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The World Beneath Our Feet: Mycorrhizal Networking and the Establishment of Ohio's Native Trees and Shrubs

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The air is cool, the ground is moist, and the leaves are falling from the trees. Beautiful pinks, purples, golden yellows, brilliant oranges, and golden browns paint the forest floor. Not the fall colors of the leaves (though they too are magnificent), but what lies beneath… the vast array of mushrooms and other fungi that appear shortly after an autumn rain. These include the mushrooms under pines, the puffball growing amongst the oaks, and morels scattered around the spruce trees. These emerging bundles of fungi are not random occurrences, but ones that has evolved over millions of years. The relationship between native fungi and Ohio's trees and shrubs roots deep and is much more intimate than what appears on the surface.

The mushroom is the above ground fungal body that produces and disperses the spores (**Figure 1**). That very structure is made of interwoven, tightly packed, filamentous hyphae (singular hypha). A common example of fungal hyphae are the white and fuzzy growth forms characteristically seen with bread molds. That filamentous growth habit allows fungi to colonize and explore their surroundings. Using our friendly little bread mold as an example, these fungi feed by releasing enzymes that digest the bread into simple sugars easily absorbed through the actively growing colony. This mechanism of fungal feeding is important for decomposition, nutrient cycling, and biological interactions with other organisms in the environment. Their efficiency at breaking down complex carbohydrates has earned the fungi their ecological role as primary decomposers of our ecosystems. This is a rather prestigious worldview of our fungal friend who just ate your last piece of bread.

Figure 1. *Mushroom fungal body of a Russula spp. growing amongst moss. This image was kindly supplied by Molly Steinwald (Photo © www.mollysteinwald.com).*

Imagine another species of fungi growing in the soil below. Now, imagine that filamentous hyphae encountering a tree root and responding by wrapping its hyphae around the root tip (**Figure 2**). Instead of decomposing that root, the fungus just initiated an intimate symbiosis called a mycorrhiza (Greek for fungus root; plural mycorrhizae). The hyphae also grow inside the root allowing for the transfer of water and nutrients to the plant host from the fungus. Thus, this partnership maximizes the root system via extensive hyphal growth allowing the plant greater access to water and minerals (**Figure 3**). The mycorrhizal fungi receive carbon produced by the plant via photosynthesis resulting in a plant and fungal relationship that is beneficial to both organisms. The healthy establishment of many of Ohio's plant species depends on the presence of a diverse mycorrhizal community.

Figure 2. *Photograph (45X) of hyphae from a mycorrhizal fungus inoculating the root of a tree. The fungal hyphae can be seen colonizing the root tip. This formation is characteristic of a certain group of mycorrhizae called ectomycorrhizae.*

Figure 3. *Photograph (45X) of fully developed mycorrhiza with the white fungal hyphae completely surrounding tree roots. This extended surface area allows the tree greater access to soil resources.*

Figure 4. *A hybrid chestnut grown from seed on a reclaimed mine site in eastern Ohio. This is a very common, indigenous puffball that will tolerate the harsh soils common in former coal mined lands.*

Colonization of plant roots by mycorrhizal fungi may occur in different ways. One example is upon seed germination. The growing roots exude chemical signals into the soil profile. The presence of these chemicals stimulates the germination of fungal spores. The newly germinated hyphae grow toward the chemical pool that accumulates around the new root system. This signaling from the plant root also stimulates existing hyphae. In many cases, the young seedling gains the attention of hyphae that may have already been involved in a symbiosis with a neighboring tree. Instead of leaving one plant for another, mycorrhizal fungi will incorporate the newly emerged seedling into an existing fungal network. Interestingly, it has been demonstrated that this fungal network is capable of transferring carbon from a mature plant to a neighboring establishing seedling. What is even further fascinating is that this carbon exchange will occur between two entirely unrelated plants (a mature birch and a pine seedling for example).

This plant and fungal relationship has been extensively studied and this natural phenomenon incorporated into commercial fungal inoculum. Commercial inoculum is a mycorrhizal fungal soil amendment that when added to the soil will colonize seedlings in greenhouse, nursery, and landscape operations. In large-scale reclamation projects, thousands of trees are planted that have been nursery inoculated with commercial mycorrhizal fungal inoculum. This is particularly useful in surface coal mine reclamation projects where trees are subjected to severely disturbed environments. In these lands the soils are high in heavy metals, low in nutrient, pH and organic matter, and highly compacted. When organic matter is limiting, the fungi have the ability to obtain nutrients by enzymatic degradation of the rock substrate common in mine soils. To remedy the toxic effects of heavy metals, the fungi have the propensity to incorporate metals into the growing hyphae, which decreases the amount absorbed into plant tissue. Most importantly, the increased root systems aid seedling establishment during the hot and dry summer months when water is drastically limited.

The question of whether to include commercial mycorrhizal inoculum in tree plantings may be of interest to both homeowners and Tree Farmers. In nature, mycorrhizal colonization is the norm. Forest trees like oaks and pines generally host many different species of mycorrhizal fungi. However, plants and their fungal counterparts are a result of two co-evolving organisms whose relationship has been selected and adapted through time for a particular soil type. Therefore, the inoculum you introduce may not inoculate at a rate that can compete with native fungi that is harbored by an existing patch of native vegetation. Tree Farms are an excellent example of existing vegetation that will harbor native fungi and act as an inoculum source for new plantings. Even on reclaimed mine sites, previous reclamation plantings harbor native fungi that will colonize seedlings aiding in their growth and survival (**Figure 4**). Utilizing native mycorrhizal fungi may alleviate ecological concerns when deciding whether or not to introduce commercial inoculum. The desired tree species like a native oak may benefit from the inoculation. However, the concern may be that an exotic shrub or non-native tree species may ***really*** benefit from the introduced inoculum. This new partnership may facilitate an invasion from an undesirable plant species and result in a colossal headache for the landowner.

Therefore, letting nature do the inoculating may be best ecologically and economically. However, some conditions merit a little help from our fungal friends. Plant species such as alder and certain orchids require the presence of specific fungal species in order to establish. In other regards, restoring grasslands that were formerly used as agriculture fields can be problematic due to the lack of available native mycorrhizal fungi. This is presumably due to the many years of cultivating non-mycorrhizal crop plants coupled with the required tilling and agricultural amendments (primarily fungicides). These situations may require additional research by the landowner to determine if mycorrhizal inoculum should be added to the particular tree crop that is being established.

The moral of this story is that everything is truly connected. The next time you hiking through Ohio's natural areas and notice a mushroom growing underneath the forest canopy try to imagine the intricate world of connectivity beneath your feet. There is grandeur in the recognition that we too are directly connected to each organism existing in the ecosystems that surround us. Our part in conservation of native landscapes literally begins from the ground up. Ways of conserving our lands include: avoiding the removal of native soils, retaining patches of native vegetation, incorporating native trees and shrubs in landscapes and restoration projects, alleviating soil compaction after construction, and minimizing use of fertilizers, pesticides, and fungicides. These small steps will promote the survival of the native fungal community. As a result, these fungi will greatly contribute to the conservation and preservation of Ohio's native trees and shrubs.

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