GreenariA
Go Green, Learn Green
An Agricultural Monthly e-Magazine
Volume 03, Issue 09, 2025
ISSN: 2584-153X
Article ID: G-25-0906

MYCORRHIZAL ASSOCIATION AND ITS RELEVANCE IN WATER MINING

D Manjari*, S Nadaradjan, K Manojkumar, T Kalaisri, L Mishore Ignatious, A J Pon Rathika
Pandit Jawaharlal Nehru college of Agriculture and Research Institute, Karaikal 609603, U.T. of Puducherry, India
**Corresponding Author Mail ID: manjari218@gmail.com*

Introduction

Arbuscular mycorrhizal fungi (AMF) are among the mycorrhizal associations that represent the symbiosis between fungi and the root system of plants. Fungi are responsible for contributing significantly to plant health through the improvement of nutrient and water uptake in plants. In the case of water-limited conditions, AMF serve as natural root extensions that access water beyond the immediate zone of the root, an activity referred to as water mining. This special skill not only enhances plant water relations and tolerance to drought but also enhances sustainable agriculture under fluctuating climatic conditions.

Mycorrhizal Association

Albert Bernhard Frank, a German mycologist and botanist coined the term “mycorrhiza” in 1885. The term “mycorrhiza” is derived from **Greek terms** “mykes” denoting fungus and “rhiza” denoting root. This term has been coined by him to refer to the symbiotic relationship of certain fungi of soil and the root systems of higher plants like forest trees, e.g., pines and beeches.

Mycorrhizal associations are symbiotic mutualistic relationships between the root of most land plants and particular fungi. During this association, fungi infect plant roots and spread extensively into the soil through networks of hyphae, which are slender thread-like structures. In exchange for carbon-rich sugars from the plant (resulting from photosynthesis), these fungi provide essential nutrients, including phosphorus, nitrogen, and water, which are the most important survival resources.

Types of Mycorrhizal Associations

1.Arbuscular mycorrhizae (AM) or endomycorrhiza

It occurs in about 80% of all vascular plants, including major crops like Wheat, Maize (corn), Rice, Legumes (e.g., beans and peas), and numerous vegetables and grasses.

In endomycorrhiza, fungi penetrate the plant root cells and develop minute tree-like structures referred to as arbuscules (the term is derived from Latin for “little trees”) for exchanging nutrients between the fungus and the plant. Vesicles are spherical or ellipsoidal storage containers developed inside or between the root cells. In that lipids and nutrients are reserved and contribute to the fungi growth and development.

They also produce an extension of thin, extended filaments known as hyphae that ramify in the soil, much further than the reach of the roots of the plant. This allows plants to uptake phosphorus, micronutrients (e.g., zinc and copper), and water. The fungus is supplied with carbohydrates (primarily sugars, e.g., glucose and sucrose) synthesized by photosynthesis in return.

Special characteristics of AM Fungi

They do not create a thick outer layer on the roots. They are endosymbiotic and reside within the root cells. They belong to the Glomeromycota clade. Fossil evidence indicates that they assisted early plants in colonizing land more than 400 million years ago.

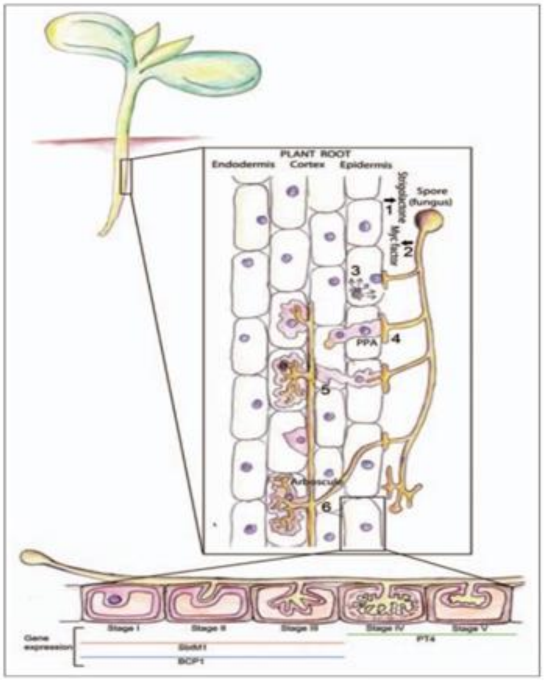

Figure 1. Diagrammatic Representation of developmental stages of arbuscular Development. Stage 1: formation of PPA; Stage 2: entry of fungal hyphae; Stage 3: formation of bird's foot; Stage 4: formation of mature arbuscule; Stage 5: collapse of arbuscule. (Adapted from C Gutjahr And M Parniske, Annual Review of Cell and Developmental Biology, Vol.29, pp.593–617, 2013

2. Ectomycorrhizae (ECM):

They are frequent in forest trees, particularly Pines, Oaks, Birches, Beeches and Eucalyptus. They are infrequent in crops and generally occur in woody trees and shrubs. The fungi do not penetrate root cells. Instead, they develop a thick sheath or mantle over the roots of the plant. From the sheath, hyphae are extended between the root cells (though not in them), developing a network named the Hartig net to facilitate exchange of nutrients. The fungal sheath is a barrier and a bridge that defends the root and facilitates nutrient absorption.

The hyphae venture out into the surrounding soil, decomposing organic matter and facilitating Nitrogen, Phosphorus, Water uptake. The tree provides the fungus with the sugars and fats (in some cases lipids) that the tree manufactures within the leaves.

Special Features of ECM Fungi

They are ectosymbiotic i.e., they grow outside the root cells. They are frequently seen with the naked eye, e.g., mushrooms and toadstools; many ECM fungi create them as fruiting bodies. They are extremely diverse, with more than 5,000 known species. They are found in groups like Basidiomycota and Ascomycota.

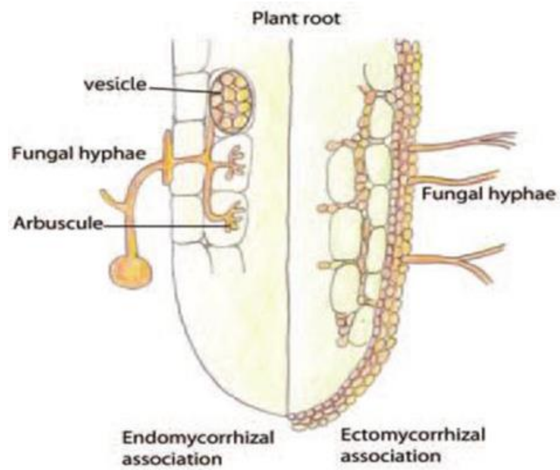

Figure 2. Schematic diagram of endo- and ectomycorrhizal association between fungus and plant. (Modified from L Taiz and E Zeiger, Plant Physiology, 2002.)

Process of Formation of Mycorrhizal Association

The mycorrhizal association formation is a highly coordinated, multi-step symbiosis among plant roots and fungi that includes signaling, recognition, colonization, and nutrient exchange.

1) **Signaling Phase**: Roots excrete chemical signals (e.g., strigolactones) into the soil to induce fungal spore germination and branching of the hyphae, particularly during low phosphate levels. Fungi respond by excreting Myc factors, which precondition plant roots for colonization by repressing immune responses and causing structural modifications in the roots.
2) **Recognition Phase:** Plant receptor proteins (e.g., LysM) detect Myc factors and activate the SYM signaling pathway, leading to the expression of symbiosis-related genes. This confirms fungal compatibility and allows the plant to permit entry without activating its full defenses.

3) **Colonization Phase**: In Arbuscular Mycorrhizae (AM), fungi enter root cortex cells and form arbuscules for nutrient exchange. In Ectomycorrhizae (EM), fungi stay between root cells, don't enter and creating the Hartig net as well as a mantle over the root area. The plant adapts its internal structure to have space for the fungi, creating specialized membranes, like the periarbuscular membrane.
4) **Nutrient Exchange Phase:** The fungus receives carbohydrates (e.g., glucose) from the plant. The fungus supplies water, phosphorus, nitrogen, zinc, and copper through hydraulic redistribution. This is achieved through a regulated interface to facilitate efficient nutrient transfers .

The symbiotic relationship improves water and nutrient uptake in the plant and promotes the growth of the fungus.

How Fungi Help Plants Access Water

1) **Extended Reach**: Fungal hyphae are thinner than roots and can reach microscopic water in small soil pores, transporting it to the plant.
2) **Better Soil Structure**: Fungi excrete glomalin, which glues soil particles together to form aggregates. This makes the soil more porous and water-permeable and prevents compaction.
3) **Deep Water Access**: Fungal hyphae are capable of extending deeper than roots, tapping water in lower layers of soil, which is particularly useful during droughts.
4) **Hydraulic Redistribution**: Fungi facilitate the movement of water from wet deep layers to dry top layers, benefiting shallow roots and adjacent plants and keeping the overall soil moisture.
5) **Drought Stress Mitigation**: Drought-stressed plants tend to close the stomata (small leaf pores) to save water, but in doing so, photosynthesis decreases.

Mycorrhizal fungi regulate the balance of plant hormones, particularly abscisic acid (ABA), which regulates stomatal opening.

They also enhance the osmotic adjustment capacity of the plant, meaning that plants are able to keep on taking up water even during dry spells. Mycorrhizal fungi-bearing plants stay healthier and photosynthetically active for longer durations in drought. They suffer less wilting, less tissue damage, and quicker recovery after drought. Fungal assistance facilitates the efficient utilization of water by plants, thus minimizing wastage and stress.

How arbuscular mycorrhizal fungi (AMF) improve plant water mining

1) Direct water uptake through fungal hyphae

AMF hyphae, usually 2–20 µm in diameter, invade narrow soil pores beyond the reach of roots and gain access to and transport water from areas outside the root depletion zone, frequently even below the wilting point, straight into the plant.

2) Increased root hydraulic conductivity through aquaporins

AMF symbiosis enhances the transcription of plant and fungal aquaporin (AQP) genes (for example, GintAQPF1/GintAQPF2 and LeNIP3;1), effectively enhancing root hydraulic conductivity under drought conditions, which maintains cell-to-cell water flow, facilitates water uptake even in drought condition.

3) Enhanced soil structure & water holding capacity

AMF hyphae and glomalin secretion increase aggregate stability by providing more soil porosity and water-holding capacity. Thus, the soil stores and supplies water better to the roots, making the general water-use efficiency improved.

4) Hormonal modulation & stomatal control

AMF affect plant hormone signalling (particularly ABA), shaping root architecture and regulating stomatal conductance to balance water conservation and CO_2 uptake. Mycorrhizal plants have increased stomatal conductance even in severe droughts. They also modify leaf stomatal density, as observed with tomatoes, thereby altering the transpiration dynamics.

Relevance and Applications of Mycorrhizal Associations

They cannot be seen with the naked eye, mycorrhizal fungi have a significant role in ecosystems, agriculture, and city planning. They can improve water uptake, make plants more resilient, and enhance the health of the soil, which is being utilized in some of the most important fields of contemporary life.

1. **Agriculture in dry lands:** Nourishing the dry world water is limited in arid and semi-arid areas (e.g., some of sub-Saharan Africa, the Middle East, and South Asia). Low yields from crops, poverty, and food insecurity are caused by drought and poor soil fertility. Irrigation is either costly or not available in most rural areas. Mycorrhizal inoculants in powdered or liquid forms with spores of helpful fungi are now being utilized by farmers to cover seeds or blend into the earth. These inoculants form symbiosis with plants like maize (corn), Sorghum, Millets and Legumes The assisting them to access increased water and phosphorus. They grow better in droughts. Utilize limited irrigation more effectively.
2. **Forest Ecosystems**: The Underground Social Network Forest ecosystems need to be stable and productive, even under climate stress, such as heatwaves and droughts. Young trees and seedlings are especially susceptible. The Mycorrhizal Solution – Forest pines, oaks, and firs establish symbiosis with Ectomycorrhizal (ECM) fungi. These fungi create extensive networks underground that link the roots of various trees a network sometimes referred to as the “Wood Wide Web.”
3. **Urban Green Infrastructure:** Greening Cities Sustainably urban conditions are stressful to plants, including shallow soils in planters or green roofs. Limited rain and heat stress due to pavement and buildings. Caring for urban vegetation involves constant watering, which is not feasible. Mycorrhizal Solution: The use of mycorrhizal fungi in urban vegetation, particularly during planting, enhances the establishment of plants, water retention, and root growth. The fungi enable plants to optimize the utilization of limited water and reduce their reliance on irrigation.
4. **Ecological Restoration:** Restoring nature the natural way most landscapes, such as mines, deserts, overgrazed pastures, and burned-out forests, are plagued by soil loss, vegetation loss, water poor retention, and desertification. Mycorrhizal Solution: Ecologists and scientists inoculate degraded soils with native mycorrhizal fungi in restoration. It is usually done by inoculating fungal spores with native plant seeds. Incorporating fungal-rich compost into soil. Inoculating saplings and grasses

Conclusion - Mycorrhizal Associations — *The Hidden Architects of Water Security*

When we search for water solutions to the world’s growing scarcity, we tend to turn to emerging technology, irrigation breakthroughs, and climatological forecasting devices. Yet, one of the strongest and most effective water strategies lies hidden under our feet in the tiny fungal filaments of mycorrhizal fungi that interweave throughout the earth. Mycorrhizal fungi enter into symbiotic relationships with plant roots, building subterranean networks that greatly increase water uptake and dissemination. These old fungi tap deep moisture using thin hyphae, secrete glomalin to enhance water holding capacity of the soil, and move water from plant to plant, particularly in dry conditions. By naturally reducing drought impacts and increasing ecosystem resilience, mycorrhizae offer a powerful and sustainable solution to global water scarcity, supporting agriculture, reforestation, and urban greening without relying on technology or chemicals.

The health of life above ground is deeply rooted in life below it.

References

1) Kuyper, T. W., Wang, X., & Muchane, M. N. (2021). The root and arbuscular mycorrhizal fungi interplay affects water and nutrient uptake and use efficiency.
2) Abdalla, M., Bitterlich, M., Jansa, J., Püschel, D., & Ahmed, M. A. (2023). The contribution of arbuscular mycorrhizal symbiosis to alleviation of drought stress in plants. Journal of Experimental Botany, 74(16), 4808–4824.
3) Dahal, A. (2024, August 22). Mycorrhiza: Definition, types, and significance. Edited by S. Aryal.
4) Barman, J., Samanta, A., Saha, B., & Datta, S. (2016, December). Mycorrhiza: The Oldest Association Between Plant and Fungi.
5) Ahmad M., Summuna B., Gupta S., Sheikh P. A. (2020). Mycorrhizal Association: An Important Tool for Management of Root Diseases. International Journal of Current Microbiology and Applied Sciences, 9(9), 49. Doi: 10.20546/ijcmas.2020.909.246
6) Abd El-Fattah, D. A., Maze, M., Ali, B. A. A., & Awed, N. M. (2022). Role of mycorrhizae in enhancing the economic revenue of water and phosphorus use efficiency in sweet corn (Zea mays L. Var. saccharata) plants. Journal of Saudi Society of Agricultural Sciences. Doi: 10.1016/j.jssas.2022.10.001
7) Maitra, D., Dhara, B., Sultana, S., Chakraborty, R., Mitra, A. K., & Choudhury, S. S. (n.d.). Mycorrhizal associations in agriculture and their role in preventing climate change.