# THE IMPORTANCE OF MYCORRPHIZAE IN FOREST NURSERIES

Dr. Donald H. Marx
Forestry Sciences Laboratory, Athens, Georgia

Most forest tree nurserymen are aware of the different damaging infections caused by fungi which attack tree seedlings. To most nurserymen the term "fungus infection" is synonymous with fungus-caused diseases, such as black root rot, Pythium root rot, fusiforme rust, and others. Disease-causing fungi are parasitic pathogens because they utilize some part of their host as food and cause damage to the host.

I wonder how many of you nurserymen are as aware of a considerably more widespread parasitic phenomenon caused by fungi infecting the feeder roots of trees that is not destructive, but instead, is beneficial to the survival, growth, and development of trees. These fungi are highly specialized root parasites but they do not cause root disease. They are symbiotic parasites because they do not cause root disease. They are symbiotic parasites because they utilize certain components of the feeder roots of their host as a source of food, but at the same time they are physiologically beneficial to their tree host. The feeder roots infected by these symbiotic fungi are called mycorrhizae, which means "fungus roots".

There are two major clases of mycorrhizae that are separated by the association of the thread-like hyphae of the mycorrhizal fungi in the root tissues. The class that occurs on pine, spruce, fir, beech, hickory, most oaks, and many other tree species is called ectomycorrhizae. Ectomycorrhizal fungi, which literally number in the thousands of species, belong to the group of fungi which produces muchrooms and puffballs. These fruit bodies readily produce an abundance of wind-disseminated spores. Feeder roots are infected from spores or hyphae of these symbionts in soil near the root. They are stimulated into rapid growth by chemical exudates from the roots, and the hyphae enventually enclose the entire feeder root in a dense sheath or fungus mantle. Hyphae penetrate between the epidermal cells and utilize the pectin and other carbohydrates of the root as food. Hyphae continue to spread between the cortical cells, developing the Hartig-net. Ectomycorrhizae are variously colored and may appear as simple, non-forked feeder roots, as "Y"-shaped (bifurcate) roots, or as multi-forked (coralloid) roots. Not all forked roots are necessarily ectomycorrhizae, however, and not all ectomycorrhizae are forked.

The class of mycorrhizae that occurs on sycamore, sweetgum, ash, poplar, box elder, locust, maples, and many other hardwoods is called endomycorrhizae. Endomycorrhizal fungi are related to watermolds and do not produce spores that are wind disseminated. Most belong to the genus *Endogone*, and there are over a dozen recognized species; many more species undoubtedly exist. Endomycorrhizal roots usually have an extensive loose network of hyphae on the feeder root surface, which is usually dotted with large, conspicuous, thick-walled, brown-yellowish spores (up to 0.8 mm in diameter). The hyphae penetrate the epidermis of the root and progress into the interior cortical tissues. Thin-walled vesicles, which are swollen, ballon-like hyphae, may be produced in the root cortex. These fungi also usually form arbuscules, which are specialized feeding structures, in cortex cells. When vesicles and arbuscules are both present in the mycorrhizae, the term "vesicular-arbuscular (VA) mycorrhizae" is used.

Unlike ectomycorrhizae, endomycorrhizae are not readily distinguishable from nonmycorrhizal roots. Both ecto- and endomycorrhizae involve only cortical tissues of the feeder root and do not infect the meristematic or vascular tissues.

Most research on mycorrhizae has been done on ectomycorrhizae of pines, spruce, and fir. Only limited published research is available on endomycorrhizae of hardwoods. The following is a list of the experimentally proven benefits of ectomycorrhizae to forest trees:

1. They increase the physiologically active absorbing surface of the feeder root system.

2. They provide a more rapid absorption and accumulation of essential elements, especially N, P, K, and Ca.

3. They increase the functional age (longevity) of feeder roots.

4. Fungal symbionts break down normally non-available nutrients in soil and render them available to tree host.

5. They increase heat and drought tolerance of hosts.

6. They act as biological deterrents to feeder root infections caused by root pathogens, such as *Phytophthora* and *Pythium* spp.

With the exception of control of feeder root disease, these benefits have been proved or are thought to apply also to endomycorrhizae.

Generally speaking, the following factors stimulate mycorrhizal development of forest trees:

1. High light intensity
2. Low or moderate soil fertility
3. Good soil aeration and moisture relations
4. High soil organic matter
5. Soil reaction of pH 4.5 to 5.5
6. Soil temperatures between 65 and 85°F.

Extremes in any of these factors usually cause a decrease in mycorrhizal development or a dysfunction in mycorrhizae already synthesized. However, certain species of mycorrhizal fungi are more ecologically adaptable than others and, consequently, are able to synthesis mycorrhizae at extremes of soil conditions as long as susceptible feeder roots are produced by the tree hosts. Certain fungi, when in mycorrhizal association, stimulate root development in their host and, thus, mycorrhizal development increases.

Certain pesticides used in disease and insect control are directly inhibitory to mycorrhizal fungi. Some fungicides inhibit competitive microbes in soil which can cause a stimulation in mycorrhizal development. Soil fumigation with methyl bromide kills most weed seeds, fungal root pathogens and nematodes, as well as mycorrhizal fungi. Since ectomycorrhizal fungi produce abundant air-borne spores periodically throughout the year, they are usually available for rapid recolonization of fumigated soil. However, endomycorrhizal fungi do not produce air-borne spores. Difficulties in growing hardwoods in these soils have been reported because of the lack of recolonization by endomycorrhizal fungi. Recolonization is normally very slow since endomycorrhizal fungi must recolonize from adjacent, non-fumigated soil, from moving water, or from soil-working equipment.

I'm sure most of you are thinking that this information I've just presented is interesting, but you are probably wondering what it means to you as a nurseryman. If you are concerned only with growing a good grade of seedling in your nursery beds, then barring certain problems, you can grow most tree seedlings to a plantable size without concern for mycorrhizae. With high soil fertility, high light intensity, good soil moisture, proper aeration and temperatures, as well as no disease or insect problems, you may, with a great deal of luck, be able to grow certain species of tree seedlings to an acceptable planting-size without mycorrhizae at all. We do this in Athens routinely, although with a great deal of concentrated effort, in our mycorrhizal research program.

However, if you are concerned not only with growing planting-size seedlings in the nursery, but also with growing seedlings that will survive and grow well in the field, then you had better be sure your seedlings have a significant quality of mycorrhizae. Seedlings with few or no mycorrhizae seldom survive the first early weeks in the field. This is particularly true if the site is dry and has low fertility and high (95°F) soil temperatures. These features characterize a great number of reforestation sites in the Southeast.

Seedlings that do somehow survive usually remain severely stunted until indigenous mycorrhizal fungi in the soil or air-borne spores infect the roots and synthesize mycorrhizae. These last statements apply to ectomycorrhizae of pine and are based on systematic research results. We do not know the value of endomycorrhizae to survival of hardwood seedlings in the field. Research is currently underway in Athens on this aspect of endomycorrhizae.

There are only limited research results, excluding simple observations, on the amount of ectomycorrhizae necessary to ensure optimum seedling survival. Additionally, there are absolutely no research results based on field experiments as to whether or not certain species of mycorrhizal fungi on roots of seedlings are better than others in ensuring survival and growth in the field. These areas are currently under investigation. We are especially interested in the possible use of spore inoculum of *Pisolithus tinctorius* for nursery bed infestation. This fungal symbiont is apparently widely adapted to adverse site conditions. Mycorrhizae formed by this fungus or other special symbionts should increase pine seedling survival not only on the average reforestation site, but also on drastically disturbed sites characterized by low fertility and organic matter, high levels of acidity and toxic metals, as well as high soil temperatures.

Pine and hardwood forest soils contain a very complex mixture of mycorrhizal fungi. For example, in a 20 to 25 year old slash pine plantation, more than 50 species of fungi can be involved in the ectomycorrhizal association. Environmental conditions, season of year, soil type, etc., influence which fungal species in this mixed population are the most prevalent and the most physiologically beneficial to their hosts. This ecosystem is totally different from that of soil in a pine nursery. In the nursery, methyl bromide has eliminated all the fungal symbionts. Pine seedlings are now dependent on air-borne inoculum of symbionts for ectomycorrhizal infection. In most nurseries the seedlings are reared in very short rotations under excellent conditions of fertility, moisture, and disease control. These factors influence which species of symbionts can effectively colonize roots of the seedlings. The eventual result is that after several months in the nursery only a few species of ectomycorrhizal fungi are involved actively on the roots.

The predominant fungus, not only in the Southeast but apparently throughout the world in pine nurseries, is *Thelephora terrestris*. This fungus was once considered a pathogen since it grows up the stems of its host and supposedly smothers the seedlings. We know now that it is the major ectomycorrhizal fungus on roots of pines growing in nurseries which had been fumigated with methyl bromide. Recently, it has been shown that *Thelephora* forms ectomycorrhizae on roots of over 30 species of pine as well as Norway spruce and Douglas fir. We know this fungus is extremely beneficial to survival and growth of pine species on the vast majority of reforestation sites. Strong evidence has been presented, however, which suggests that it cannot survive, and therefore neither can its host, on certain reforestation sites with high soil temperatures, soil toxins, and low fertility. If these sites are to be reforested, procedures must be developed in which specific symbionts can be introduced and maintained on roots of seedlings that can tolerate these adverse site conditions.

In closing, I would like to remind you of a few statements that Dr. R. G. Hitt of the Washington Office made to you at the Alexandria, La. Nurserymen's meeting in 1968. He stated that phrases like "It can't be done" were yesterdays words, "How soon?" are todays words, and "What's next?" are tomorrows words. He stated that you--the nurserymen--soon will be producing planting stock that is tailored for specific reforestation needs. In my opinion, yesterdays words "It can't be done" were appropriate to any possible broad scale application of the knowledge we had on mycorrhizae in 1968. We are, I think, beyond this stage today. We can give a fairly good educated answer to the question "How soon?" we can apply current information. We are at the nursery and field testing stage now and results look excellent. Within the next couple of years we should be able to furnish you with the procedures necessary to tailor pine seedlings with specific ecologically adapted, mycorrhizal fungi. These specific fungal symbionts, we feel, will significantly increase survival and growth of tree seedlings not only on marginal reforestation sites, but in particular on those sites that are considered nearly impossible to reforest.