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Mycorrhizae and their importance in agriculture

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Abstract

There has been a significant increase in the identification and culture of beneficial soil species over the past few decades. It is reported that when in short supply, many bacteria and fungi may assist plants in fighting diseases, finding nutrients and acquiring water. A diverse community of fungi called mycorrhizae, which occur within beneficial species. These fungi grow in combination with most plants and have been investigated as growth and quality enhancers in agricultural crops. The term “mychorrhizae” means “Fungus Root” indicates the mutually beneficial symbiotic relationship that the mycorrhizae have with the roots of the plants. Mycorrhizae are unique to the host and can colonise only those plants, so there are no native mycorrhizae in certain soils that will support these plants. Thus, the majority of plants will also benefit from the addition of mycorrhizae to the soil. In all kinds of soils and climates, there are more than 150 species of mycorrhizal fungi found around the world. There are several general groups for categorising mycorrhizal fungi, but ectomycorrhiza and endomycorrhiza are the two most common groups. This paper mainly tends to focus on the classification of mycorrhizae and their importance in agriculture.

Introduction

Until recently, there were two parts of the biological world i.e. plants and animals. More recently, however, a variety of other components, including fungi, have been recognised by the science community, which are largely invisible but where the greatest amount of biological activity occurs and where the greatest diversity of genes and organisms exists (Hardoim *et al.,* 2015). We know that at least 80 percent of plants establish a mutually beneficial association with soil fungi, and probably over 95 percent forms a beneficial relationship with plants (Heijden *et al.,* 2015). Mycorrhizal fungi are by far the most common fungi that are related to at least 90 percent of plants (Treseder *et al.,* 2006). Mycorrhiza is a symbiotic relationship between a fungus and a green plant. Through photosynthesis, the plant produces organic molecules like sugars and supplies them to the fungus, and the fungus supplies the plant with water and mineral nutrients, such as phosphorus which is taken up from the soil (George *et al.,* 1995).

Mycorrhiza is mainly located on the roots of the plants but associations are also observed in bryophytes. The symbiotic relationship is established when fungal spores germinate developing thread-like structures called hyphae that enter the epidermis of plant roots (Meyer, 2007). The fungus sends out a large network of hyphae across the soil after colonisation of the root to shape a greatly improved absorptive surface area. This leads to improved acquisition and absorption of nutrients by plant roots, especially elemental phosphorus (P), zinc (Zn), manganese (Mn) and copper (Cu) and water. The plant supplies nutrients for the fungus in exchange (Ramasamy *et al.*, 2020).

Figure 1: Mycorrhizae establishment in the plant.

Classification of Mycorrhizae

The mycorrhizal classification is mainly based on the interrelationship between plant root cells and fungal hyphae. They are classified into two common groups, which is endomycorrhizae and ectomycorrhizae

Endomycorrhizae

On the outer surface of the plant roots, ectomycorrhiza forms a compact mantel of hyphae, but do not penetrate the plant root cells. They form structures with the cortical cells, growing intercellular at the same time which enables the fungus to be in direct contact with the plant (Ali, 2009). Even though there are many types of endomycorrhizae, the most commonly known endomycorrhizae is Vesicular-arbuscular mycorrhiza (VAM), *ericoid* and *orchid mycorrhiza*. VAM fungi being the most abundant are at present classified as a separate phylum, *Glomeromycota*. They belong mainly to four genera, *Acaulospora*, *Gigaspora*, *Glomus* and *Sclerocystis* (Brundrett, 2004).

The VAM is characterized by the formation of (i) intracellular structures within the cortex cells, (ii) intercellular hyphae in the cortex, and (iii) a mycelium that extends well into the surrounding soil. They are obligate symbionts with limited saprophytic ability. They depend on plants for their carbon nutrition (Bago *et al.*, 1998). VAM fungi are capable of symbiotic association with most terrestrial plants and play an important role in supplying the plant with P, S, N, and various other micronutrients from the soil (Gyaneshwar *et al.*, 2002). VAM fungi mobilize N and P from organic polymers, release mineral nutrients from insoluble particulate matter, and mediate plant responses to stress factors and resistance to plant pathogens. The hyphae of these fungi can access soil pores that are inaccessible to plant roots (Courty *et al.*, 2010). They also have positive interactions with various microorganisms promoting two-way transfer of resources. Endomycorrhizae helps plants by improving the absorption of plant nutrients and water, minimizing environmental stresses, and improving overall plant growth (Kumar *et al.*, 2018). Numerous studies have shown advantages for land reclamation plants, landscape installations, home planting, fruit and vegetable crop producers, and greenhouse/nursery crop growers. These benefits can improve plant production efficiencies and decrease the cost of plant production for growers.

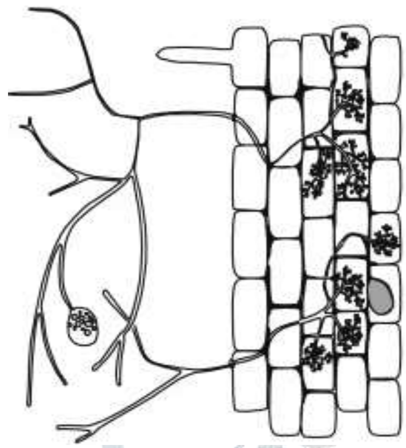

Figure 2: Schematic diagram of main structural features of VAM mycorrhizae

Ectomycorrhiza

Ectomycorrhizal symbiosis is the most diverse of all mycorrhizal associations. The diversity arises primarily from the fungal partners including about 5,000 to 6,000 species, mostly Basidiomycetes, some Ascomycetes, and a few Zygomycetes. Ectomycorrhiza occurs on woody plant roots and only rarely on herbaceous and graminaceous perennial plants (Smith and Read, 2008). Ectomycorrhizal (ECM or EM) associations are mutualistic associations in the plant between higher fungi and gymnosperms or angiosperms. ECM interactions consist of a mycelium system of soil, connecting mycorrhizal roots and systems of storage or reproduction (Heller *et al.*, 2008). These associations are primarily based on the host's fine root tips, which are unevenly distributed across the soil profile, becoming more prevalent in humus-containing topsoil layers than in mineral soil underlying layers. The majority of ECM roots have a modified pattern of lateral root branching. This pattern, called heterorhizy, consists of short lateral mycorrhizal roots (called short roots) backed by a long-roots network. The long and short roots are essentially similar in structure in heterorhizic root systems, but short roots typically develop far more slowly than long roots (Hodge *et al.*, 2009). They contribute greatly to several ecosystem processes and functions, notably nutrient cycling, and help the host trees to survive, especially in conditions of stress. They also communicate with other soil microorganisms, especially the associated helper bacteria. Ectomycorrhizal associations have also been shown to be helpful in forest environments, especially in the processes of forest regeneration.

Figure 3: Example of ectomycorrhizal symbiosis, root tip mycelia from genus Amanita.

Importance in Agriculture

Mycorrhiza apart from providing nutrients to the plants also contributes to soil health and other benefits which include

- The threads of mycorrhizal fungi, or filaments, facilitate drought tolerance in the partner plant by improving the soil's water-holding ability.
- The fungi specifically exclude the passive absorption of toxic components that restrict the sensitivity of the partner plant to heavy metals, such as lead & cadmium.
- Mycorrhizal fungi degrade and absorb nutrients from primary rock surfaces at high latitudes, high altitudes and other rocky conditions.
- Mycorrhizal fungi can also protect plants both directly and by fostering plant vigour against pests, such as nematodes, and diseases.
- The fungi may shield their partner plants against high salt concentrations in saline soil.
- The filaments' outer walls produce gluey compounds that cause fine earth particles to clump together, forming soil structure and make the soil less susceptible to erosion

In addition to plant growth promotion, by fixing more carbon in the vegetation, mycorrhizal fungi may also contribute directly or indirectly to the stabilisation of soil carbon. First, the filaments of fungi have a portion rich in carbon that can remain for decades in the soil. Second, it provides the first step in transforming plant waste into stable soil carbon for other soil fungi.

Advantages of Mycorrhizal Application

- A single treatment can last for the whole lifetime of the plant
- Minimizes the fertiliser use, watering costs and plantation management costs.
- It is compatible with herbicides and insecticides that are commonly used.
- Mycorrhizal plants exploit nutrient sources in the soil at maximum making it a sustainable approach of cultivation and production systems while using the minimum of agrochemicals.
- Artificial inoculation with mycorrhizal fungi brings mycorrhiza to new planted plants and trees helping them in their establishment, growth and survival rate.

Conclusion

Soil is important to sustaining our lives. Not only does it provide food, but it is a vital factor in combating climate change. We will only be able to feed a growing population and alleviate the effects of soil erosion and nutrient depletion on agricultural soils through its successful management. Mycorrhizae being the symbiotic relationship with plants and fungi can become a significant factor in improving soil quality plant productivity and in providing quality food and sustainable agriculture.

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