancing plant nutrient uptake, particularly phosphorus, which is essential for various physiological and biochemical processes. Improved phosphorus nutrition strengthens plant defense mechanisms by promoting the synthesis of structural and protective compounds such as lignin and phenolics. These compounds contribute to the reinforcement of cell walls and act as barriers against pathogen invasion.

In addition to improved nutrition, AVM colonization enhances overall plant vigor and metabolic activity, enabling plants to better withstand stress conditions. This improved physiological status helps plants allocate more resources toward defense responses, thereby reducing their susceptibility to diseases.

Recent studies have further shown that plants associated with arbuscular mycorrhizal fungi (AMF) exhibit enhanced physiological performance under both biotic and abiotic stress conditions. Such improvements include better water relations, increased photosynthetic efficiency, and enhanced antioxidant activity. These factors collectively contribute to stronger plant resilience and indirectly reduce the likelihood and severity of pathogen infection (Sun *et al.*, 2025).

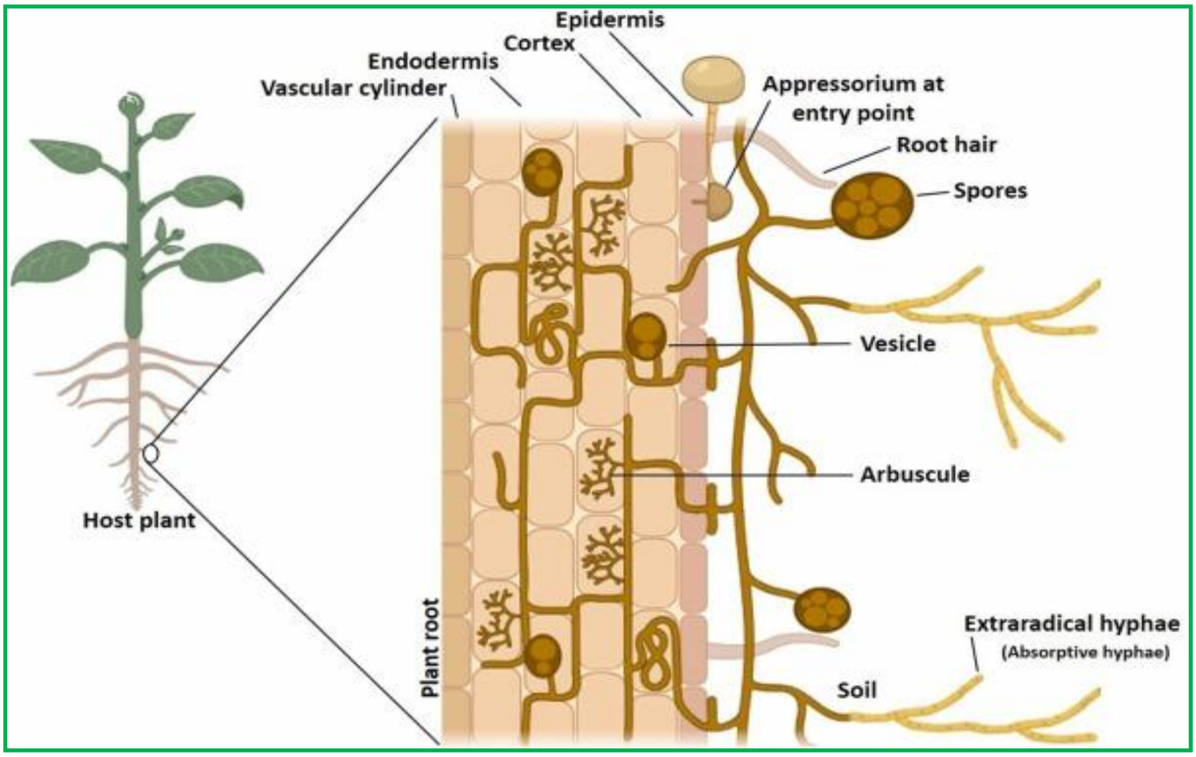

Fig 2: Schematic illustration of the symbiotic system of Arbuscular Mycorrhizal Fungi (AMF) in the host plant root

Induced Systemic Resistance (ISR)

One of the most important mechanisms of disease suppression by AVM is the induction of systemic resistance. AMF colonization activates plant defense pathways, leading to enhanced production of defense-related enzymes such as peroxidase, polyphenol oxidase, and phenylalanine ammonia-lyase. According to Umer *et al.* (2025) AMF-mediated ISR significantly enhances plant tolerance against a wide range of pathogens by priming plant immune responses.

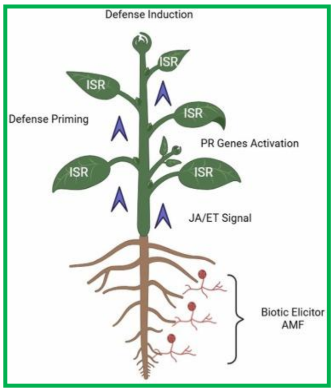

Fig 3: General mechanism of AMF inducing induced systemic resistance in plants

Competition and Rhizosphere Modification

AVM fungi compete with pathogens for space and nutrients in the rhizosphere. They also modify root exudates, thereby influencing the microbial community structure.

Recent research shows that early AMF inoculation can shift rhizosphere microbial functions toward beneficial communities that suppress pathogens (Moreno *et al.*, 2025).

Physical Barrier and Root Protection

AMF colonization forms a protective layer in root tissues, reducing pathogen penetration. This structural modification acts as a physical barrier against soil-borne pathogens.

Role Against Soil-Borne Pathogens

AVM fungi are particularly effective against soil-borne pathogens such as *Fusarium*, *Rhizoctonia*, *Sclerotium*, and *Pythium*. Studies demonstrate that AMF significantly reduce disease incidence by enhancing plant defense and suppressing pathogen growth (Wang & Chen, 2024).

Additionally, AMF have shown promising results in managing bacterial diseases. For example, their interaction with *Ralstonia solanacearum* in potato reduces disease severity through improved plant resistance (El-Abeid *et al*., 2025).

Role in Nematode Management

AMF also play a role in controlling plant-parasitic nematodes such as *Meloidogyne* spp. They reduce nematode infection by:

- Limiting root penetration
- Altering root morphology
- Inducing resistance mechanisms

These effects contribute to lower nematode population density and reduced damage to host plants.

Role in Foliar Disease Management

Although AVM colonizes roots, its effects extend to aerial plant parts through systemic resistance. Recent studies indicate that AMF reduce the severity of foliar diseases such as powdery mildew and leaf spots by enhancing plant immunity (Jian *et al*., 2024).

Interaction with Other Biocontrol Agents

Interacts synergistically with other beneficial microorganisms such as *Trichoderma*, *Pseudomonas*, and *Bacillus*. Dastjerdi *et al.* (2025) reported that combining AMF with biocontrol fungi significantly improves disease suppression and plant growth compared to individual applications.

Role in Sustainable Agriculture

AMF are considered key components of sustainable agriculture due to their ability to:

- Reduce dependence on chemical fertilizers and pesticides
- Improve soil health and biodiversity
- Enhance crop productivity

Recent reviews emphasize that AMF act as "ecosystem engineers" by improving nutrient cycling and plant resilience (FEMS Review, 2026).

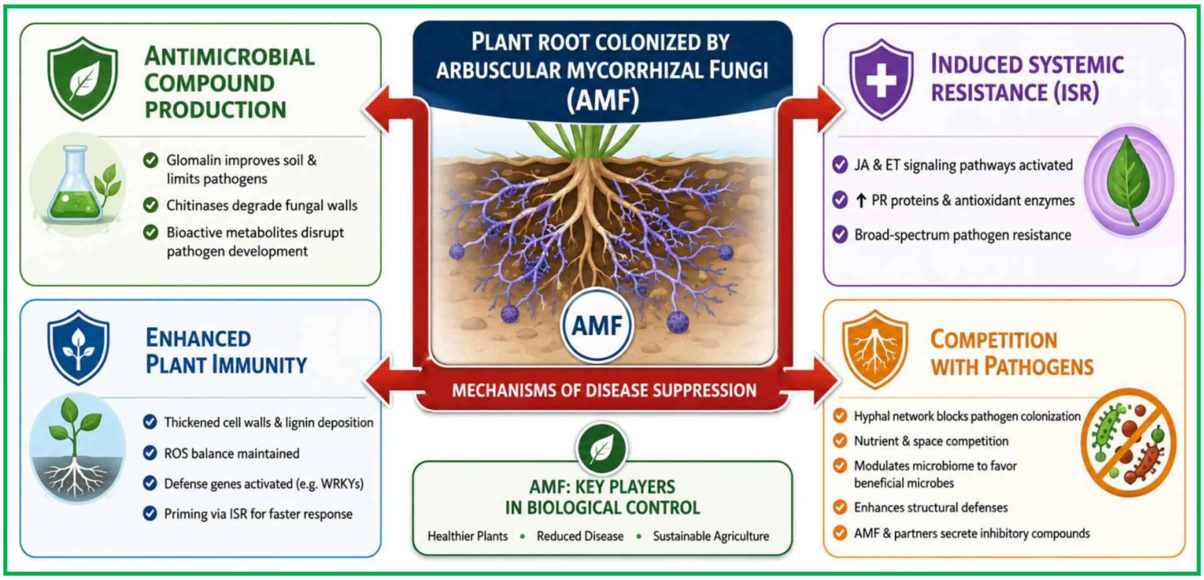

Fig. 4. Mechanisms of disease suppression mediated by Arbuscular Mycorrhizal Fungi.

Factors Affecting Efficiency

The effectiveness of AVM depends on:

- Soil conditions (pH, moisture, nutrient status)
- Host plant species
- AMF species diversity

Higher fungal diversity is associated with better disease suppression and plant performance (Wang & Chen, 2024).

Future Prospects

Future research should focus on:

- Development of efficient AMF inoculum production systems
- Molecular understanding of AMF–plant–pathogen interactions
- Integration with modern farming practices

Emerging studies highlight the importance of AMF in climate-resilient agriculture and microbiome engineering (FEMS Review, 2026).

Conclusion

Arbuscular vesicular mycorrhiza plays a significant role in plant disease management through multiple mechanisms, including improved nutrition, induced systemic resistance, and rhizosphere modification. Recent advancements confirm that AMF are powerful biocontrol agents capable of reducing disease incidence and improving plant health sustainably (Umer *et al*., 2025). Their integration into agricultural practices offers a promising pathway toward eco-friendly and resilient crop production systems.

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