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Mycorrhiza: A Classical Fungus and It's Role

Sardar Singh Kakraliya, Dechan Choskit and Stanzin Diskit
Ph.D. Scholar, Department of Plant Pathology,
Sher-e-Kashmir University of Agricultural Science and Technology of Jammu
Corresponding author: sardarchoudhary70@gmail.com
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Introduction

In 1885, Albert Bernard Frank, in his study of soil microbial-plant relationship introduced the Greek term 'mycorrhiza', which literally means 'fungus roots'. Mycorrhizal fungi form symbiotic relationships with plant roots that is quite similar to relationship of root nodule bacteria with legumes. Mycorrhizae are classic examples of mutualistic symbiosis, primarily characterized by carbon gain of fungus from the plant, also a reciprocal nutrient transfer from fungus to plant, next to other effects relating to improving water relation and pathogen tolerance (Smith and Read, 1997). Arbuscular mycorrhizae symbiosis between roots of 80% of all terrestrial plant species and member of phylum Glomeromycota (Wang *et al.*, 2008) are diffuse and often nonspecific (Selosse *et al.*, 2006). When fungus mycelium colonizes roots and link together two or more plants, sometimes belonging to several species, common mycorrhizal network is formed (CMN), a major component of terrestrial ecosystem with important effects on plant community (Selosse *et al.*, 2006), on invasive plants trajectory (Pringle *et al.*, 2009), as well as on the mycorrhizal community structure and functionality in invaded habitats. Depending on their morphology and the plants and fungus species involved mycorrhizae associations can be distinguished into several types.

Mycorrhiza: are highly evolved mutualistic associations between soil fungi and plant roots. The partners in this association are members of the fungus kingdom (Basidiomycetes, Ascomycetes and Zygomucetes) and most vascular plants. In the mycorrhizal literature, the term symbiosis is often used to describe these highly interdependent mutualistic relationships where the host plant receives mineral nutrients while the fungus obtains photosynthetically derived carbon compounds. Mycorrhizal associations involve 3-way interactions between host plants, mutualistic fungi and soil factors.

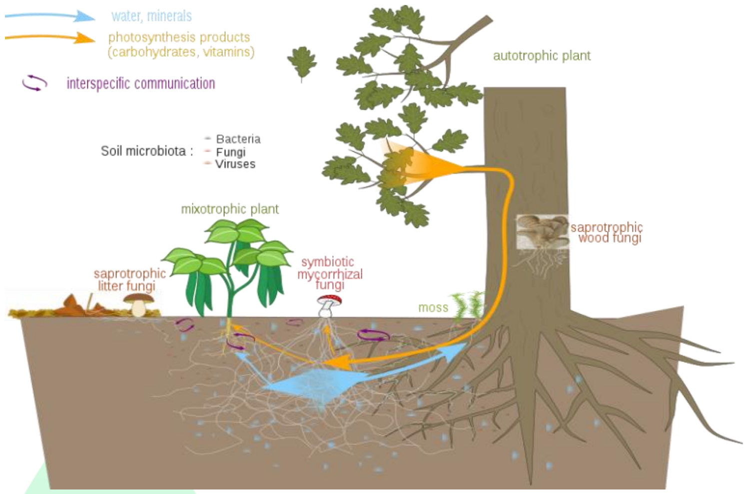

Fig. 1. Nutrient exchange and communication between a mycorrhizal fungus and plants.

Type of Mychorrhizal associations

- **i.** Ectomycorrhizae (e.g. *Amanita muscaria, Boletus, Scleroderma citrinum*)
- **ii.** Endomycorrhizae (e.g. *Acaulospora,Glomus)*
- **iii.** Ectendomycorrhizae (e.g. *Wilcoxina*)
- **iv.** Ericoid mycorrhizae (e.g. *Rhizoscyphus, Sebacina*)
- **v.** Arbutoid mycorrhizae (e.g. *Boletus, Scleroderma*)
- **vi.** Monotropoid mycorrhizae (e.g. *Monotropa hypopitys)*
- **vii.** Orchideoidal mycorrhizae (e.g. *Sesbania, Russula*)

i. Ectomycorrhizae: Ectomycorrhizas or ECM, are typically formed between the roots of around 10% of plant families, mostly woody plants including the birch, dipterocarp, eucalyptus, oak, pine, and rose families and fungi belonging to the Basidiomycota, Ascomycota, and Zygomycota. Ectomycorrhizae are association, where fungi form a mantle around the roots. There is no hyphal penetration of cells. Fungal hypha is generally separate. A distinct Hartig's net is present between the cells.

ii. Endomycorrhizae: Endomycorrhiza Arbuscular Mycorrhiza (AMs) is a type of mycorrhiza in which the fungus penetrates the cortical cells of the roots of a vascular plant. Arbuscular mycorrhizae are characterized by the formation of unique structures such as arbuscules and vesicles by fungi of the phylum Glomeromycota. AM fungi help plants to capture nutrients such as phosphorus and micronutrients from the soil. It is believed that the development of the arbuscular mycorrhizal symbiosis played a crucial role in the initial colonisation of land by plants and in the evolution of the vascular plants.

iii. **Ectendomycorrhizae:** the fungi belongs to Basidiomycotina, which covers both gymnosperms and angiosperms plants. Ectoendomycorrhizae show many of the same characteristics of Endomycorrhizae but also show extensive intercellular penetration. The formation of Ectendomycorrhizae begins with formation of a hartig's net, which grows behind the apical meristem of the growing root. The hartig net penetrates between the epidermal and outer cortical cells and later extends to the inner cortex.

iv. **Ericoid mycorrhizae:** have hyphal coils in outer cells of the narrow "hair roots" of plants in the plant order Ericales. These associations also occur in thicker roots of Australian members of the *Epacridaceae.*

v. **Arbutoid mycorrhizae:** Arbutoid mycorrhiza forms a fungal sheath that encompasses the roots of the plant. However, the hyphae of the arbutoid mycorrhiza penetrate the cortical cells of plant roots, differentiating it from ectomycorrhizal fungi. These associations are seen between fungal members of Basidiomycota and plant order Ericales.

vi. **Orchideoidal mycorrhizae:** consist of coils of hyphae within roots of plants in the family *Orchidaceae.* Young orchid seedlings and some adult plants which lack chlorophyll are entirely dependent on mycorrhizal fungi for their survival**.**

vii. **Monotropoid mycorrhizae:** This type of mycorrhiza occurs in the subfamily Monotropoideae of the *Ericaceae*, as well as several genera in the *Orchidaceae*. These plants are heterotrophic or mixotrophic and derive their carbon from the fungus partner. This is thus a non-mutualistic parasitic type of mycorrhizal symbiosis.

Mutualistic dynamics: Mycorrhizal fungi form a mutualistic relationship with the roots of most plant species. In such a relationship both the plant and host fungi, are said to be mycorrhizal. Relatively few of the mycorrhizal relationships between plant species and fungi have been examined till date, but 95% of the plant families investigated are predominantly

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mycorrhizal either in the sense that most of their species associate beneficially with mycorrhizae, or are absolutely dependent on mycorrhizae.

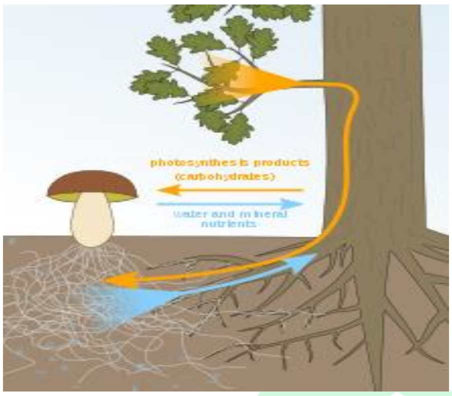

Fig.2. Within mutualistic mycorrhiza, the plant gives carbohydrates (products of photosynthesis) to the fungus, while the fungus gives the plant water and minerals in exchange

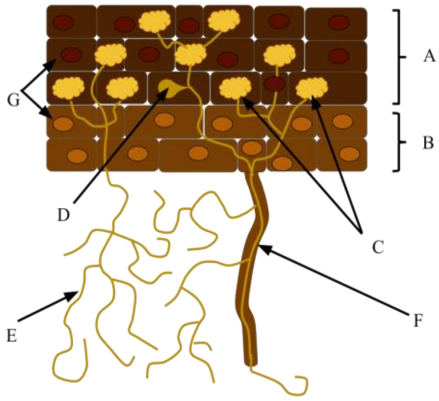

Fig.3. In this mutualism, fungal hyphae (E) increase the surface area of the root and uptake of key nutrients while the plant supplies the fungi with fixed carbon (A=root cortex, B=root epidermis, C=arbuscle,

The *Orchidaceae* are notorious as a family in which the absence of the correct mycorrhizae is fatal even to germinating seed. Recent research into ectomycorrhizal plants in boreal forests has indicated that mycorrhizal fungi and plants have a relationship that may be more complex than simply mutualistic.

Sugar-water/mineral exchange

The mycorrhizal mutualistic association provides the fungus with relatively constant and direct access to carbohydrates such as glucose and sucrose. The carbohydrates are translocated from heir source (usually leaves) to root tissue and on to the plant's fungal partners. In return, the plant gains the benefits of the mycelium's higher absorptive capacity for water and mineral nutrients, partly because of the large surface area of fungal hyphae which are much longer and finer than plant root hairs and partly because some such fungi can mobilize soil minerals that are unavailable to the plants' roots. This effect is thus to improve the plant's mineral absorption capabilities.

Unaided plant roots may be unable to take up nutrients that are chemically or physically immobilised; examples include phosphate ions and micronutrients such as iron. One form of such immobilization occurs in soil with high clay content or soils with a

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strongly basic pH. The mycelium of the mycorrhizal fungus can, however, access many such nutrient sources and make them available to the plants they colonize. Thus, many plants are able to obtain phosphate, without using soil as a source. Another form of immobilisation is when nutrients are locked up in organic matter that is slow to decay such as wood. Some mycorrhizal fungi act directly as decay organisms and able to mobilize the nutrients and passing some onto the host plants. For example, in some dystrophic forests, large amounts of phosphate and other nutrients are taken up by mycorrhizal hyphae acting directly on leaf litter, bypassing the need for soil uptake. *Inga* alley cropping, proposed as an alternative to slash and burn rainforest destruction, relies upon mycorrhiza within the root system of species of *Inga* to prevent the rain from washing phosphorus out of the soil.

In some more complex relationships, mycorrhizal fungi do not just collect immobilised soil nutrients, but connect individual plants together by mycorrhizal networks that transport water, carbon, and other nutrients directly from plant to plant through underground hyphal networks. *Suillus tomentosus*, a basidiomycete fungus, produces specialized structures known as tuberculate ectomycorrhizae with its plant host lodgepole pine (*Pinus contorta* var. *latifolia*). These structures have been shown to host nitrogen fixing bacteria which contribute a significant amount of nitrogen and allow the pines to colonize nutrient-poor sites.

Beneficial roles of mycorrhizal fungi

Benefits to plants:

1. Increased plant nutrient supply by extending the volume of soil accessible to plants.
2. Increased plant nutrient supply by acquiring nutrient forms that would not normally be available to plants.
3. Non-Nutritional benefits to plants due to changes in water relations, phyto-hormone levels, carbon assimilation, etc.
4. Mycorrhiza can cause growth form changes to root architecture, vascular tissue, etc.
5. Some ECM and ericoid fungi have the capacity to breakdown phenolic compounds in soils which can interfere with nutrient uptake.
6. Mycorrhizal benefits can include greater yield, nutrient accumulation and reproductive success.

7. Root colonization by ECM and VAM fungi can provide protection from parasitic fungi.
8. Significant amounts of carbon transfer through ECM fungus mycelia connecting different plant species have been measured. This could reduce competition between plants and contribute to the stability and diversity of ecosystems.
9. Networks of hyphae supported by dominant trees may help seedling become established or contribute to the growth of shaded understory plants.
10. Nutrient transfer from dead to living plants can occur.

Other roles in ecosystems:

1. Soil hyphae are likely to have an important role in nutrient cycling by helping to prevent losses from the system, especially at time when roots are inactive.
2. Soil hyphae may have an important role in nutrient cycling by acquiring nutrients from saprophytic fungi.
3. Mycroorhizal roots, fungal hyphae and fruit bodies are important as food sources and habitats for invertebrates.
4. Hyphae are conduits that may transport carbon from plant roots to other soil organisms involved in nutrient cycling processes. Thus, cooperating with other members of the decomposition soil food - web.
5. Mycorrhiza's influence soil microbial populations and exudates in the mycorrhizosphere and hyphosphere.
6. Mycorrhizal fungi contribute to carbon storage in soil by altering the quality and quantity of soil organic matter.
7. Epigeous and hypogeous sporocarps of ECM and VAM fungi are important food sources for placental and marsupial mammals.

Values to people:

1. These mushrooms have also been used as medicines and natural dyes.
2. ECM fungi are economically and nutritionally important as human food resources.
3. Fungal diversity is a bio-indicator of environmental quality.
4. Fungi which have adapted to local soil conditions are required for agriculture, horticulture and forestry.

5. Fungi have aesthetic values and are an important part of the culture, folklore and appreciation of nature by many people.

Conclusion

Though, the exploitation of microbes as biofertilizers, biostimulants and plant protection against pathogens and heavy metals in different fields of sciences, ecological complexity of microbes in the rhizosphere needs to be taken into consideration and optimization of rhizosphere systems need to be tailored and exploited for the beneficial of the mankind.

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