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Bridging the Gap with Mycorrhizae

By Mike Amaranthus, Ph.D.

This is the forest primeval. The murmuring pines and the hemlocks,
Bearded with moss, and in garments green, indistinct in the twilight,
Stand like Druids of old.
— Henry Wadsworth Longfellow

LONGFELLOW'S IDYLLIC FOREST PRIMEVAL IS FAR FROM today's modern urban landscape. Urban landscapes face many threats to the health of trees. Shortage of organic matter in the soil, compaction, poor soil drainage, diseased soils, erosion, unstable pH, and temperature extremes are definitely not the conditions that trees faced in the forest primeval (see table 1). How do trees in the forest primeval attain great ages, heights and diameters without irrigation, fertilizers and pesticides? The answer is that soils in the forest primeval contain a wide range of beneficial organisms that soils in the urban landscape lack. Probably the most important of these, and the most studied group of beneficial soil organisms, are the mycorrhizal fungi.

Mycorrhizae literally means fungus-root and is a symbiotic (mutually beneficial) relationship between plant roots and certain specialized soil fungi. All known tree species form the mycorrhizal relationship in their native habitats. Two types of mycorrhizal fungi dominate the forest primeval; arbuscular mycorrhizae (formerly termed endomycorrhizae) and ectomycorrhizae (see figure 1). Arbuscular mycorrhizal fungi benefit ash, gum, maple and other trees as well as shrubs and ornamental plants. Ectomycorrhizal mycorrhizal fungi benefit most conifer species, such as pine, fir, spruce and hemlock, and hardwoods such as oak, birch, beech and madrone (see figures 2a and 2b).

This page: Figure 1: Cluster of Rhizopogon sp. ectomycorrhizae.
Photo courtesy of Mycorrhizal Applications Inc.

What are the Benefits?

More than 50,000 research studies have been conducted regarding the mycorrhizal and plant partnership. Arborists and landscape professionals are now putting this information to wise and practical use. Essentially, mycorrhizae form a secondary and expansive extension of the tree root system. Mycorrhizal filaments form an extensive web that research has shown to increase the absorptive surface of root systems 10 to 1,000 times greater than non-mycorrhizal trees (see figure 3). Mycorrhizal filaments absorb significantly more nitrogen, phosphorous, calcium and micronutrients than non-mycorrhizal roots. It is much more efficient for trees to support a mycorrhizal web beneath the soil surface compared to roots themselves. It would take approximately 100 times more tree-supplied photosynthate to support roots that covered the breadth and reach of the mycorrhizal fungal network. Studies have demonstrated a well colonized mycorrhizal root system is more tolerant of drought, soil salinity, soil pathogens, parasitic nematodes and chemical imbalances in the soil (see figures 4a and 4b). Mycorrhizal fungi also improve soil structure. Mycorrhizal filaments produce humic compounds and organic "glues" that bind soils into aggregates and improve soil porosity. Soil porosity and soil structure positively influence the growth of trees by promoting aeration, water movement into soil, and root growth that more closely mimic the soil condition in the forest primeval.

Forest Primeval and Nursery Stock

Trees raised in nurseries receive intensive care. Sterile, soilless mixes are generally used during early development, and fungicides are needed to keep soil-borne diseases to a minimum. Fertilizers and water push above-ground development but discourage the need for an expansive feeder root system.

Root systems are often severely reduced with lifting and transplanting, and injured root systems become more susceptible to disease. Intensive care approaches produce vast quantities of trees for sale but make tree establishment a challenge. For trees to survive and thrive in their outplanted environment they must be weaned from the intensive care so they can begin fending for themselves.

Forest Primeval versus My Urban Site

Soils from the forest primeval generally contain robust and diverse populations of mycorrhizal fungi. Intensive disturbance associated with site preparation and equipment operation in urban landscapes greatly reduces these populations. Research shows that compaction, scarification, erosion, topsoil and vegetation removal reduce and sometimes eliminate mycorrhizae completely. The arbuscular mycorrhizae and many of the top performing ectomycorrhizal fungi do not disperse their spores in the wind and move slowly by growing root to root or by the activities by wildlife species. These strategies for mycorrhizal dispersal worked for millions of years in the forest primeval. In disturbed urban environments, however, mycorrhizal fungi often do not recolonize an area. Many cases have been documented in which plants in disturbed urban and suburban environments have not formed mycorrhizae many years after outplanting, and are surviving only through intensive feeding and care.

Forest Primeval and Managed Turf Systems

Trees that are grown in close proximity to managed turf receive additional stresses. Managers schedule their irrigation for turf without regard for the needs of surrounding trees. Too much water keeps turf areas green but drowns the roots of trees and high levels of inorganic fertilizers keep root systems from developing normally. High levels of nitrogen and phosphorous will discourage a development of the expansive root system that trees need upon transplantation. Fertilizer practices can result in salt buildups, unstable and increasing pH that trees rarely encounter in their natural environments. Compaction, poorly drained subsoils, competition with the fibrous root systems of turfgrasses compound the inhospitable environment trees encounter.

Improving Tree Establishment the Natural Way

One approach to improving the functioning of roots systems is to arm trees with mycorrhizal fungi before or during outplanting. Commercial quantities of high-quality mycorrhizal inoculum are now available. Mycorrhizal inoculants often contain a diverse mix of mycorrhizal species and let the tree select the proper species for those particular growing conditions.

The form of mycorrhizal inoculant depends upon the needs and conditions of the applicator. Mycorrhizal inoculants are available as root dips, granular mixes, tablets or injectible solubles. Inoculants are most often used dry at transplanting or as an injectible suspension in the root zones of established trees. Many companies provide the granular form which is sprinkled on or near the tree root systems at planting (see figure 5). When trees are bareroot and small enough a root dip gel can be used. For existing trees, spring and fall applications of

Top left, Figure 2a: Mature madrone before soil injection with mycorrhizal inoculant, and
Top right, Figure 2b: 6 months after soil injection with mycorrhizal inoculant.
Photo courtesy of James Causton, certified arborist
Center: Figure 3: Pine tree grown in glass box shows extensive development of white mycorrhizal filaments.
Photo courtesy of David Read

Table 1: Comparison of characteristics of undisturbed forest soil and disturbed intensively managed urban soils

Undisturbed Forest Soil	Disturbed, Intensively Managed Urban Soil
Loose, well aggregated	Compacted, massive
Fungal dominated	Bacteria dominated
Low to moderate fertility	High fertility
High levels of mycorrhizal fungi	Low levels of mycorrhizal fungi
Seasonal moisture inputs, well drained	High levels of irrigation, poorly drained
High levels of organic matter inputs	Low levels of organic matter inputs
Low, stable pH and temperature	High, variable pH and temperature
Low levels of surface erosion	High levels of surface erosion
Low salt concentrations	High salt concentration
Low levels of soil borne diseases	High levels of soil borne diseases

injectible soluble inoculants are best but mycorrhizal inoculants can be used any time roots are active or trees are under stress. Injections in a grid pattern near the drip line provide the most contact with existing feeder roots. Costs vary among manufactures but overall the price for mycorrhizal inoculants has decreased dramatically in the last 5 years as mycorrhizal spores have been produced in greater quantities. Typically a one-gallon transplant can be inoculated for about a dime, and a one-inch caliper tree for less than $1.

There are plenty of economic savings when using mycorrhizal inoculants. Mycorrhizal trees require less intensive care than non-mycorrhizal trees. Fewer trees need replacement because mycorrhizal trees are better able to survive extremes of moisture, fertility and disease. Arbor and landscape professionals will find that a mycorrhizal tree will require less frequent watering and fertilizing as the mycorrhizal web is far more efficient in the capture and uptake of water and nutrients. In general, once the mycorrhizal inoculant is placed near the root system, practices that

Top, Figure 4a: Red maples treated with a granular mycorrhizal inoculant at outplanting survived summer drought and
Bottom, Figure 4b: non-treated red maples planted adjacent to the treated maples did not survive
Photo courtesy of
Mycorrhizal Applications Inc.

Figure 5: Pine tree on the left was treated with a granular mycorrhizal inoculant at outplanting and pine on the right was not treated.
Photo courtesy of Mycorrhizal Applications Inc.

encourage root growth will encourage the mycorrhizal web to form and expand. Allowing soils to drain and low to moderate soil fertility are best for mycorrhizal fungi.

Getting Real

Clearing of natural areas and new construction in the urban and sub-urban landscape represents the extreme of soil and plant disturbance. Getting trees established is often a great challenge. The tight or tenuous links between trees and soil microorganisms that operate so effectively in the forest primeval are broken. Such linkages in the forest primeval have allowed plants to survive and thrive in natural environments for millions of years without the use of fertilizers, pesticides and irrigation. Arborists and landscape professionals are gaining increased appreciation of the living soil and more frequently incorporating an understanding of soil biology and mycorrhizal products into their practices.

Mycorrhizal fungi are not a silver bullet. Mycorrhizal fungi will not correct problems associated with poor planting practices, poor site and species selection or unhealthy stock. What mycorrhizal fungi will do is work in partnership with the tree below the soil surface, allowing the plant to quickly establish, accumulate site resources and handle stress. A mycorrhizal root system greatly increases a tree's opportunity for health and longevity and can help bridge the below-ground gap between the forest primeval and the reality of the urban landscape. **AA**

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