



Role of Mycorrhiza in Soil and Plant Health

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Mycorrhiza is a symbiotic and mutually beneficial association between certain soil fungi and the roots of higher plants. This relationship plays a critical role in maintaining soil fertility, plant nutrition, and overall ecosystem stability. Mycorrhizal fungi improve nutrient and water absorption, enhance soil structure, protect plants against pathogens, and help them tolerate environmental stress. In recent years, mycorrhiza has gained immense importance in sustainable and smart agriculture as a biofertilizer and bioprotectant. This article provides a detailed overview of the types, functions, mechanisms, ecological roles, and agricultural applications of mycorrhiza, emphasizing its contribution to soil and plant health.

Introduction

Soil is the lifeline of agriculture, supporting plant growth and providing nutrients, water, and anchorage. However, modern intensive farming practices, involving excessive use of chemical fertilizers and pesticides, have degraded soil health and reduced its biological activity. To counter these challenges, the role of soil microorganisms, especially mycorrhizal fungi, has come into focus. The term *Mycorrhiza* (first introduced by A.B. Frank in 1885) refers to a mutualistic relationship between plant roots and certain fungi. In this association:

- The fungus colonizes the plant root system.
- It extends its hyphal network into the surrounding soil.
- The fungus helps the plant in the uptake of water and nutrients, particularly phosphorus (P).
- In return, the plant supplies carbohydrates (sugars) produced through photosynthesis to the fungus.

This exchange system benefits both partners and significantly enhances the soil-plant interface, making mycorrhiza one of the most important natural biofertilizers in the ecosystem.

Historical Background

Mycorrhizal associations are ancient, dating back over 400–460 million years, when early land plants first evolved. Fossil evidence shows that mycorrhiza-like associations existed even in the earliest terrestrial plants. This long co-evolution highlights the essential role of mycorrhiza in the colonization of land by plants and in the maintenance of soil fertility through geological time.

Types of Mycorrhiza

Ectomycorrhiza

- Found mainly in **forest trees** such as pine, oak, birch, eucalyptus, and poplar.
- The fungal hyphae form a **dense sheath (mantle)** around the root surface.

- Hyphae extend between root cortical cells forming the **Hartig net**, but do not penetrate cells.
- They help in phosphorus, nitrogen, and micronutrient absorption.
- Common fungal genera: *Boletus*, *Amanita*, *Lactarius*, *Pisolithus*.

Endomycorrhiza (Arbuscular Mycorrhiza or AM)

- The most common type, found in nearly **80–90% of all terrestrial plants**, including cereals, legumes, vegetables, and fruit crops.
- Fungal hyphae **penetrate cortical root cells**, forming **arbuscules** (site of nutrient exchange) and **vesicles** (storage structures).
- Common genera: *Glomus*, *Acaulospora*, *Gigaspora*, *Scutellospora*.

Other Specialized Types

- **Ericoid Mycorrhiza:** Found in Ericaceae family (e.g., Rhododendron).
- **Orchid Mycorrhiza:** Essential for germination of orchid seeds, which lack endosperm.
- **Ectendo Mycorrhiza:** Shows intermediate features between ecto and endo forms.

Structure and Mechanism of Function



The **hyphal network** of the mycorrhizal fungus acts as a natural extension of the plant's root system.

- Hyphae are extremely fine and can explore small soil pores inaccessible to roots.
- **Arbuscules** (tree-like structures) increase the surface area for nutrient exchange between fungus and root cells.
- **Vesicles** store nutrients and lipids that can be mobilized later.
- **Extraradical hyphae** spread in the soil, absorbing nutrients and water.

Nutrients, especially phosphorus (P), are absorbed by the hyphae from the soil and transferred to the plant root cortex through **cytoplasmic streaming** and **active transport** processes. Simultaneously, the plant translocates sugars and other organic compounds to the fungus, creating a **reciprocal nutrient exchange**.

Role of Mycorrhiza in Soil Health

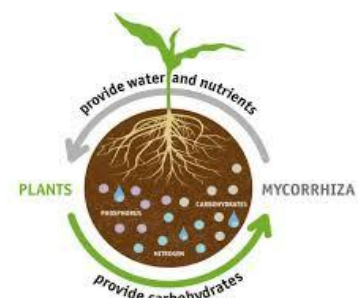
Improvement of Soil Structure

Mycorrhizal hyphae exude **glomalin**, a glycoprotein that binds soil particles together into stable aggregates. This improves:

- Soil porosity and aeration
- Water infiltration and retention
- Resistance to erosion and compaction

Glomalin also contributes to long-term **carbon sequestration**, making soils more resilient.

Enhanced Nutrient Cycling



Mycorrhiza plays a vital role in **nutrient mineralization and cycling** by connecting plant roots with soil microorganisms and decomposing organic matter. They enhance the availability of **phosphorus, nitrogen, sulfur, zinc, and copper** through enzymatic activity.

Increased Soil Microbial Diversity

Mycorrhizal hyphae create **microhabitats** and **food sources** for beneficial soil microorganisms such as bacteria and actinomycetes, promoting microbial diversity and ecosystem balance.

Bioremediation and Pollution Control

Certain mycorrhizal species can immobilize or detoxify heavy metals (e.g., cadmium, lead, arsenic), thus contributing to **phytoremediation** and **soil pollution reduction**.

Role of Mycorrhiza in Plant Health

Enhanced Nutrient Uptake

Mycorrhizal plants show greater uptake of essential nutrients:

- **Phosphorus:** Enhanced solubilization and absorption.
- **Nitrogen:** Improved assimilation through fungal enzymes.
- **Micronutrients:** Better uptake of Zn, Cu, Mn, and Fe.

This leads to increased **photosynthetic efficiency, biomass, and yield**.

Improved Water Absorption

The extensive hyphal network improves the plant's access to water stored in small soil pores. Mycorrhizal plants show higher **water-use efficiency**, particularly in dry or sandy soils, reducing drought stress.

Disease Resistance

Mycorrhiza acts as a **biological shield** against root pathogens:

- Prevents pathogen entry by occupying root infection sites.
- Stimulates plant defense mechanisms (induced systemic resistance).
- Reduces infections caused by *Fusarium*, *Phytophthora*, *Rhizoctonia*, and *Pythium* species.

Tolerance to Abiotic Stress

Mycorrhizal associations help plants tolerate:

- **Drought and salinity** (by maintaining osmotic balance and water status)
- **Heavy metal toxicity** (by immobilizing metals in fungal structures)
- **pH stress** (by enhancing buffering capacity and ion balance)

Enhanced Growth and Productivity

Due to better nutrition, disease protection, and stress tolerance, mycorrhizal plants show:

- Greater root and shoot biomass
- Improved flowering and fruiting
- Higher crop yield and quality

Role of Mycorrhiza in Sustainable and Smart Agriculture

The concept of **smart farming** emphasizes precision input use, environmental protection, and sustainability. Mycorrhiza fits perfectly into this framework as a **biofertilizer and bioprotectant**.

Its use in agriculture provides:

- **Reduced fertilizer dependency:** Up to 40–50% less chemical fertilizer requirement.
- **Sustainable soil fertility:** Through natural nutrient cycling.
- **Environmental benefits:** Lower greenhouse gas emissions and pollution.
- **Climate resilience:** Improved plant adaptability to changing environments.

In India, several mycorrhizal inoculants such as *Glomus intraradices*, *Rhizophagus irregularis*, and *Gigaspora margarita* are commercially available and used in crops like wheat, rice, maize, sugarcane, tomato, and legumes.

Ecological and Environmental Importance

- **Forest Ecosystem Stability:** Mycorrhiza supports tree seedling establishment and forest regeneration.
- **Carbon Sequestration:** Glomalin and fungal biomass contribute to soil organic carbon pools.
- **Biodiversity Conservation:** Maintains balance among soil microorganisms.
- **Soil Restoration:** Helps reclaim degraded lands and mine spoils by improving soil fertility and structure.

Future Prospects

Modern research is focusing on:

- **Mass production** of high-efficiency fungal strains.
- **Bioformulations** combining mycorrhiza with beneficial bacteria (PGPR).
- **Molecular and genomic studies** to identify stress-tolerant fungi.
- **Integration with precision agriculture** through IoT-based soil sensors.
- Use of **AI and GIS tools** to map soil–fungal interactions and optimize inoculation strategies.

Mycorrhiza-based biotechnologies will play a major role in **regenerative agriculture** and **carbon-smart farming systems** in the near future.

Conclusion

Mycorrhiza serves as a vital link between **soil health and plant productivity**. It improves soil structure, enhances nutrient and water uptake, and protects plants against biotic and abiotic stresses. Beyond its biological role, it supports **sustainable agriculture, climate resilience, and environmental conservation**. The integration of mycorrhiza into mainstream agricultural practices will reduce dependence on synthetic inputs, restore degraded soils, and ensure **long-term food and environmental security**. As we move toward smart and eco-friendly farming systems, **mycorrhiza stands out as one of the most powerful allies of the plant kingdom**.