

## Mycorrhiza

Roots of most terrestrial plants form symbiotic associations with fungi. These ubiquitous symbioses are called mycorrhizas. In short, mycorrhizas are symbiotic association between fungi and plant roots. They function as conduits (a channel for conveying water or other fluid) for the flow of energy and matter between plants and soils. The term mycorrhiza implies the association of fungi with roots and the relationship is called mycorrhizal association. These involve the absorption of nutrients from soil. These associations are found between hyphal fungi and the underground organs of the gametophytes of many bryophytes and pteridophytes, as well as the roots of seed plants and the sporophytes of most pteridophytes. Perhaps more than 80% of the species of higher plants have these relationships, and so do many pteridophytes (ferns and their allies) and some mosses (especially liverworts). They are as common on crop plants (cereals, peas, tomatoes, onions, apples, strawberry, etc) as well as in wild plant communities. In several cases they have been shown to be important or even essential for plant performance i.e. growth and development.

To a large degree, mycorrhizas seem to be symbiotic (**mutualistic**) relationships, in which the fungus obtains at least some of its sugars from the plant, while the plant benefits from the efficient uptake of mineral nutrients (or water) by the fungal hyphae. However, there can be circumstances in which the fungus is mildly detrimental, and others in which the plant feeds from the fungus.

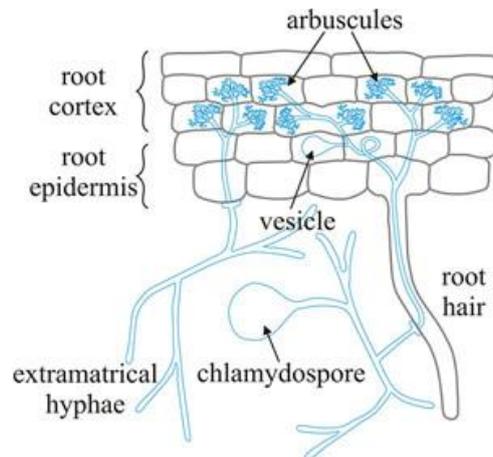
Mycorrhizal fungi frequently stimulate plants to reduce root biomass while simultaneously expanding nutrient uptake capacity by extending far beyond root surfaces and proliferating in soil pores that are too small for root hairs to enter. Mycelial networks of mycorrhizal fungi often connect plant root systems over broad areas. These fungi frequently comprise the largest portion of soil microbial biomass. The mycorrhizal symbioses physically and chemically structure the rhizosphere, and they impact communities and ecosystems. **The term "mycorrhizosphere" was coined to describe the unique properties of the rhizosphere surrounding and influenced by mycorrhizas.**

The two main types of mycorrhizas are arbuscular mycorrhizas (AM) or Vesicular-arbuscular mycorrhizas (VAM) and ectomycorrhizas (EM), which differ considerably in their structure and physiological relationships with symbionts. Arbuscular mycorrhiza (AM) formerly were also known as endomycorrhizas.

**Arbuscular mycorrhiza (AM) or Vesicular-arbuscular mycorrhizas (VAM)** (formerly endomycorrhizas or endotrophic mycorrhizas)

Arbuscular mycorrhizas (AM) or **Vesicular-arbuscular mycorrhizas (VAM)** are zygomycetes fungi belonging to the order Glomales. According to both fossil records and DNA sequences, the appearance of both AM and plants is almost 400 million years old. The unique characteristic of AM is that it increases their surface area significantly while they are in symbiotic relationship with plant roots. This is due to production of extensive hypha thereby helping plants grow under relatively harsh conditions such as drought stress or nutrient deficient condition. This association is also referred to as the vesicular-arbuscular mycorrhiza (VAM). But because the arbuscule is the unifying feature of these associations and vesicles are formed only by a subset of AM fungi, it has been proposed recently that the name be simplified to arbuscular.

AM are the most common mycorrhizal type. The name 'arbuscular' is derived from characteristic structures i.e. the arbuscules. Arbuscules occur within the cortical cells of many plant roots and also some mycothalli colonized by AM fungi. Together with storage vesicles located within or between the cells, these structures have been considered diagnostic for AM symbioses. They are formed by bryophytes, pteridophytes, gymnosperms, and angiosperms, and are ubiquitous in most temperate and tropical ecosystems including agricultural systems. The fungal partners in AM associations are remarkably abundant, accounting from 5 to 50 percent of the microbial biomass in agricultural soils.



**Fig: Arbuscular mycorrhiza**

These fungi are members of the Glomeromycota, a monophyletic phylum containing 150-160 described species. Arbuscular mycorrhizas are sometimes called “**endomycorrhizas**” because the fungal partner forms intraradical structures (i.e., inside plant roots). In AM associations, the interface between plant and fungal tissues that facilitates exchange of materials between plant and fungal symbionts takes the form of arbuscules or coils. Arbuscules and coils are modified fungal hyphae that provide a large surface area for resource exchange. Several genera of AM fungi also form intraradical vesicles that function as fungal storage organs.

The extraradical hyphae of AM fungi lack regular cross walls allowing materials, including nuclei, to flow relatively freely within the mycelium. These hyphae can be very abundant; one gram of grassland soil may contain as much as 100m of AM hyphae.

The taxonomy of AM fungi is based upon the morphology of large asexual spores produced in the soil or within roots. Beneficial plant–microbe interactions in the rhizosphere are primary determinants of plant health and soil fertility. Arbuscular mycorrhizas, which forms symbioses with majority of plants, influence plant community development, nutrient uptake, water relations, and above ground productivity. Arbuscular mycorrhizas also act as bioprotectants against pathogens and toxic stresses. However, in order to maximize the benefits of AM, it is essential to ensure that management practices include minimum tillage, reduced use of chemical fertilizer, adopt appropriate crop rotations with minimal fallow, and rationalized pesticide use.

The number of species of plants forming arbuscular mycorrhizas is very large and their diversity is considerable, not only in taxonomic position but also in life form and geographical distribution. Nearly all herbaceous plants, shrubs and trees of temperate and tropical habitats can form arbuscular mycorrhizas. Whereas most fungi are generalists, associating with a wide range of plants, there is increasing evidence for specificity or selectivity of some plant species for particular fungal symbionts. This is an important area which, together with increasing appreciation of functional diversity among plant–fungus combinations, has significant implications for roles of AM fungi in plant communities.

### **Ectomycorrhizas (EM):**

Ectomycorrhizas occur in certain families of woody gymnosperms (e.g., *Pinaceae*) and angiosperms (e.g., Dipterocarpaceae, Betulaceae) and are extremely important in many temperate and boreal forests. The fungal partners in ectomycorrhizal (EM) associations account for an estimated 30 percent of the microbial biomass in forest soils. These fungi are a diverse assemblage of at least 6000 species of basidiomycetes, ascomycetes, and zygomycetes.

The oldest fossils providing clear evidence of EM associations date back 50 million years. Yet the association is hypothesized to have evolved 130 million years ago. In ectomycorrhizas, the fungus forms a structure called the mantle (or sheath) which encloses the rootlet. From it hyphae or

rhizomorphs radiate outwards into the substrate. Hyphae also penetrate inwards between the cells of the root to form a complex intercellular system, which appears as a network of hyphae in section, called the **Hartig net**. There is little or no intracellular penetration. In a few plants, the development of the Hartig net is slight or absent. For example in *Pisonia*, here, it is particularly important for experiments to confirm that these associations behave in a typically mycorrhizal manner. Ectomycorrhizas may be of following types -

*Ectendomycorrhizas*: In ectendomycorrhizas, the sheath may be reduced or absent. The Hartig net is usually well developed, but the hyphae penetrate into the cells of the plant. As already mentioned, the same species of fungus may form ectomycorrhizas on one species of plant and ectendomycorrhizas on others.

*Arbutoid mycorrhizas*: These possess sheath, external hyphae and usually a well-developed Hartig net. In addition, there is extensive intracellular development of hyphal coils in the plant cells. In the Orchidaceae, the plants are partially or wholly achlorophyllous for some part of their life. They form mycorrhizas with basidiomycetes of various affinities.

The division between orchids that are green for part of their lives and those that are wholly achlorophyllous is mirrored by the identities of their fungal associates. Whereas the fungal symbionts of green orchids are highly effective saprophytes broadly belonging to the form-genus *Rhizoctonia*, those of achlorophyllous orchids are more likely to be able to form ectomycorrhizas on autotrophic plants. For the green orchids, there is new evidence that the adult plants have some capability to provide the fungal symbionts with recent photosynthate for part of the life of the symbiosis, thus apparently reversing the direction of Carbon flow between the partners. The mechanisms behind such bidirectional transfer of organic Carbon have not yet been revealed, but it appears that, contrary to previous suppositions, there is the potential for mutualism.

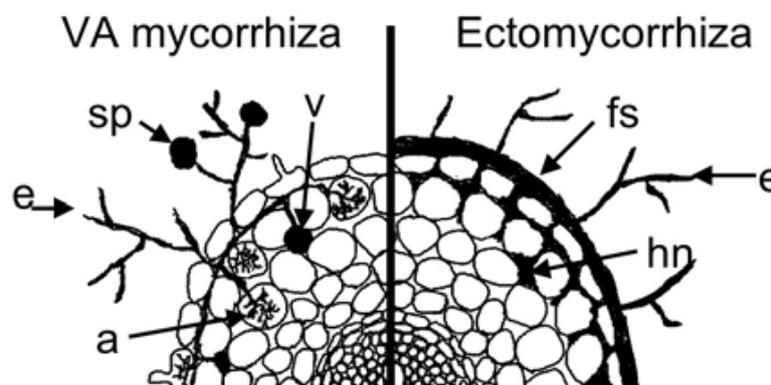


Fig: Schematic overview of the two major mycorrhizal types, i.e., vesicular–arbuscular mycorrhiza (VA mycorrhiza) and ectomycorrhiza. (a - arbuscule; v - vesicle; sp - spore; e - external mycelium; fs - fungal sheath; hn - Hartig net)

About 3% of vascular plants, mainly forest trees (*Fagaceae*, *Betulaceae*, *Pinaceae*, Eucalyptus, and some Woody legumes) form ectomycorrhizas. In spite of the relatively low number of plant species forming ectomycorrhizas, these mycorrhizal associations and the tree species involved play a key role in forest ecosystems and are widely distributed. The fungi involved are mostly Basidiomycota and Ascomycota. In endomycorrhizas, no sheath is formed and the fungi colonize the root cortex both intercellularly and intracellularly.

Experiments on functioning of EM with radioactive tracers have shown that when labelled CO<sub>2</sub> is applied to leaves of tree seedlings, the label is found in plant sugars (sucrose, etc.) which move to the roots; then the label enters the fungal sheath where it occurs in the form of typical 'fungal carbohydrates' such as **mannitol** and **trehalose**. Most plants and plant tissues cannot metabolise these compounds, so there is, in effect, a one-way flow of carbohydrate to the fungus. The cost of

this to the plant may be considerable. However, the plant also can benefit from the association, because the fungal hyphae that ramify into soil are very efficient in capturing mineral nutrients; these accumulate in the sheath but at least some minerals are transferred to the plant, presumably from the Hartig net.

Recent work has shown that several ectomycorrhizal fungi can degrade proteins (they release **protease** enzymes) and thus can obtain nitrogen from the decomposing leaf litter. This could be highly significant in temperate and sub-boreal forests, where the rates of mineral nutrient recycling are low because of the low microbial activity in cool, acidic conditions. Ectomycorrhizal fungi might thus play a key role in the nitrogen nutrition of trees.

It has also been shown that young seedlings growing in the shade of 'mother' trees can be attached to the 'parent' by a common network of mycorrhizal hyphae in the soil. In these conditions, at least some movement of labelled carbohydrates has been shown to occur from the roots of the parent to the younger trees, perhaps helping to nurture the seedlings.

Non-mycorrhizal plants and plants which form more than one type of mycorrhiza are found in a number of families, supporting the idea that loss of AM status or gain of another type of mycorrhiza has evolved many times, probably as a result of different selection pressures and based on different mechanisms.

Mycorrhizas involve plant exchange of photosynthates in return for fungal exchange of mineral nutrients. The convergence of so many unrelated forms of mycorrhizas is a testament for the mutual benefits of these trading partnerships. Most mycorrhizal fungi depend heavily on plant photosynthate to meet their energy requirements. AM fungi are obligate biotrophs while EM ericoid fungi are biotrophs with some saprotrophic abilities.