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Biogeography of Mycorrhizal Fungi and Their Use in Ornamental Container Production©

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Mycorrhizae – from the Latin words myco and rhizi, meaning fungus and roots – refers to a partnership association between plants and soil-dwelling fungi. Horticulturists consider mycorrhizae as beneficial when both partners realize a net gain from the association. Sometimes colonization of plant roots by mycorrhizal fungi results in an enhancement of plant growth. Mycorrhizae play an important role in plant nutrition and the stability of plant communities. Three types of mycorrhizae are most common: ectomycorrhizae, ectendomycorrhizae, and endomycorrhizae. Our research focuses exclusively on a class of endomycorrhizae called arbuscular mycorrhizal or AM fungi.

Arbuscular mycorrhizal fungi have unique vegetative and reproductive life stages. During their vegetative stage, they develop a hyphal matrix (or mycelium) comprised of runner, penetration, or absorbing hyphae that extend out from the surface of colonized fine lateral roots. Runner hyphae follow growth of fine lateral roots as they grow in the soil. Sometimes runner hyphae grow out into the soil probing for more roots. Penetrating hyphae branch off runner hyphae and infect fleshy young roots usually within a short distance of the root growing tip. Once inside the root, these hyphae pierce cortical cell walls and form arbuscules between the root cell wall and cell membrane, called the plasmalemma. Arbuscules are organs for exchanging nutrients with root cells. In addition to arbuscules, penetrating hyphae also produce storage organs called vesicles in spaces between root cells. Finally, absorbing hyphae branch off of runner hyphae in a fan-like pattern. They grow into soil surrounding the infected root and absorb water and nutrients. The absorbed water and nutrients subsequently move to the penetrating hyphae and into the infected root.

In general, a developmental pattern occurs in which runner hyphae follow growing root tips to form arbuscules and vesicles. About the same time, absorbing hyphae probe the surrounding soil for water and nutrients. Runner hyphae grow out into the soil, perhaps contacting young roots of other plants. Formation of a "living bridge" between plants is possible. Roots attract AM fungal hyphae by exuding organic acids that act as chemical signals. As root tips continue to grow out into the soil, the infected root tips begin to harden. This hardening causes an end to the mycorrhizae and ensures that fungal colonization of roots occurs only on fleshy portions of the root system that are most active in absorbing water and nutrients.

Arbuscular mycorrhizal fungi interact with plants by changing patterns of nutrient allocation and distribution. Plants apportion as much as 20% of carbon fixed during photosynthesis to the fungus. This carbon is mostly in the form of simple sugars. The fungus converts the sugars to more complex organic molecules, which limit re-absorption into the root. Absorbing hyphae extend into the soil and serve as extensions of the root system absorbing water and nutrients by functionally increasing the root-absorbing surface area. Though mycorrhizal fungi are known to uptake over 15 essential nutrients, enhancement of phosphorus uptake by plant roots under conditions of low soil fertility is the most recognized nutritional benefit of mycorrhizae.

Phosphorus is mainly insoluble and immobile in the soil. AM fungi explore beyond the root zone and acquire phosphorus for roots. In the past, researchers thought that AM fungi, regardless of species or the geographic region in which they naturally occurred, were functionally equivalent. This meant that the uptake of phosphorus was the sole cause of AM promotion of plant growth. Based on this assumption, researchers concluded a plant's need to be mycorrhizal was related directly to the amount of phosphorus in the soil. If phosphorus was low then AM fungi were necessary to facilitate phosphorus extraction. However, if soil phosphorus was adequate or high, then mycorrhizal fungi became little more than root parasites levying a carbon tax on the plant. Recent research evidence is causing these ideas to change.

Research evidence is mounting that AM fungi are not functionally equivalent. Considerable physiological differences exist between AM species and even between AM fungi of the same species from different geographic regions. The term edaphotype is sometimes used to distinguish between the same species of AM fungi from different soils that caused different responses in host plants. More recently, we found that *Glomus intraradices* from a subtropical desert location to have promoted adaptation of trees to high temperatures compared with *G. intraradices* from cooler temperate grasslands. Other researchers report that some AM fungi increase plant drought or salt tolerance, while AM fungal species had no effect or even aggravated plant stress.

The concept of mycorrhizae does not mean that a root-fungal association is always beneficial. Specific soil situations occur where the fungus helps to enhance plant growth under one set of conditions but has no effect or causes a reduction in plant growth under another. Researchers are learning from this complex picture of AM fungi that it is inadequate to measure the efficacy of mycorrhizae solely in terms of host plant phosphorus nutrition or an enhancement of plant growth. Other adaptational responses may be equally important. For example, under drought conditions, AM promotion of growth should take a back seat to improved plant water relations. Or, plants recently transplanted into the landscape could benefit more from AM fungi that promote root exploration of soil rather than promote shoot growth.

In nursery and landscape horticulture, practices and environmental conditions that affect mycorrhizae-plant interactions include soil fertility and water, organic matter concentrations, extent of soil cultivation, compaction disturbance, and construction activities, soil erosion, removal of vegetation/top soil layers. Functional differences in management strategies exist between propagation, nursery production, and cultural practices of plants in landscapes. These functional differences are shown in Table 1.

Table 1. Functional differences between strategies for nursery production and care of plants in urban landscapes.

	Nursery	Landscape
Plant growth requirements	Fast growth	Moderate to slow growth
Environmental manipulation	Controlled environment	Uncontrolled environment
Organic matter composition	Soil less, high	Variable, low
Substrate fertility	Balanced, highly managed	Variable, sometimes deficient
Overall objective	Crop turnover	Plant establishment, adaptation

Some of our most recent research findings on mycorrhizal fungi and urban landscapes suggest that it might take as long as 45 years for the re-establishment of a diversity of mycorrhizal fungi in soils after landscape installation. Since AM fungi generally enhance host plant growth under suboptimal or less than optimal soil conditions, use of inoculating nursery plants with appropriate AM fungal isolates or populations during nursery production should not be viewed as a management strategy for enhancing nursery crop turnover because most nursery production systems provide plants with near optimal growing conditions. Rather, inoculation of nursery plants with AM fungi is most likely to benefit host plant performance after transplanting into special landscape conditions. These conditions are low soil fertility, especially phosphorus, urban sprawl/new landscape developments, restoration/reclamation, and reforestation/re-vegetation. In conclusion, some points to consider if a nursery operator is considering whether or not to inoculate their nursery plants with AM fungal inoculum:

- Does the product contain species/geographic isolates of mycorrhizal fungi that will actually colonize the plant you are inoculating?
- Is system fertility high, particularly with high levels of phosphorus or organic matter?
- Does the site have good soil and are landscape plants already thriving in this site? Chances are new transplants may not derive much benefit from mycorrhizae.
- Mycorrhizal fungi are living organisms that will not survive indefinitely in the product. Is the product dated and is shelf-life information provided?
- Has a commercial inoculum product undergone an independent quality control assay for commercial inoculants?