How Mycorrhizae Can Improve Plant Quality©

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WHAT ARE MYCORRHIZAE?

A mycorrhiza (plural mycorrhizae) is an anatomical structure that results from a symbiotic association between a soil fungus and plant roots. In exchange for a "home," the fungus provides numerous benefits to the host plant which we'll discuss in the next section. Mycorrhizal fungi produce an extensive network of microscopic hyphal threads that extend into the surrounding soil or growing medium (Fig. 1).

Literally thousands of research papers have been written on mycorrhizal fungi, but many growers are unsure whether their plants have mycorrhizae or how to identify them. Numerous brands of commerical mycorrhizal inoculums are available but, unfortunately, some have been marketed as a "silver bullet" that will cure all your propagation problems. Since you are all experienced propagators who already know how to grow plants, we'd like to share with you how to make them even better.

BENEFITS OF MYCORRHIZAE

The numerous benefits of mycorrhizae can be divided into those that help to grow plants in the nursery and those that improve sales or outplanting performance.

Nursery Benefits. The hyphal network of mycorrhizal roots (Fig. 1) greatly increases the access and uptake of water and mineral nutrients. However, because growers supply these normally limiting factors, the benefits of mycorrhizae are often much harder to see in nurseries. Progressive propagators are looking for ways to minimize potentially polluting nutrients such as nitrogen and phosphorus in runoff water and inoculating your plants with mycorrhizae can do just that (Sharma and Adholeya, 2004). Mycorrhizae greatly increase rooting volume physiology which translates to faster growth and a shorter production cycle (Gianinazzi et al., 1990). A dramatic example demonstrating the benefits of mycorrhizae can be seen in bareroot nurseries following soil sterilization by fumigation. Fungal re-colonization can be very slow and irregular producing a mosaic pattern of normal and stunted plants (Fig. 2). Mycorrhizae also protect roots against pathogenic root fungi due to both the physical effects of a mycorrhizal-produced chitin cell wall covering and certain chemical effects such as antibiotic exudates (Linderman, 1994).

After-the-Sale and Marketing Benefits. The mycorrhizal benefits of increased access to water and mineral nutrients and protection from root pathogens continue after the plants leave the nursery. This is especially valuable when plants encounter stressful transplant or outplanting situations as has been repeatedly demonstrated in horticultural research and ecological restoration projects where mycorrhizal plants greatly outperform non-inoculated controls (Klironomos et al., 2008; Meikle and Amaranthus, 2008; Steinfeld et al., 2003).

Marketing mycorrhizal-inoculated plants also increases their value and "green appeal." Knowledgeable customers and consumers recognize the noticeably larger root plugs and root systems typical of mycorrhizal plants. They know that more

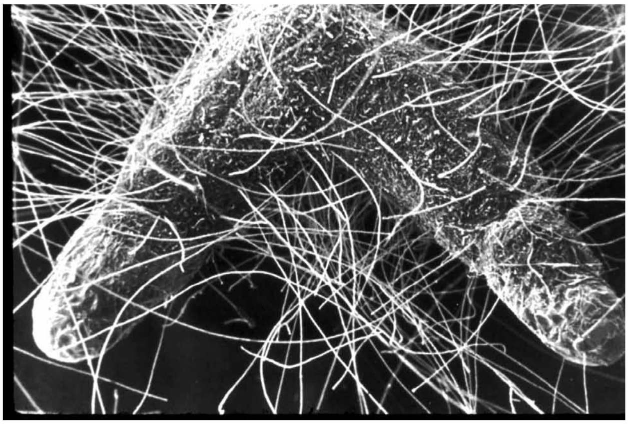

Figure 1. Several benefits of mycorrhizae are due primarily to the network of hyphal filaments which extend out into the soil or growing medium.

Figure 2. The slow and irregular recolonization of fumigated soils produces a mosaic growth pattern of healthy plants with mycorrhizae (note mushrooms) and stunted plants without mycorrhizae.

vigorous and physiologically active roots translate into successful establishment and long-term plant health.

TYPES OF MYCORRHIZAL ASSOCIATIONS AND THEIR HOST PLANT SPECIES

The vast majority of plants form mycorrhizal relationships with one or more species of soil fungi. Mycorrhizae can be divided into three categories, which vary by types of inoculum application methods (Table 1):

Ectomycorrhizae. These are the most well-known type of mycorrhizae because the fungal mycelia are easily visible on the root systems and because the spores are airborne. Characteristic fruiting bodies usually develop above the soil or growing medium. Two types of ectomycorrhizal inoculums are available: vegetative or spores (Table 1). Vegetative inoculum consists of a carrier such as vermiculite which contains strands of fungal mycelia and is incorporated into the soil or growing medium prior to sowing seeds or sticking cuttings. Because spores can remain dormant for long periods, spore inoculum has an extended shelf-life and can be watered into the soil or growing medium after the crop plants have become established. Inoculation success can be visually confirmed by estimating percent coverage under a binocular microscope. A list of common ectomycorrhizal host plants is available at the website: <www.mycorrhizae.com>.

Arbuscular Mycorrhizae. This is by far the largest and most diverse category of mycorrhizal fungi in terms of host plants. Arbuscular mycorrhizae are often unrecognized because the root structures are internal and therefore invisible to the naked eye and no fruiting bodies are produced (Fig. 3). The relatively large spores are soilborne or waterborne which greatly slows the re-colonization process in areas where they have been lost due to disturbance, soil erosion, and loss of vegetation (Perry and Amaranthus, 1997, Reeves et al., 1979). Arbuscular mycorrhizal inoculum consists of spores or colonized root fragments (Table 1), and is available in powder, granular, or liquid formulations (Fig. 4). Powders are effective because they may be applied directly to seeds and therefore are in immediate contact with developing roots. Granular products are usually incorporated into the soil or growing medium prior to sowing or transplant, whereas liquid inoculum can be applied through irrigation systems or as a drench on established plants. Inoculation success can be confirmed in the laboratory by clearing and staining the roots and measuring percent colonization through a microscope.

Ericoid Mycorrhizae. This category of mycorrhizae is the rarest and occurs primarily with plants from the order Ericales, such as azaleas and rhododendrons. Because spores are not produced reliably, there is no commercial source of inoculum. So, the only way to inoculate plants is to collect soil containing roots from beneath colonized host plants and mix it into the soil or growing medium (Table 1). Success of colonization must be confirmed by clearing and staining roots and examining them under a microscope.

ECONOMICS OF INOCULATION

The decision to inoculate your crop with mycorrhizae often comes down to cost, so there are many things to consider.

Table 1. Propagation Considerations of the Three Types of Mycorrhizae

Type of Mycorrhizae	% of Plant Species	Type of Inoculum	Method of Application
Ectomycorrhizae	5 to 10%	Spores	Water-in or inject into irrigation system
		Vegetative	Incorporate into soil or growing medium
Arbuscular mycorrhizae	70 to 80%	Spores and colonized root fragments	Powder: Apply to seeds or incorporate into soil or growing medium
			Granular: Incorporate into soil or growing medium
			Liquid: Water-in or inject into irrigation system
Ericoid mycorrhizae	< 1%	Native Soil and colonized root fragments from the field	Incorporate into soil or growing medium

In general, it is most cost effective to inoculate very young plants where the average cost can be as low as a penny per plant. Larger plants require more inoculum so costs are proportionately greater.

Another important consideration is to learn which type of mycorrhizal fungi occurs with your crop species. A list of plants with their mycorrhizal associates can be found at the website <www.mycorrhizae.com> or, better yet, contact a mycorrhizal specialist to make sure that you select the proper type of inoculum (Table 1). The next decision is what type of inoculum to buy and how best to apply it. Spore-based inoculums have the most options. The least expensive inoculation method is to apply powdered inoculum to seeds. Incorporating mycorrhizal inoculums into soil or growing media also works well. Mycorrhizal inoculums come in three formulations (powder, liquid, or granular) and the choice will depend on the needs of the grower and the application equipment available. Here is one important consideration regarding cost-benefit ratios. When evaluating the use of mycorrhizal inoculums, it's tempting to consider only the benefits of increased plant growth or reduced fertilizer cost in the nursery. Instead, try to account for all the cumulative mycorrhizal benefits in the nursery, including at sale, or after outplanting — if each incremental benefit contributes 5% to 10%, the combined benefits can total 20 to 40%.

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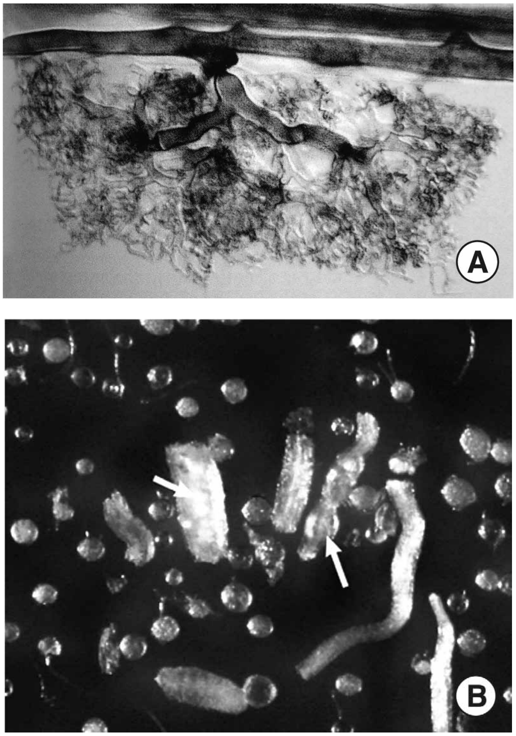

Figure 3. Arbuscules (A) are found inside the root cell of all arbuscular mycorrhizal plants, and arbuscular mycorrhizal inoculum contains spores and colonized root fragments (B).

Figure 4. Arbuscular mycorrhizal inoculums are available in powder, liquid, or granular formulations, which allows for a wide variety of application methods and timing

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