# Mycorrhizae: Benefits and Practical Application in Forest Tree Nurseries

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Specialized root-inhabiting fungi form beneficial associations with all forest tree species. These fungi invade the feeder root tissues and form modified roots called mycorrhizae (fungus-roots), which greatly increase efficiency of nutrient and water uptake. Most plants require mycorrhizae for normal growth and development in natural soils.

Mycorrhizae can be classified into two primary types: ectomycorrhizae and endomycorrhizae.

With ectomycorrhizae, which are normally found on pine, spruce, fir, beech, eucalyptus, alder, oak, and hickory, the fungi grow between rather than within root cells. They form a structure known as the Hartig net between the cells, as well as a fungus mantle or cover on the surface of feeder roots. The ectomycorrhizal feeder roots develop a swollen appearance, and in pines they normally have a forking habit (fig. I-7).

The endomycorrhizae are found on maple, sycamore, ash, gum, walnut, cypress, some poplars, and some other conifers. This mycorrhizal type also occurs on all agronomic crops, such as sorghum, corn, and grasses used as cover crops in tree nurseries. These fungi grow into the root cells, and a mantle or exterior cover is lacking. Endomycorrhizal fungi frequently produce large, conspicuous, ornamented spores on hyphae attached

***Figure I-7***—Several types of ectomycorrhizae on conifer roots.

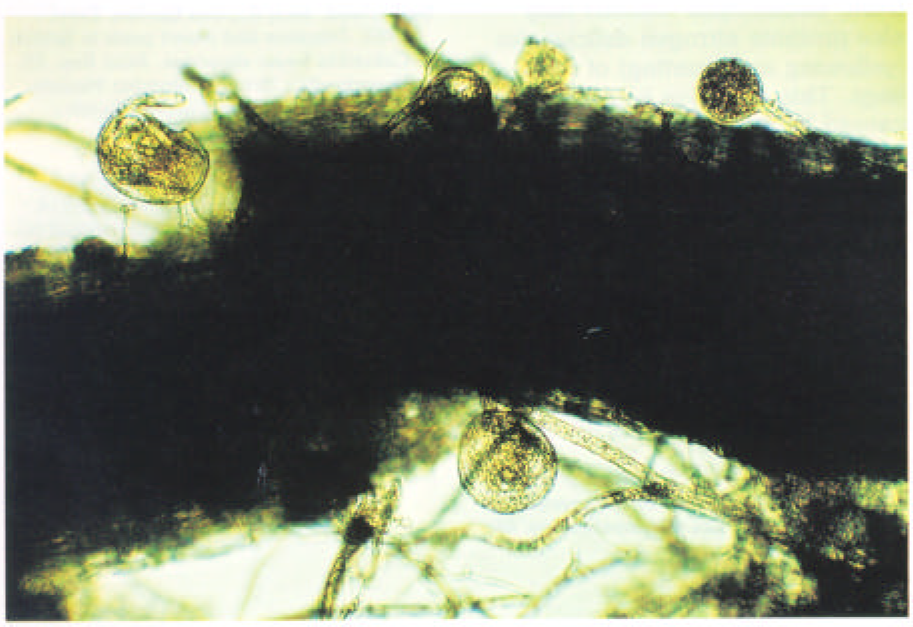

***Figure I-8***—Brownish spores of an endomycorrhizal fungus on the root surface.

to endomycorrhizal roots (fig. I-8), which are detectable under low magnification and represent a reasonably reliable indicator of endomycorrhizal fungus root infection.

Mycorrhizal feeder roots are responsible for the uptake of most of the nutrients and water from natural soils. These structures are essential to the health and vigor of plants, especially forest trees that grow in stressful environments.

Seedlings of ectomycorrhizal tree species commonly grown in fumigated nursery soils form ectomycorrhizae with naturally occurring fungi that originate from windblown spores. These spores are produced by mushrooms and/or puffballs in adjacent windbreaks, seedling beds, or forested stands. *Thelephora terrestris* is the most common naturally occurring ecto-mycorrhizal fungus in bareroot seedling nurseries in the United States (fig. I-9). In southern pine nurseries, which usually produce 1-0 stock, 25 to 75 percent of feeder roots are ectomycorrhizal with T. *terrestris* by lifting time.

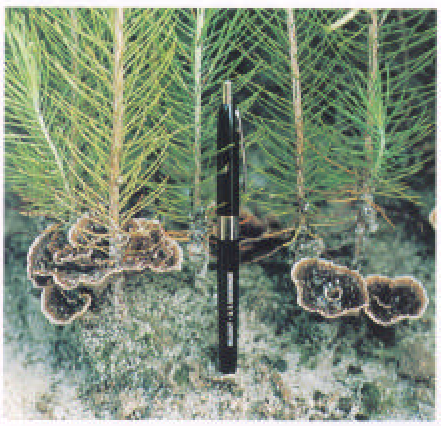

***Figure I-9***—Fruiting body of *Thelephora terrestris*.

This fungus is well adapted to the optimum growing conditions in nursery beds, but, unfortunately, not to the adverse conditions of many reforestation sites.

Hardwood seedlings grown in fumigated nursery soil may have poor endomycorrhizal development. Nonselective soil fumigation reduces populations of these fungi, which do not have the capability to rapidly recolonize the partially sterilized soil, as do ectomycorrhizal fungi. Endomycorrhizal fungi do not produce large, aboveground fruiting bodies and windblown spores for effective recolonization of soil. Because of inadequate endomycorrhizal development, these seedlings may grow poorly in the nursery.

Container nurseries have special problems. Seedlings are produced under artificial conditions, and artificial inoculations may be the sole source of mycorrhizal development. Thus, mycorrhizal inoculation in container nurseries is often required. Artificial seedbed and container inoculations with pure cultures of mycorrhizal fungi are likely to become standard practices in those operations where these fungi are absent or deficient.

## Ectomycorrhizae

Recent research has identified an ectomycorrhizal fungus, *Pisolithus tinctorius* (Pt), that is ideal for adverse planting sites (fig. I-10). Procedures have been developed for using Pt in bareroot and container nurseries. Studies have shown that

***Figure I-10***—Fruiting body of *Pisolithus tinctorius*.

when nursery seedlings are inoculated with this fungus, numbers of cull seedlings are reduced, and survival and growth in field plantings are increased. The increases have been most apparent on adverse forestation sites like strip mine spoil banks, but consistent and significant improvements have also been observed on many routine sites. The tailoring of seedlings with Pt mycorrhizae before planting on adverse and many routine sites is certainly worthwhile. Use of the fungus may be generally beneficial on all sites because poor conditions, especially soil water deficits, during and following planting can make the best field sites temporarily adverse.

Techniques for inoculation have been developed in research studies and tested in more than 100 nursery trials. Inoculation techniques are reliable, but they are not well understood by most nurserymen.

In bareroot nurseries, Pt mycelial or spore inocula can be placed in prefumigated (preferably spring) seedbeds before or at seed sowing. In cooperation with private industry, the USDA Forest Service has developed an ectomycorrhizal fungus inoculum applicator to apply Pt mycelial inoculum during seed sowing in bareroot nurseries (fig. I-11). This machine uniformly applies bands of inoculum into the root zone and levels the soil in preparation for sowing seed in the nursery bed. Mycelial inoculum can also be broadcast on the seedbed surface by hand, but using the machine reduces the inoculum needed by two-thirds and places it in the drill rows, where it is most needed. Spore inoculum can be applied as bulk and pelletized spores, on spore-encapsulated seeds, and with hydromulch applications.

In container nurseries, Pt spore or mycelial inoculum can be added to the growing medium before containers are filled. Another technique is to apply either spore pellets or bulk spores onto the growing medium after seeds are sown. A third is to encapsulate the seeds in spores before they are sown.

*Figure I-11*—Machine for applying mycelial inoculum to nursery beds.

In general, spore inoculum has not been as effective as mycelial inoculum in early establishment of Pt ectomycorrhizae on seedling roots. In addition, encapsulation of seeds of some species with spores inhibits germination somewhat. Nevertheless, spore inoculum appears to be practical in some nursery operations. Figure I-12 illustrates how the root system of loblolly pine seedlings can be enhanced with Pt.

Inoculation failures in nursery trials are usually attributable to adverse soil conditions and cultural practices, and nonviable inoculum. Certain pesticides, especially the systemic fungicide triadimefon (Bayleton®), inhibit formation of ectomycorrhizae from both Pt inoculum and natural sources. However, this fungicide is highly effective for fusiform rust control, and it is used routinely in nurseries where rust hazard is high. The main edaphic factor affecting ectomycorrhizae development is pH. Soil pH above 6.0 strongly inhibits development. Soil phosphorus up to 150 ppm and applications of nitrogen totaling 400 lb per acre during the growing season do not inhibit ectomycorrhizae.

## Endomycorrhizae

Most major hardwood species form endomycorrhizae and require them for normal development in forest plantings. Adequate development of endomycorrhizae in the nursery has two benefits. First, seedling quality in the nursery is improved. Second, hardwood seedlings that have good lateral roots and good endomycorrhizal development before outplanting do not die back as much after outplanting as those with poor lateral roots and endomycorrhizal development.

Hardwood seedlings with endomycorrhizae are better able to compete with undesirable vegetation on the planting site. The most important long-term effect is in phosphorus uptake. Forest soils usually do not have sufficient phosphorus in available form for optimum tree growth. Naturally occurring endomycorrhizae aid in phosphorus uptake. Without them, many trees would die. Fortunately, the endomycorrhizal fungi are present naturally in forest soils. Maintaining them in nursery soils requires special management.

Cover crops of such species as sorghum, corn, millet, and sudex are ideally suited for increasing the populations of endomycorrhizal fungi in soil. The crops also add organic matter to the soil and reduce water and wind erosion. In addition, the dense feeder root systems of most cover crops increase

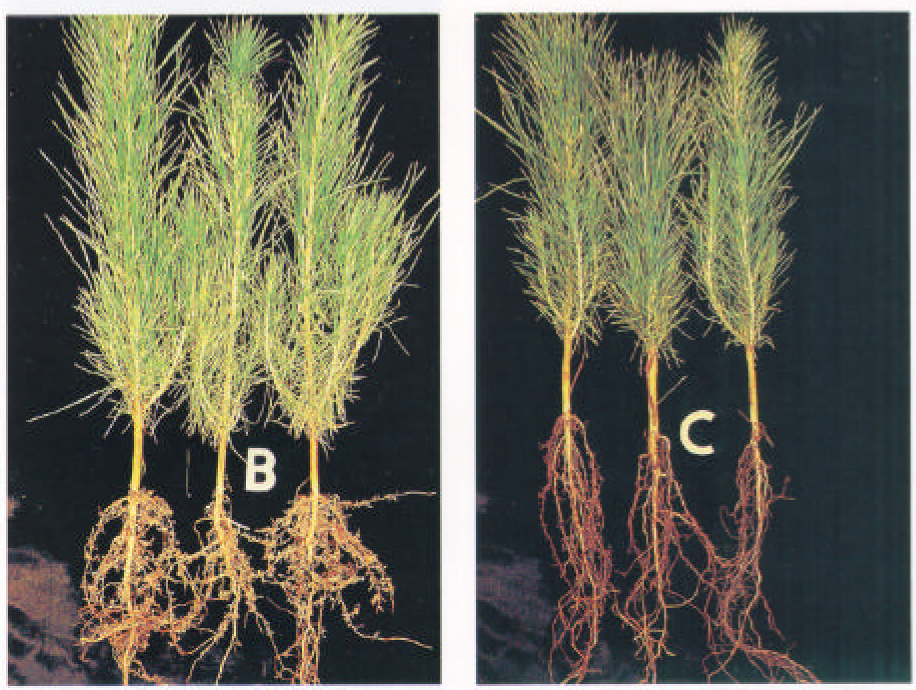


*Figure I-12*—Loblolly pine root systems with abundant *Pisolithus tinctorius* (B) and normal (C) ectomycorrhizae.

natural levels of inoculum of endomycorrhizal fungi.

Unfortunately, soil fumigation can nullify all of these benefits if it is applied after the cover crop is worked into the soil and before hardwood seed sowing. The nonselective fumigant removes most of the endomycorrhizal fungi from the top 8 inches of soil. Therefore, routine soil fumigation for hardwood seedling crops should be applied before the cover crop is planted. In addition, the cover crop should be permitted to mature. Maturity of annual plants appears to be essential for the completion of the life cycle of the endomycorrhizal fungi. Only at the end of the growth cycle are the spores for inoculating the tree crop produced in large quantities. Some nurseries use two cover crop rotations in a single growing season in the hope of adding more organic matter to the soil. From the standpoint of endomycorrhizal development, this practice is not advisable if the second crop does not have adequate time to mature.

Phosphorus fertilization of nursery beds must be carefully monitored to permit good mycorrhizal development. Available soil phosphorus should be maintained between 75 and 100 parts per million (Bray II test). Less than 50 ppm without mycorrhizae will inhibit seedling development, and higher than 100 ppm will inhibit endomycorrhizal development. Six to eight applications of nitrogen (50 lb per acre, as ammonium nitrate) are also recommended.

Seedlings with few mycorrhizal roots do not absorb water and nutrients from the soil efficiently. Thus, they suffer severely from transplanting shock and often die.

Mycorrhizae are living, somewhat delicate structures on the feeder roots of plants. They can easily be damaged mechanically or by desiccation. Improper harvesting operations can strip seedlings of most of their mycorrhizae, as can careless handling, packing, storage, or shipping. Excessive root pruning for convenience in packing, shipping, or planting can remove the majority of mycorrhizae as well as root tissues containing food reserves that will be needed during the hard times following outplanting. Root systems must be kept cool and moist from the time the seedlings are lifted in the nursery until they are planted in the field.

## For More Information

For the latest information on mycorrhizal technology in forest tree nurseries, write: Dr. Charles E. Cordell, National Mycorrhizal Applications Coordinator, USDA Forest Service, Region 8, Forest Pest Management, Asheville, NC 28804; (704) 257-4320.

Two types of inoculum are commercially available-spores and vegetative (mycelium). At present, mycelial inoculum is available only from Mycorr Tech, Inc., University of Pittsburgh Applied Research Center, Pittsburgh, PA. Spore pellets, spore-encapsulated seeds, and bulk spores are available either from International Tree Seed Company, Odenville, AL, or from South Pine, Inc., Birmingham, AL. An ectomycorrhizal fungus inoculum applicator is presently available from R.A. Whitfield Forestry Equipment Manufacturing Company, Mableton (Atlanta), GA.

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