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**POPULAR ARTICLE**

**Fungal highways beneath our feet: transforming crop resilience naturally**

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**Intricacies and elaborated concept**

*Arbuscular mycorrhizal* fungi (AMF) establish symbiotic relationships with the roots of most land plants, forming extensive hyphal networks that extend into the surrounding soil. These networks significantly improve the plant's ability to absorb nutrients and water, particularly phosphorus and essential micronutrients. In addition to enhancing nutrient acquisition, AMF contribute to better soil structure by promoting the formation of stable aggregates and increase plant resilience to environmental stresses such as drought and salinity. They also influence root system development and interact with soil microbial communities, thereby supporting overall plant health. The use of AMF as biofertilizers has shown considerable promise in lowering dependence on synthetic fertilizers while maintaining crop yields and improving soil quality. Its an environmenatly free approach to incresase the yield and to protect environmentA deeper understanding of their diversity, ecological roles, and functional mechanisms is essential for advancing sustainable agricultural systems.

**Keywords:** Symbiotic, biofertilizers, soil, microbial, relationship

**Introduction**

*Arbuscular mycorrhizal* fungi (AMF) are beneficial soil organisms that form symbiotic associations with plant roots, playing a key role in enhancing nutrient and water uptake. By extending their fine hyphal threads into the soil, they effectively increase the root's absorptive capacity, allowing plants to access nutrients that are otherwise difficult to obtain—particularly phosphorus and various micronutrients. Recent research has emphasized the importance of AMF in improving phosphorus availability through their interactions with the soil microbiome. These fungi influence microbial processes in the hyphosphere, promoting nutrient cycling and enhancing phosphate solubilization, while also potentially affecting sulfur dynamics (Wang *et al.*, 2023; Lu, 2023). Beyond nutrient uptake, AMF contribute to soil aggregation, regulate microbial populations in the rhizosphere, and help plants tolerate environmental stresses such as drought, salinity, and nutrient limitations. The growing interest in AMF as bioinoculants reflects their potential to reduce reliance on chemical fertilizers while sustaining crop productivity and soil health. Understanding their ecological diversity and functional roles is therefore crucial for integrating them into modern, sustainable farming practices.

## Types of mycorrhizae

Mycorrhizal fungi exist in several forms, but two major types are particularly relevant in agriculture:

### 1. Arbuscular mycorrhizal fungi (AMF)

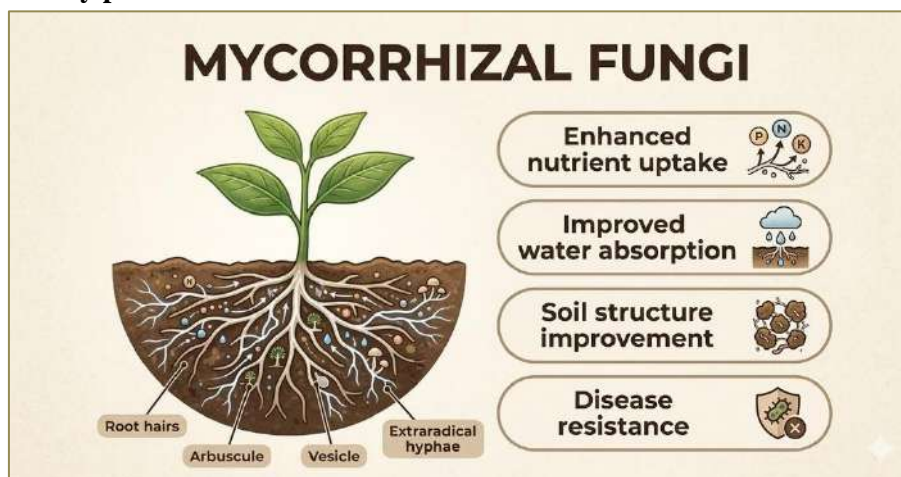
These fungi penetrate the cortical cells of plant roots and form specialized, branched structures known as arbuscules, which facilitate nutrient exchange between the plant and the fungus. AMF are especially efficient at improving phosphorus and micronutrient uptake (Brar and Singh, 2024). Most agricultural crops,

including cereals like maize, wheat, and rice, as well as many vegetables, rely on this type of association.

### 2. Ectomycorrhizal fungi

Unlike AMF, ectomycorrhizal fungi do not enter root cells. Instead, they form a protective sheath around root tips and develop a network between root cells. These fungi are commonly associated with woody plant species such as pine, oak, and eucalyptus, where they play a vital role in forest ecosystems (Wahdan *et al.*, 2024).

**Fig 1: Arbuscular mycorrhizal fungi enhance soil fertility and promote efficient nutrient uptake by plants**



## Benefits of Mycorrhizal Associations

Mycorrhizal fungi provide numerous advantages to plants, many of which contribute directly to growth and resilience:

### Improved Nutrient Availability:

They enhance the uptake of phosphorus, nitrogen, and trace elements, reducing the need for external fertilizers. Better Water Access: Their extensive hyphal systems enable plants to draw moisture from deeper soil layers, improving drought tolerance. Enhanced Soil Structure: Production of glomalin helps bind soil particles together, improving soil stability, aeration, and water retention. Protection

Against Diseases: By colonizing root surfaces, these fungi limit the entry of harmful pathogens and may produce compounds that suppress disease-causing organisms. Increased Stress Resistance: Mycorrhizal plants are better equipped to withstand salinity, temperature extremes, and heavy metal stress.

### Role in sustainable agriculture

Modern farming systems often depend heavily on chemical fertilizers, which, when overused, can degrade soil health, disrupt microbial balance, and contaminate water resources. Mycorrhizal fungi offer a natural and environmentally friendly alternative.



The application of AMF through biofertilizers or seed treatments can help farmers:

- Decrease chemical fertilizer inputs
- Improve nutrient use efficiency
- Enhance crop yield and quality
- Maintain long-term soil fertility

Research indicates that crops such as maize, wheat, and rice inoculated with AMF can achieve comparable or higher yields with reduced phosphorus inputs. In horticultural crops, mycorrhizal associations have been linked to improvements in fruit quality, including size, color, and shelf life.

### **Promoting mycorrhizal activity in fields**

Farmers and growers can encourage the presence and effectiveness of mycorrhizal fungi through several practical approaches:

#### **Application of bioinoculants:**

Use commercially available mycorrhizal formulations on seeds, seedlings, or soil.

- **Balanced fertilization:** Avoid excessive use of phosphorus and nitrogen, which can suppress fungal colonization.
- **Reduced tillage:** Limiting soil disturbance helps preserve fungal networks in the soil.
- **Organic matter addition:** Incorporating compost and crop residues supports fungal growth and overall soil biology.
- **Diverse cropping systems:** Crop rotation and intercropping promote a wider range of beneficial microbial interactions.

### **Challenges in field application**

Despite their benefits, the practical use of mycorrhizal fungi in agriculture is not without

limitations. Their performance can vary depending on environmental conditions, soil characteristics, and interactions with native microorganisms. In soils already rich in nutrients-especially phosphorus-plants may show reduced dependence on mycorrhizal associations.

Additionally, awareness and adoption of mycorrhizal technologies remain limited in many farming communities. To overcome these challenges, current research is focusing on developing more effective inoculant formulations, improving application methods, and integrating these fungi into precision agriculture systems for consistent performance.

### **Conclusion**

Mycorrhizal fungi represent a vital yet often underutilized component of plant health and soil ecosystems. By enhancing nutrient uptake, improving water relations, and increasing stress tolerance, they provide a natural foundation for sustainable agriculture. Their ability to support soil structure and long-term fertility further strengthens their importance in modern farming. Incorporating mycorrhizal fungi into agricultural practices offers a pathway to increased productivity while minimizing environmental impact. As scientific understanding and practical adoption continue to grow, these symbiotic organisms may play a key role in ensuring food security and preserving soil resources for future generations.

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