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Mycorrhiza: A Natural Resource for Sustainable Agriculture

Vineet Dheer[1*], Krishna Kumar Singh[2] and Jaykar Singh[1]

[1]Dept. of Agronomy, [2]Dept. of Soil Science and Agricultural Chemistry, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh (208 002), India

Corresponding Author

Vineet Dheer

✉: vineetdheer@gmail.com

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Abstract

Mycorrhizae, intricate symbiotic associations between fungi and plant roots, profoundly impact ecosystem functioning. This mutualistic relationship enhances plant nutrient uptake, particularly phosphorus and nitrogen, while offering plants improved stress resistance and disease tolerance. Ectomycorrhizae and arbuscular mycorrhizae (AM) are the two major types, each with distinct colonization strategies and ecological roles. Ectomycorrhizae primarily form on woody plants, creating a sheath around root tips, while AM penetrate root cells to form arbuscules for nutrient exchange. Mycorrhizal networks facilitate nutrient transfer and communication among plants, influencing community dynamics and nutrient cycling. Overall, mycorrhizae's role in nutrient acquisition and ecosystem stability underscores their significance in diverse ecosystems and sustainable agricultural practices.

Keywords: Biofertilizer, Fungi, Nutrient uptake, Sustainable

Introduction

Even before their presence was widely understood, the microbe was used in agriculture and industrial activities from the very dawn of civilization. Traditional processors have been in use since the dawn of civilization for the production of fermented drinks, bread and vinegar. In the soil, filamentous fungus mostly breaks down organic matter and aid in soil aggregation. In addition to this characteristic, bound species of *Alternaria*, *Aspergillus*, *Cladosporium*, *Dematium*, *Gliocladium*, *Humicola* and *Metarhizium* produce substances that resemble organic molecules in soil and may therefore be required for the preservation of soil organic matter. Crop yield has been increased using chemical fertilizers and plant growth regulators. The use of chemical fertilizers on crop plants has a severe impact on the environment and human health. Recent research has concentrated on finding alternate strategies to improve plant yield and safeguard the soil.

Mycorrhiza, found in the Glomeromycota phylum of Fungi kingdom, plays a vital role in agriculture. Soil-borne diseases harm crops, and chemical treatments are risky. Scientists seek alternatives, like using beneficial microbes to boost plant defense and growth. Fungi primarily thrive in soil were root systems, an integral part of all plant species occurs. These fungi produce numerous bioactive compounds that can stimulate plant growth. They also serve as biofertilizers, providing plants with essential inorganic nutrients like phosphate, nitrate and ammonium. Microorganisms in the rhizosphere exhibit remarkable endurance against competition and adverse environmental conditions. Mycorrhiza, a network of filaments, forms a symbiotic connection with plant roots, enabling the extraction of nutrients from soil that the root system alone cannot access. This mutualistic partnership promotes plant growth and accelerates root development. Remarkably, a single litre pot containing a growing plant may host up to one kilometre of these fine filaments, reaching into the tiniest soil crevices for water and nutrients (Dighton, 2009). Mycorrhiza boosts plant resilience against diseases and environmental stress. In return, plants supply fungi with glucose and nutrients. Fungi use these for growth and to produce compounds like glomalin. Glomalin improves soil structure and organic matter content.

Classification of Mycorrhizae

The taxonomy of mycorrhizae is mostly predicated on

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the interaction that exists between the root cells of plants and the hyphae of fungi. They are divided into two major categories, which are called Endomycorrhizae and Ectomycorrhizae, respectively.

Endomycorrhizae

Ectomycorrhiza forms a dense hyphal mantle around plant roots without invading root cells, establishing intercellular growth with cortical cells to establish direct plant-fungus contact. The prevalent endomycorrhizal types include Vesicular-arbuscular mycorrhiza (VAM), ericoid and orchid mycorrhiza. VAM fungi, primarily found in the Glomeromycota phylum, dominate this category, with notable genera like Acaulospora, Gigaspora, Glomus and Sclerocystis. VAM fungi create intracellular structures within cortical cells, intercellular hyphae and mycelium that penetrates the soil, displaying obligate symbiosis with limited saprophytic abilities. They obtain carbon from plants. VAM fungi establish mutualistic relationships with most terrestrial plants, delivering essential nutrients like phosphorus (P), sulfur (S), nitrogen (N) and micronutrients from the soil. These fungi mobilize nitrogen and phosphorus from organic polymers, liberate mineral nutrients from insoluble particles and mediate plant stress responses and disease resistance. This fungal partner can access soil pores inaccessible to plant roots while also engaging in resource exchange with other microbes. Endomycorrhizae significantly enhance plant growth, nutrient and water absorption and resilience to environmental stress. Diverse beneficiaries, including land reclamation projects, landscape installations, home gardens, as well as fruit, vegetable and greenhouse/ nursery crop cultivators, stand to gain from the insights provided by extensive research. Leveraging these benefits, growers can realize cost savings and heightened efficiency.

Ectomycorrhiza

Ectomycorrhizal associations exhibit remarkable diversity, encompassing a broad spectrum of around 5,000 to 6,000 fungal species, predominantly belonging to Basidiomycetes, Ascomycetes and Zygomycetes. These fungi contribute to the wide array of interactions. Ectomycorrhiza primarily thrives on woody plant roots, with occasional occurrences on herbaceous and graminaceous perennials. This symbiotic relationship is most commonly formed between higher fungi and gymnosperms or angiosperms. The roots of these plants are linked by a network of soil mycelium, connecting mycorrhizal roots with storage or reproductive systems. These connections are established by the host's fine root tips, which are more abundant in the upper layers of humus-rich topsoil than in the underlying mineral soil layers. Most ectomycorrhizal roots exhibit modified lateral branching. This pattern, known as heterorhizy, involves the support of short lateral mycorrhizal roots by longer roots. Heterorhizic root systems comprise both long and short roots with comparable structures, but the short roots tend to develop at a slower pace. These adaptations aid host trees in coping with stress and play a role in critical ecosystem processes like nutrient cycling. Ectomycorrhizal associations also involve communication with soil microbes, particularly beneficial bacteria, contributing to the overall health of the ecosystem. Furthermore, these ectomycorrhizal connections play a pivotal role in facilitating forest regeneration processes.

How to Use Mycorrhiza?

• To prepare the plant roots for transplantation, immerse them in a solution that has 5 millilitres of mycorrhiza for every litre of water. Do this step before transplanting the plants.

• At the rate between 200 and 250 g acre^{-1} of land, mycorrhizal fungi are dispersed across the area using drip irrigation.

• If you can only locate mycorrhiza in powder form, you should soak the plants in a solution containing between 100 and 200 litres of water for 2-3 hours before planting them in the field. If you can only find mycorrhiza in powder form, you should dissolve 250 g of the powder in between 100 and 200 litres of water.

Importance in Agriculture

In addition to supplying nutrients to the plants, mycorrhiza also adds to the health of the soil and offers a number of other benefits, including the following:

• Mycorrhizal threads enhance soil water retention, aiding companion plants during droughts.

• The fungus actively prevents the uptake of harmful elements, lowering the partner plant's vulnerability to heavy metals such as lead and cadmium.

• In high latitude, altitude, and rocky areas, mycorrhizal fungi break down and extract nutrients from primary rock surfaces.

• Mycorrhizal fungi protect plants from harmful organisms like nematodes and diseases, both directly and by boosting plant health.

• The fungi might offer protection to their partner plants against the elevated salt concentrations found in the saline soil.

• Filament outer walls release adhesive chemicals that bind fine soil particles, forming soil structure and decreasing erosion risk.

Advantages of Mycorrhizae

• *Nutrient Uptake*: Mycorrhizal fungi are responsible for extending the range of plant roots by developing a network of hyphae, which are very fine filaments. These hyphae have the ability to acquire nutrients in the soil such as phosphate that are normally immobilised there. This increases the efficiency of nutrient uptake, particularly in soils that are poor in nutrients (Fall *et al*., 2022).

• *Water Absorption*: Mycorrhizae enhance plants by expanding root surface area, aiding water absorption. Valuable in drought-prone or arid regions with limited water supply.

• *Stress Tolerance*: Mycorrhizal connections enhance a plant's resilience to stresses like drought, disease, and soil-borne pathogens. Symbiotic interaction boosts the plant's defense systems and adaptability to challenging environments.

• *Soil Structure Improvement*: The presence of mycorrhizal hyphae assists in the process of binding soil particles together, which leads to the formation of aggregates that enhance the structure of the soil. This can contribute to improvements in water circulation, aeration and the overall health of the soil (Fall *et al.*, 2022).

• *Reduced Need for Fertilizers*: Mycorrhizal connections potentially reduce synthetic fertilizer usage by enhancing plant nitrogen uptake. This saves farmers money and mitigates environmental harm linked to excessive fertilizer application.

Arbuscular Mycorrhizal Fungi (AMF) as a Biofertilizer

Enhancing soil fertility can be achieved through the utilization of bio-fertilizers, which comprise naturally existing components. These fertilizers bring substantial benefits not only to soil health but also to the growth and overall development of plants. In the past two decades, extensive research focused on Arbuscular Mycorrhizal Fungi (AMF) has highlighted their multifaceted advantages for soil health and crop productivity. The application of mycorrhizal fungi shows promise in significantly reducing the reliance on chemical fertilizers, particularly phosphorus-based ones. This potential shift is attributed to the effective role of mycorrhizal application in diminishing the need for chemical fertilizers. Prolonged use of chemical fertilizers, herbicides and fungicides has resulted in a spectrum of challenges affecting soil, plants and human well-being. The negative repercussions stemming from these chemicals have impacted the quality of food, soil health and environmental systems including air and water (Begum *et al.*, 2019). AMF is speculated to have the capacity to slash chemical fertilizer use in agriculture by up to fifty percent. However, this estimation is contingent upon factors such as the plant species being cultivated and the prevailing environmental conditions (Table 1).

When using mycorrhizal products, it's important to take certain precautions to ensure their effective application and maximize their benefits.

Some Precautions to Consider

• *Compatibility*: Check to see if the mycorrhizal product you're using is appropriate for the type of plant you're cultivating before applying it. There is a possibility that various plant species have varying requirements or responses to mycorrhizae.

• *Avoid Chemicals*: Mycorrhizal fungi are susceptible to being harmed or killed by certain herbicides, fungicides and high-strength fertilizers. It is important to refrain from using these chemicals around the time that mycorrhizae are being applied.

• *Soil pH*: Before adding any mycorrhizal treatments, you should determine the pH level of your soil. The majority of mycorrhizal fungi thrive on soils that range from slightly acidic to neutral in pH. They may not be able to live in environments with pH values that are too high.

Table 1: Stress conditions in different crop species with their fungal species used as biofertilizer

Sl. No.	Stress	Host species	Fungal species
1	Drought	*Glycine max* L.	AMF
2	Drought	*Triticum aestivum* L.	*Glomus* spp., *Gigaspora decipiens*
3	Drought	*Triticum durum*	*Rhizophagus intraradices*
4	Drought	*Ipomoea batatas*	*Glomus* spp.
5	Drought	*Zea mays*	*Rhizophagus intraradices,* strain BGCBJ09
6	Drought	*Hardeum vulgare*	*Glomus intraradices*
7	Heat	*Triticum aestivum* L.	*Rhizophagus irregularis, Funneliformis* spp., *Claroideoglomus claroideum*
8	High temperature	*Solanum lycopersicum*	*Rhizophagus irregularis*
9	Metal-General	*Sesbania rostrata*	*Glomus mosseae*
10	Metal- Cd and Zn	*Cajanus cajan* L.	*Rhizophagus irregularis*
11	Salinity	*Cucumis sativus* L.	*Glomus etunicatum, Glomus intraradices, Glomus mosseae*
12	Salinity	*Oryza sativa* L.	*Claroideoglomus etunicatum*

• *Application Method*: Always make sure to apply the product in accordance with the manufacturer's suggested procedures. This could involve administering the mycorrhizal inoculant to the root zone directly, combining it with the soil, or covering the seeds with it.

• *Storage Conditions*: Keep clear from direct sunlight and temperatures that are too high or too low when storing mycorrhizal goods. A cool, dry environment is ideal. The spores of the fungus can lose their ability to reproduce if they are not stored properly.

• *Avoid Overuse*: Getting better outcomes from using an excessive number of mycorrhizal products is not guaranteed to be the case. Be sure to adhere to the dosage guidelines given by the manufacturer to prevent unnecessary waste and any side effects.

• *Planting Depth*: When using mycorrhizal inoculants, proper placement at the right depth for direct contact with the root zone is crucial. Incorrect mixing depth may compromise their effectiveness.

• *Watering*: Establishment of mycorrhizal fungi requires that sufficient moisture be present. After adding the inoculant to the soil, watering the ground will help bring the fungus spores into close proximity with the plant's roots.

• *Avoid Hot Water or Heat*: Mycorrhizal spores are susceptible to being destroyed by high temperatures and hot water in particular. Make sure that the water temperature is not excessively high when you are either combining inoculants or applying them through the process of irrigation.

• *Use of Beneficial Bacteria*: Beneficial bacteria and mycorrhizal fungi frequently form a synergistic relationship that is mutually beneficial. Because they have a synergistic impact, microbial inoculants should be used, if possible, that include both mycorrhizal fungus and beneficial bacteria.

• *Label Instructions*: Always make sure to read and abide by the instructions provided on the label by the manufacturer. It's possible that several mycorrhizal products will come with their own set of instructions for administration, dose and time.

• *Observation and Monitoring*: After applying mycorrhizal materials to crops, closely monitor their growth, health, nutrient uptake, and disease resistance for any changes.

• *Educate Yourself*: Familiarize yourself with mycorrhizal associations, their benefits, and interactions with your specific crop and soil type. This knowledge will guide informed decisions during the application process.

Conclusion

Mycorrhizae showcase intricate interactions crucial for ecosystems. They benefit plant health, nutrient cycles, soil structure, and ecosystem longevity. These effects aid in ecological restoration and agriculture. As we uncover mycorrhizae's potential, we appreciate their role in shaping robust ecosystems. These fungi's hidden connections have sustained Earth's life. Understanding their impact on crops can enhance sustainability in agriculture, addressing population growth and climate change. Strengthening the plant-fungi bond can lead to a greener, more abundant future.

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