

THE AM (ARBUSCULAR MYCORRHIZAL) FUNGI, A NEW BIOLOGICAL TOOL

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Abstract: The AM Fungi has emerged as a new biological tool. An arbuscular mycorrhiza (plural mycorrhizae or mycorrhizas) is a type of mycorrhiza in which the fungus penetrates the cortical cells of the roots of a vascular plant. Arbuscular mycorrhizae (AMs) are characterized by the formation of unique structures such as arbuscules and vesicles by fungi of the phylum Glomero-mycota (AM fungi). AM fungi (AMF) help plants to absorb 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 (Brundrett, 2002).

Keywords: AM Fungi, VAM Fungi, Arbuscules, Phosphorus uptake, Derived benefits.

INTRODUCTION

Most of the plants form mycorrhizae as it can be said that it is quicker to list the plants that do not form mycorrhizae than those that do (Harley *et al.* 1983). This symbiosis is a highly evolved mutualistic relationship found between fungi and plants, the most prevalent plant symbiosis known, (Simon *et al.* 1993) and AM is found in 80% of vascular plant families of today (Schüßler, A. *et al.* 2001). Arbuscular mycorrhizal (AM) fungi have been shown to increase crop yield and nutrient uptake, enhance resistance to plant pathogens, and to stabilize soil structure. AM fungi live in symbiosis with plants. This means they live in close association with each other, enjoying a mutually beneficial relationship. AM fungi live partially within the roots of their plant hosts. The plant provides the fungus with carbon (a product of photosynthesis), while the fungus provides the plant with phosphorus and other nutrients absorbed from the soil. Other direct benefits provided by mycorrhizal fungi to some plant hosts include improved drought tolerance (Fitter, 1988) and resistance to specific pests and diseases (Hooker *et al.* 1994).

AM fungi are biotrophs; they require a host as they cannot live in the absence of a plant host except as dormant spores. Arbuscular mycorrhizal fungi are so named because they form a fungal structure known as an arbuscule. Arbuscules are tree-shaped structures that the fungus forms inside plant cells. These structures are responsible for nutrient exchange between the plant and the fungus. Some AM fungi also produce a structure known as a vesicle, which is thought to have a function in

nutrient storage. Vesicle production was once believed to be common among all AM fungi, which were then called vesicular arbuscular mycorrhizal (VAM) fungi. Later on research identified a family of supposedly VAM fungi that didn't produce vesicles. Since all types produce arbuscules, the name was amended to become AM fungi. Arbuscules are connected to strands of AM fungal tissue that extend into the soil (called extra radical hyphae). These hyphae absorb water and nutrients for the fungus and the plant. They extend the root system and, in effect, increase the plant's root surface area. AM fungal hyphae are finer than plant root hairs, which allows them to penetrate smaller soil pores. This allows a plant with AM fungi to absorb water and nutrients from areas of the soil profile that roots can't reach, providing plants with a higher tolerance for drought and increased uptake of certain nutrients, such as phosphorus. Extraradical hyphae can colonize multiple roots of either the same plant or different plants, forming a mycorrhizal network. This network can mediate the transfer of water and nutrients between different plant species. In one study, soybean plants received nutrients via the AM fungal network from adjacent weeds following an herbicide application. AM fungi produce thick-walled spores on extraradical hyphae. The spores are released into the soil surrounding roots colonized by AM fungi and are spread by anything that moves soil, including wind, water, and machinery. Spores germinate near roots in response to root exudates, including various phenolic compounds (flavonoids in particular). After germination, the AM fungus colonizes fine roots (germinating spores do not colonize woody roots).

Why to use the AM Fungi.

AMFs (arbuscular mycorrhizal fungi) are obligate symbionts. They have limited saprobic ability and are dependent on the plant for their carbon nutrition (Harley *et al.* 1983). AM fungi take up the products of the plant host's photosynthesis as hexoses. The transfer of carbon from the plant to the fungi may occur through the arbuscules or intraradical hyphae (Pfeffer *et al.* 1999). An increase in the carbon supplied by the plant to the AM fungi increases the uptake of phosphorus and the transfer of phosphorus from fungi to plant (Bücking & Shachar-Hill 2005). Phosphorus uptake and transfer is also lowered when the photosynthate supplied to the fungi is decreased. Species of AMF differ in their abilities to supply the plant with phosphorus. In some cases arbuscular mycorrhizae are poor symbionts providing little phosphorus while taking relatively high amounts of carbon (Smith *et al.* 2003).

The benefit of mycorrhizae to plants is mainly attributed to increased uptake of nutrients, especially phosphorus. This increase in uptake may be due to increase surface area of soil contact, increased movement of nutrients into mycorrhizae, a modification of the root environment and increased storage. Mycorrhizae can be much more efficient than plant roots at taking up phosphorus. Phosphorus travels to the root via diffusion and hyphae reduce the distance required for diffusion thus increasing uptake. The rate of inflow of phosphorus into mycorrhizae can be up to six times that of the root hairs (Bolan, 1991).

In some cases the role of phosphorus uptake can be completely taken over by the mycorrhizal network and all of the plant's phosphorus may be of hyphal origin (Smith *et al.* 2003). The available phosphorus concentration in the root zone can be increased by mycorrhizal activity. Mycorrhizae lower the rhizosphere pH due to selective uptake of NH_4^+ (ammonium-ions) and release of H^+ ions. Decreased soil pH increases the solubility of phosphorus precipitates. The hyphal uptake of NH_4^+ also increases the flow of nitrogen to the plant as NH_4^+ is adsorbed to the soil's inner surfaces and must be taken up by diffusion (Hamel). Recent research has shown that AM fungi release an unidentified diffusional factor, known as the myc factor, which activates the nodulation factor's

inducible gene *mtENOD11*. This is the same gene involved in establishing symbiosis with the nitrogen fixing, rhizobial bacteria (Kosuta *et al.* 2003). When rhizobium bacteria are present in the soil, mycorrhizal colonization is increased due to an increase in the concentration of chemical signals involved in the establishment of symbiosis (Xie *et al.* 2003). Effective mycorrhizal colonization can also increase the nodulations and symbiotic nitrogen fixation in mycorrhizal legumes.

A relatively new approach to restore land and protect against desertification is to inoculate the soil with arbuscular mycorrhizal fungi with the reintroduction of vegetation. A long term study demonstrated that a significantly greater long term improvement in soil's quality parameters was attained when the soil was inoculated with a mixture of indigenous arbuscular mycorrhizal fungi species compared to the non inoculated soil. The benefits observed were an increased plant growth and soil nitrogen content, higher soil organic matter content and soil aggregation. The improvements were attributed to the higher legume nodulation in the presence of AMF, better water infiltration and soil aeration due to soil aggregation.

Inoculation with native AM fungi increased plant uptake of phosphorus, improving plant growth and health. The results support the use of AM fungi as a biological tool in the restoration of biotopes to self-sustaining ecosystems (Jeffries, 2003). Most agricultural crops can perform better and are more productive when well colonized by AM fungi. AM symbiosis increases the phosphorus and micronutrient uptake and growth of their plant host (George *et al.* 1992). Management of AM fungi is especially important for organic and low input agriculture systems where soil phosphorus is generally low, although all agroecosystems can benefit by promoting arbuscular mycorrhizae establishment.

Some crops that are poor at seeking out nutrients in the soil are very dependent on AM fungi for phosphorus uptake. For example flax, which has poor chemotaxic ability, is highly dependent on AM mediated phosphorus uptake at low and intermediate soil phosphorus concentrations (Thingstrup *et al.* 1998). Proper management of AMF in the agroecosystems can improve the quality of the soil.

The benefits of AMF are greatest in systems where inputs are low. Heavy usage of phosphorus fertilizer can inhibit mycorrhizal colonization and growth. As the soil's phosphorus levels available to the plants increases, the amount of phosphorus also increases in the plant's tissues, and carbon drain on the plant by the AM fungi symbiosis become non-beneficial to the plant (Grant, 2005).

AM fungi improve plant growth profoundly through increased uptake of phosphorus, nitrogen and other nutrients. The use of AM fungi in enhancing plant growth and yield of many crops has gained momentum in recent years because of the higher cost and hazardous effects of heavy doses of chemical fertilizers. The extra matrical hyphae of AM fungi act as extensions of roots and increase the surface area of the root system, making it more efficient for absorption of water and diffusion-limited nutrients, this effect being more pronounced in P-deficient soils (Bagyaraj and Reddy, 2000). Other beneficial effects are in the biological control of root pathogens, biological nitrogen fixation and increased ability to withstand abiotic stresses.

Useful for Farmers:

All the farmers of India should use the AM fungal inoculums so that their crop yield increases with minimum input and government and other agencies should take appropriate steps to make this fungal culture available to all farmers. Proper plans, schemes and strategies should be made for the production and supply of these beneficial AM inoculums for the benefit of farmers.

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