POTENTIAL BENEFITS OF MYCORRHIZAE IN THE URBAN ENVIRONMENT [1]

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ABSTRACT.--Trees colonized by selected mycorrhizae-forming fungi may benefit in a variety of ways from the resulting association. These potential benefits, and the steps which must be followed to achieve them, are described.

Certain fungi are capable of infecting roots and forming a symbiotic relationship with them. The resulting structure is called a mycorrhiza, or literally fungus-root. The fungus acquires carbohydrates from the host plant, but the host plant benefits in a wide variety of ways. First, water and nutrients absorbed by the fungal hyphae are transferred to the roots. Not only is the absorbing surface of the roots effectively increased, but the hyphae are able to absorb mineral elements that are in forms normally unavailable to roots. The elements proven to be absorbed more efficiently by mycorrhizae than roots are phosphorous, potassium, calcium, copper, and iron.

Roots of some mycorrhizal associations have been found to be resistant to infection by root rotting fungi and parasitic nematodes. The source of resistance ha's not been fully defined yet, but is probably a combination of things. The mycorrhizal fungus may present a physical barrier to the pathogenic fungus and/or produce antibiotics that limit growth of the pathogen. It is also possible that the mycorrhizal fungus stimulates the host to produce chemicals that inhibit the growth of any other fungus on the root. Once a root is infected by one mycorrhizal fungus it is even difficult to infect that root system with a different mycorrhizal fungus.

Plants with mycorrhizal roots may survive and grow better than non-mycorrhizal plants under adverse conditions

[1] Metro. Tree Impr. Alliance (METRIA) Proc. 3:77-82, 1980.

such as high soil temperature, pH extremes, and soils with a high metal content. How the mycorrhizae accomplish this is not well understood, but it appears to be related to an ability of the fungus hyphae to selectively absorb essential mineral elements under the adverse conditions.

To achieve these benefits, we must thoroughly understand the different types of mycorrhizal associations and the implications of their differences. There are ectomycorrhizae, endomycorrhizae, and ectendomycorrhizae. The hyphae of ectomycorrhizal fungi grow in the intercellular spaces of the root; they do not penetrate the cells. They also form a dense fungal mantle around the root tips and extend out into the soil. Most ectomycorrhizal fungi are basidiomycetes and reproduce by forming basidiocarps, which are nothing more than puffballs. The airborne spores are easily dispersed over a large area. Examples of genera of trees forming ectomycorrhizal associations are listed in Table 1.

Table 1. Plant genera forming ectomycorrhizal associations

Abies	Fagus	Populus
Alnus	Larix	Pseudotsuga
Betula	Ostrya	Quercus
Carpinus	Picea	Salix
Cedrus	Pinus	Tsuga
Corylus		

The hyphae of endomycorrhizal fungi penetrate the root cortical cells and extend out into the soil, but do not form a fungal mantle around the root tips. Some form structures in the root cells called vesicles and arbuscules and are referred to as vesicular-arbuscular (VA) mycorrhizae. Most are phycomycetes and reproduce by forming chlamydospores in the soil near the surface of the roots. These spores must be disseminated by water or animals, as they rarely get windborne. This severely limits the spread of endomycorrhizae forming fungi into areas free of them. Despite this limitation, endomycorrhizae are naturally occurring in almost all soils and form associations with 90% of all higher plants. The genera of trees listed in Table 2 have been found to form endomycorrhizal associations.

Ectendomycorrhizae have characteristice of both, but will not be discussed here because they are consistently found on a very limited number of genera.

Table 2. Plant genera forming endomycorrhizal associations

Acer	Ginkgo	Robinia
Aesculus	Gleditsia	Sophora
Amelanchier	Liriodendron	Sorbus
Celtis	Malus	Ulmus
Cercidiphyllum	Platanus	Zelkova
Fraxinus		

Plants that form ectomycorrhizae do not normally form endomycorrhizae, and vice versa. However, the fungi within these broad categories are generally not host specific and will form mycorrhizal associations with a wide range of plants. For instance, the ectomycorrhizae-forming fungus Pisolithus tinctorius will form mycorrhizae with plants in most of the genera listed in Table 1.

The problem is that not all fungi impart the same benefits to their hosts, and a specific fungus may benefit one host more than another. Our goal is to determine which fungus-host combination will form the mycorrhizal association most beneficial to the plant. Plants growing on adverse sites develop the optimum relationship through the process of evolution. Those that have it survive and multiply, and those that do not eventually are crowded out and die. This process does not take a million years but may occur in the first year a seed or seedling is planted on a site such as an abandoned strip mine.

Where urban trees are concerned, though, we do not give them an opportunity to evolve. Trees are taken directly from nurseries, where they are grown in good soil and receive regular applications of fertilizer, and are often placed in environments not suitable for plant growth. The mycorrhizae on their roots are adapted to nursery conditions and not to the hostile environments found along city streets. The chance of a more beneficial fungus colonizing the roots is low because there may be no source of inoculum readily available; and even if there was, its infection of the roots would be inhibited by the existing mycorrhizal fungus.

To form the specific association most beneficial to the plants, they should be inoculated in the nursery during propagation. If they are not inoculated at the time of propagation, they will be infected by naturally occurring fungi, and it will be very difficult for the specific desired fungus to colonize them at a later stage in the production cycle.

Under standard nursery practices it would be relatively simple to inoculate the plants. Cuttings are rooted in sterile media and seedbeds are normally fumigated, a process which not only destroys root-rotting organisms but often kills mycorrhizae as well. Under these conditions the inoculum has no competition and can readily colonize the roots.

This brings us to the question of how exactly do we convert the potential benefits of mycorrhizae to actual benefits? First, we must determine which relationships produce the desired results--improved survival and growth of trees planted in urban environments. This problem can be approached in two ways. We can start with a specific tree and determine which fungus imparts to it the maximum benefit. The alternative is to start with a fungus which is known to be effective and determine which trees it will colonize and whether or not it will benefit all of them. The possibility exists that a fungus which forms a mycorrhizal association with two different tree species may benefit one but not the other.

The fungus which has received the most attention in this regard is Pisolithus tinctorius. Tree seedlings colonized with P. tinctorius have consistently shown increased survival and growth on adverse sites when compared with seedlings-colonized by other mycorrhizal fungi. It is time to evaluate trees infected with this fungus on urban streets. The problem is that we need trees colonized as seedlings and grown for 7 to 10 years before they can be planted in the hostile urban environments.

After we have determined which fungus-host relationships are most beneficial, mycorrhizal plants will have to be planted and evaluated in a number of locations. There are strains of fungi which are effective in certain climates but not others. These limits will have to be defined for each fungus.

A system for propagating the fungus on a large scale must be developed. This is less of a problem for ectomycorrhizal fungi because they can be grown in pure culture. Abbott Laboratories is currently evaluating a system they have developed for producing inoculum of P. tinctorius. The system can be used to produce large quantities of other ectomycorrhizal fungi as well.

Producing inoculum of endomycorrhizal fungi on a large scale has a number of inherent problems. The fungi must be grown on roots of living plants for approximately three months before the inoculum is ready to harvest. The chances of contaminating the roots with another mycorrhizal fungus are remote because spores of endomycorrhizae-forming fungi are not airborne, but spores of other fungi such as fusarium or botrytis may infect the host plants or their residue and contaminate the inoculum. These problems are currently being addressed by the personnel of Abbott Laboratories.

After systems for producing the inoculum on a commercial basis have been developed, the product must be evaluated. Initial comparisons between laboratory grade and commercially prepared inoculum of P. tinctorius suggested the laboratory grade was superior. This is to be expected with a new and rapidly developing technology. There is no reason to believe these problems will not be overcome, though.

Nurserymen must then be educated in the benefits of mycorrhizae and how to use them. Instruction on the storage and handling of inoculum, inoculation techniques, and special cultural requirements of mycorrhizae will have to be provided. Within a few years inoculation may be simplified to the point that tree seeds will be inoculated with a fungal symbiont in the same way that soybeans are now. The International Forest Seed Company is currently producing conifer seeds encapsulated with basidiospores of P. tinctorius for testing by researchers or interested nurserymen.

Mycorrhizae do not develop well under high fertility conditions. To educate nurserymen on how to encourage development of mycorrhizae on their plants, extensive field demonstrations will have to be carried out. Research is currently being performed on the use of slow release fertilizers during the time the mycorrhizal association is being established. In this way supplemental mineral elements are constantly being provided to the plant, but at rates low enough that they do not interfere with root colonization.

Finally, the consumers of these trees with customized root systems must be convinced of the trees' value. They will undoubtedly be more expensive, but a slight increase in cost should not be a deterrent. Replanting a tree that does not survive transplanting involves the costs of removal, purchasing a new tree, and planting it. When the proper mycorrhizal association has been found for urban environments, the amount of money saved in these steps will more than cover the increased cost of the customized trees. The added benefit provided at this point will be that the surviving trees will grow and develop better than trees currently being planted in urban areas.

The final point I want to make today is where trees with these customized root systems are needed. Sites for urban trees can be classified into four general categories: parks, wide tree lawns, narrow tree lawns, and holes in concrete. In parks, wide tree lawns, or any other open areas, tree roots will develop mycorrhizal associations with naturally occurring fungi. They will probably have access to adequate water and mineral elements. Customized trees may not be needed in these sites, and in fact, probably would not perform any better than trees grown under standard nursery practices.

Trees planted in the other site categories will have very restricted root zones and will be in soil not meant to support plant life. In these sites, carefully selected mycorrhizae can improve the survival and growth of urban trees by providing them with some or all of the recognized benefits of their associations.