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Science Helping Your Plants Grow Better

Mycorrhizae- Are They Right For Me?

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Nursery And Landscape Professionals Today Are Faced With A Bewildering Array Of Conditions And Treatments. Propagate, Aerate, Irrigate, Fertilize, Mulch, And Transplant Are But A Sampling Of The Activities Utilized By Today'S Practicing Industry Professional. One Of The Activities That Fuels The Greatest Debate In The Industry Is Using *Mycorrhizae.* What are they and are they really useful? The answer to these questions depends on what you, the professional, are dealing with. For years the nursery and landscape industry has responded to plant problems with conventional solutions fertilizing, pruning, spraying, and other cultural practices. Some practices are successful, many are not. In most cases, the choice of practices failed to consider "the root" of the problem that lies hidden from view beneath the soil surface.

Below the soil surface some 400 million years ago, long before plants had "help" to survive man-made environments, plant communities were faced with many natural stresses. Infertile soils, diseases, drought, extreme temperatures, competition, and wind are not new. To survive, plant species adapted strategies to persist in the physical, chemical and biological stresses that surrounded them. Perhaps the most fundamental and successful strategy, the mycorrhizal relationship, has allowed plants to adapt to the harsh conditions of life on land. Radiating out from the roots of plants are miles of tiny filaments that occupy great expanses of soil volumes and trap mineral nutrients and water essential to support plant growth needs (Figure 1).

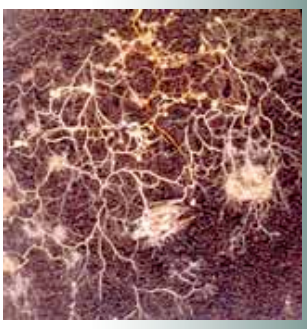

Figure 1. Conifer Seedling Grown In Glass Box. White Threads Are Mycorrhizal Fungi Exploring Soil For Mineral Resources And Water. (Photo Courtesy Of David Read)

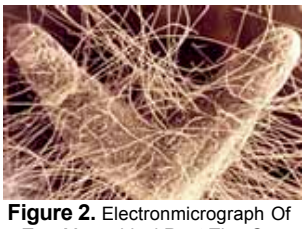

Figure 2. Electronmicrograph Of Two Mycorrhizal Root Tips On Pine. Radiating Threads Are Mycorrhizal Fungi That Act As Extensions Of The Plant Root System.

These tiny filaments (mycorrhizal fungi) actually attach and penetrate between and within the outer cells of the root cortex of plants and effectively become extensions of the root system itself (Figure 2).

The association between roots and fungi has been known or suspected since classical times. Theophrastus, a Greek naturalist of some 2000 years ago, traced the mycelium of certain mushroom species back to oak trees. The word Mycorrhizae is of Greek origin (fungus-roots) and defines the mutually beneficial relationship between an estimated 90% of the world's land plants and this specialized group of root colonizing soil fungi. The mycorrhizal relationships with plants have been found on every continent except Antarctica. It is likely that there is no woody plant on the face of the earth that does not form a "fungus-root" in some part of its range. Mycorrhizal relationship with plants have been found in the earliest fossil records. It is quite possible that the fungus-root relationship spawned the evolutionary leap that allowed plants to colonize the harsh terrestrial land surface.

What Are The Benefits?

Mycorrhizal fungi function through a network of threads. At one end the threads attach to and enter the root

tissue. It is here that the plant and fungus exchange essential materials. The plants receive mineral nutrients, water, and a variety of other growth promoting substances. In exchange, the fungus receives essential sugars and compounds to fuel its own growth. On the other end, fungal threads as individuals (hyphae) or in clusters (mycelium) fan out into the soil and exponentially expand the amount of soil which the roots may explore for raw materials. Estimates of amounts of mycorrhizal filaments present in soil associated with plants are astonishing. Several miles of filaments can be present in less than a thimbleful of soil. Mycorrhizal fungal filaments in the soil are truly extensions of root systems and more effective in nutrient and water absorption than the roots themselves.

Figure 3(a). Non Mycorrhizal Root System Lacks Branching;

Many other exchanges occur between plants and their mycorrhizal symbionts. Mycorrhizal fungi produce soil compounds which stimulate the plant to produce additional roots on which the fungus can grow (Figure 3a, 3b). Conversely, roots in turn secrete substance upon which stimulate the growth of the fungus. Mycorrhizal fungi release powerful chemicals into the soil that dissolve hard to capture elements such as phosphorous, iron and other "tightly bound" soil nutrients. Other chemicals produced by mycorrhizal fungi include enzymes to degrade organic carbon and nitrogen sources. These extraction processes are particularly important in plant nutrition and explains why non mycorrhizal plants require high levels of fertility to maintain their health.

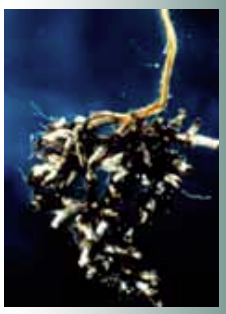

Figure 3(b) A Single Root Tip Colonized By A Mycorrhizal Fungus Branches Into Dense Cluster Of Absorbing Tips.

Figure 4(a). Mycorrhizal Inoculated Cherry Tree Survived The Summer Drought Without Stress;

Mycorrhizal fungi form an intricate web that captures and assimilates nutrients and water, conserving the ability of soils to remain productive during periods of stress. In non irrigated conditions, mycorrhizal plants are under far less drought stress compared to non mycorrhizal plants. Results from numerous studies strongly indicate that mycorrhizal fungi can help plants to tolerate and recover from soil water deficits. (Figure 4a, 4b). The mycelial network produced by mycorrhizal fungi play an important role in water uptake storage and movement back into plants demonstrated the enhanced tolerance to drought stress.

Figure 4(b) Cherry Tree Planted The Same Day But Not Inoculated By Mycorrhizal Fungi Wilts In The Hot Summer Sun.

Disease and pathogen suppression is another benefit for a mycorrhizal plant. Mycorrhizal fungi attack pathogens or disease organisms entering the root zone. Excretions of specific antibiotics produced by mycorrhizal fungi immobilize and kill disease organisms. Numerous studies have shown that many mycorrhizal fungi exhibits strong antibiotic activity and these antibiotics form a chemical barrier protecting plant roots from disease. In addition some mycorrhizal roots contain have a mantle (a tight, interwoven covering of dense filaments) that acts as a physical barrier against the invasion of root diseases.

Mycorrhizal fungi also improves soil structure. Mycorrhizal filaments produce humic compounds and organic "glues" (extra cellular polysaccharides) that bind soils into aggregates and improves soil porosity. Soil porosity and soil structure positively influence the growth of plants by promoting aeration, water movement into soil, root growth, and distribution. In sandy or compacted soils the ability of mycorrhizal fungi to promote soil structure may be the most important factor improving plant performance.(Figure 5)

Mycorrhizal Diversity Is Important

Natural areas generally contain an array of mycorrhizal

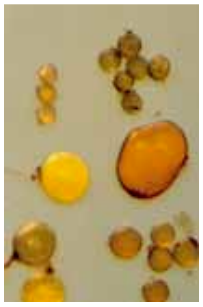

Figure 6. A Diversity Of Mycorrhizal Spores From The Genus *Glomus.*

fungal species. Not all mycorrhizal fungi have the same capacities and tolerances. Some are better at imparting drought resistance while others may be more effective in protecting against pathogens or have more tolerance to soil ph or temperature extremes. Because of the wide variety of soil, climatic, and biotic conditions characterizing man-made environments, it is improbable that a single mycorrhizal fungus could benefit all host species and adapt to all conditions. For example, the types and activities of mycorrhizal fungi associated with young plants may be quite different from those associated with mature plants Likewise, mycorrhizal fungi needed to help seedlings establish themselves on difficult sites may differ from those which sustain productivity at the nursery. The diversity of mycorrhizal fungi formed by a given plant may increase its ability to occupy diverse below ground niches and survive a range of chemical and physical conditions (Figure 6).

Figure 5. Threads Of Mycorrhizal Fungi Bind Sand Grains Promoting Soil Porosity And Structure

Modern Practices And Man-Made Environments

The below-ground landscape of native habitats is teeming with thousands of organisms, including mycorrhizal fungi that provide many of the necessary components that all plants need to survive. Mycorrhizal fungi, like plants, are affected by soil conditions. Research indicates many common practices can degrade the mycorrhizae-forming potential of soil (figure of degradation environment). Tillage, fertilization, removal of topsoil, erosion, site preparation, road and home construction, fumigation, invasion of non native plants, and leaving soils bare are some of the activities that can reduce or eliminate these beneficial soil fungi (Figure 7). In many man-made landscapes we have reduced or eliminated the soil organisms necessary for plants to function without high levels of maintenance.

Figure 7. Compaction, Topsoil Removal And Displacement Reduce Or Eliminate Mycorrhizal Fungi On Most Construction Sites.

Reintroducing mycorrhizal fungi in areas where they have been depleted can dramatically improve plant establishment and growth. In fact, in their natural environments it is likely that the distribution of mycorrhizal fungi is what determines the distribution of a particular plant species. For example, when an oak tree grows on a particular site, it may do so because the soil conditions there are hospitable for it. In fact, the tree is possibly growing where the soil conditions are best for the fungus! Utilizing this important partnership on an operational basis can assist the practicing nursery and landscape professional in getting high value plants established and maintaining plant health over time.

Plant Production

Plants raised in most nurseries receive intensive care and feeding. The artificial conditions, high levels of water and nutrients and sterile soils at the nursery keep certain soil born diseases to a minimum and produce vast quantities of plants for sale. Unfortunately, the high levels of water and nutrients and the lack of mycorrhizae discourage the plant to produce the extensive root system it will need for successful transplantation. The result are plants poorly adapted to the eventual out planted condition that must be weaned from intensive care systems and begin to fend for themselves. Application of mycorrhizal inoculum during the nursery growth cycle or transplanting can encourage plant establishment and set the plant on track to feed for itself. Research studies document the need of plants to generate a mycorrhizal roots system in order to become established. There are practical solutions to some of the mycorrhizal deficiencies in man-made environments and reintroducing mycorrhizal fungi in areas where they have been depleted can dramatically improve plant establishment and growth.

Figure 8. The Rose Bush On The Left Was Inoculated With Mycorrhizal Fungi And Had Fewer

To reduce input costs of water/fertilizers/pesticide inputs, many growers have looked at increasing the plants ability to uptake these vital components and protect itself naturally from diseases. But if the soil and its vital components are in disrepair this process will be limited. Thus the plant will have slower growth rates, weaken defense mechanisms, higher management maintenance cost and overall poor health (Figure 8). Improving the soil and its beneficial organisms can reduce many problems common in nursery and agricultural production. Until recently, this would have been economically unfeasible. The cost of mycorrhizal inoculant has declined significantly with greater usage. When one considers the benefits and low cost of application, mycorrhizal

Problems Following Transplanting. The Rose Bush On The Right Was Not Treated.

inoculation has become very cost effective for nursery and landscape use.

New Landscape And Plant Installation

Current construction practices can destroy 20,000 to 40,000 years of soil development with just one pass of heavy equipment. The challenge for the landscape professional is to try to establish quality plant material on a severely degraded site. The new construction landscape business has truly become a land reclamation business. The objective is to re-create thousands of years of soil improvements in a short period of time, with a limited budget and with a public that wishes to have more and more unusual, nonnative plant material. In many cases the industry is asked create a healthy plant ecosystem in a biological desert of poor soil conditions and the altered environments of concrete and asphalt.

How does the landscape professional improve soil conditions in new landscape installations at highly disturbed sites? Most new construction sites are a formidable foe for plant establishment without intervention of good soil reclamation practices. Green industry professionals must plan and develop a plan for soil reclamation as they would for site design. Creating a favorable below ground environment is as important to the overall success of the planting as the plant selections themselves. Mycorrhizae can be a key to the success of a planting on a highly disturbed site where plants must quickly access the water and nutrients necessary to become established (Figure 9). In the field, as in the nursery, introducing mycorrhizae can be accomplished in a variety of ways. Inoculations with liquid drenches, a root dip gel or by granular incorporation into the soil are all possible mechanisms.

Figure 9. Difference In Root Development Between Mycorrhizal Inoculated Tree (Left) Vs. Non-Inoculated Tree (Right) After One Year Planted In The Field.

What Types Of Mycorrhizal Products Are Available?

A nursery manager and landscape contractor can enhance plant root growth and transplant success and ameliorate many problems that result from current intensive care practices. Plants grew and thrived on this planet for millions of years without intensive care. Nature provides the template. A more sustainable approach to plant establishment and growth includes using mycorrhizal fungi. Certain mycorrhizal spores or "seeds" of the fungus have been selected for their establishment and growth-enhancing abilities. The goal is to create physical contact between the mycorrhizal inoculant and the plant root. Generally, mycorrhizal application is inexpensive and requires no special equipment. Typically for small plants the cost ranges from less than a penny to a few cents per seedling. For larger plants more inoculum is needed and costs are higher.

Nursery And Landscape Professionals Have At Least Four Options To Inoculate With Mycorrhizal Fungi.

Figure 10. A Granular Mycorrhizal Inoculant.

The first method is an incorporation of a granular mycorrhizae at the time of planting or out planting plant stock into the field site (Figure 10). The granular material can be incorporated into potting soil or soiless mixes. It can also be poured beneath the plant before placing into the planting hole or distributed around the root ball after placement.

The second option is a soil drench. This method can be accomplished through existing spray devices in the nursery or field or by soil injection (Figure 11). It is essential that the mycorrhizal fungi reach the vicinity of roots themselves. Porous or artificial soils are not a problem for a drench. In clayey or compacted soils the drench must be added to the planting back fill or sprayed to the surface of the root ball.

The third option is to purchase plant stock that have been pre-inoculated and have mycorrhizae present. The difference in performance of pre-inoculated liners vs. uninoculated plant stock can be dramatic. Pre inoculated stock can more rapidly establish and grow in the field.

The fourth option is inoculation with a mycorrhizal root dip gel during out planting in the field. Root dip gels are used by many

landscapers as a means of reducing losses and increasing speed of establishment especially in non irrigated conditions.. The grower dips small potted liners or bare root liners into a slurry. This slurry contains a blend of mycorrhizal spores, biostimulants, water holding gel. The mycorrhizal spores attach to the roots, and rapidly form mycorrhizae associations. A root gel treatment is often a very economical treatment and can reduce transplant losses significantly.

Figure 11. A Subsurface Application Of Liquid Mycorrhizal Inoculum Using A Soil Probe.

Mycorrhizal products often contain other ingredients designed to increase the effectiveness of the mycorrhizal spores. For example, organic matter is often added to encourage microbial activity, soil structure and root growth. Stress vitamins improve nutrient uptake and builds root biomass. Water absorbing gels help "plaster" beneficial mycorrhizal spores in close proximity to feeder roots and encourage favorable soil moisture conditions for mycorrhizae to form and grow. Organic biostimulants, in general are effective ingredients in mycorrhizal products. By promoting field competitiveness, stress resistance and nutrient efficiency biostimulants reduce barriers for rapid mycorrhizal formation especially during the critical period following root initiation or transplanting. The synergistic relationship between mycorrhizal fungi and biostimulants can mean 1+1=3 for the successful establishment of plants.

So Are Mycorrhizae For Me?

The answer to this questions begins with a simple assessment of the below ground landscape or nursery environment. If your soils are in a natural state or produce plants of model health and growth without large levels of human intervention, then mycorrhizae are probably not for you. But if you grow plants in below-ground environments that are sterile or severely disturbed and the plant community suffers from disease, drought, soil compaction, infertility, transplanting shock, and simply poor outward appearance, then mycorrhizae is for you! The landscape industry is asked to create ecosystems of plant communities with limited budgets and with less than acceptable soil conditions in a very short period of time. Professionals now have an assortment of low-cost and effective mycorrhizal inoculants that can build a sustainable plant-mycorrhizae system as nature has done for millions of years.

Today's nursery and landscape professionals integrate complex and changing economic and environmental values. This requires understanding of how plants function, how the soil and plants work together, and how they are linked and interdependent. Plants and mycorrhizal fungi form a dynamic and coherent partnership whose relationship has co-evolved over millennia. We can no longer consider plants in isolation from the belowground symbionts that promote plant health. Mycorrhizae, are they right for you?