Use of Mycorrhizae for Native Plant Production

Ted St. John, Ph.D.
(949) 728-0685
DoctorTed@mycorrhiza.com
Tree of Life Nursery
PO Box 736
San Juan Capistrano, CA 92693

Abstract

The mycorrhizal symbiosis is well known, but not yet in widespread use in the commercial nursery trade. The often-cited mycorrhizal growth response is in not the most significant mycorrhizal effect. Instead, the important effects are performance in the field and improved nutrition and disease resistance in the nursery. These benefits may be of use in meeting regulatory requirements related to fertilizer runoff and pesticide use. A nursery mycorrhiza program requires modification of some current practices and careful choice of appropriate fungi.

Introduction to Mycorrhizal Inoculation in the Nursery

Everyone in the nursery trade has heard of mycorrhiza at this point: a beneficial association between a fungus and the roots of a higher plant. There is still some feeling that these fungi are microorganisms and thus must be everywhere. Mycorrhizae do take care of themselves if you are planting into unsterile field soil that has not been subject to serious disturbance. Ectomycorrhizal fungi are a bit more likely than endomycorrhizal fungi to take care of themselves, especially if native vegetation grows nearby. On the other hand, endomycorrhizae almost never take care of themselves in soilless media or on graded or badly damaged field sites. Regardless of the type of mycorrhiza, a lack of fungi accounts for a large share of the failures that plague restoration, reforestation, and mine reclamation.

I have published several earlier papers on this subject (St. John and Evans 1990; St. John 1993, 1996). In this paper I will focus on some newer concerns that bear on the commercialization of mycorrhizae. The earlier papers are available in PDF format at the Tree of Life Web site, www.mycorrhiza.com.

About twelve years ago Tree of Life Nursery in California began producing mycorrhizal native plants. We started slowly with only a few species that we knew to be mycorrhiza-dependent. A few years later we were inoculating every endomycorrhizal host species that the nursery produces. At this point we inoculate every suitable endomycorrhizal host species- over a period of years this has included two hundred or more plant species. We have become a tourist attraction for nursery owners from other countries and other parts of this country. These visitors have convinced us that our program is unique, at least in the number of plant species that we inoculate.

We use inoculum that we produce in-house, and in recent years we have offered this inoculum for direct use at restoration sites under the name VAM80. We inoculate at the first transplant stage, since practical considerations have prevented our inoculating in seed or cutting flats. We place about 2 ml of granular inoculum under the new transplant as it goes into a liner. Our staff does not consider it to slow them down significantly. In plug trays the plants are grown from seed with inoculum mixed into the medium.

Benefits of Mycorrhizal Inoculation in the Nursery

The emphasis throughout the history of mycorrhizal research has been on the greatly improved growth rate of inoculated plants. I will share a secret that is rarely made clear in the mycorrhiza literature: the practical importance of the famous growth response is rather limited.

First, you can equal or exceed the mycorrhizal growth response, in almost every case, with phosphorus fertilization. Second, the magnitude of the growth response depends strongly on the properties of the soil in which the test is conducted, and on the plant species that you select for the test. Perhaps most significantly, you are unlikely to observe the growth response in nursery conditions if you try to do a greenhouse test. The symbiosis is very sensitive to some generally underrated and widespread greenhouse problems. Greenhouses are generally too dark, too high in ethylene and related compounds, and too low in carbon dioxide for optimal mycorrhiza formation. Summertime experiments have the best chance for success, since photoperiod is very important. If your water spends any time in copper or galvanized storage, it may have inhibitory levels of metal ions. Low or "sub-clinical" levels of root pathogens can reduce or eliminate mycorrhizal colonization. Small containers present the worst problems, perhaps because both temperature and moisture tend to oscillate widely. These are factors that will keep what seems like a simple test from working as expected. They will also complicate, or even completely sabotage, an honest effort to produce mycorrhizal container plants.

To understand why anyone would go to the trouble and expense of setting up a serious mycorrhizal program at a commercial nursery, you have to consider what I call the "real" benefits of the symbiosis. The "real" benefits can be divided into field and nursery categories.

The benefits in the field include faster growth, better outplanting survival, improved disease resistance, and improved soil structure. If you plant from seed around the container plants, you will see a higher diversity of native plants from seed in the vicinity of the container plants, and in some conditions resistance to weed invasion. It is the customer who realizes these benefits, but the superior plants will reflect well on your nursery.

The benefits in the nursery include improved performance of some very mycorrhiza-dependent species. It is almost impossible to keep these happy with chemicals. We had some seasonal phosphorus nutrition problems which our inoculation program has solved. Rock phosphate is generally considered to be in the province of organic gardeners, but there is solid research to show that for mycorrhizal plants in soilless container mix, it is a steadier and more reliable source of phosphorus than highly soluble phosphate (Graham and Timmer 1985). Phosphorus in farm or nursery runoff can be a serious contaminant in waterways. A switch to mycorrhizal inoculation and rock phosphorus, in place of chemical phosphorus, could significantly reduce this problem.

A second important benefit in the nursery mycorrhiza's role in biological disease control. Ectomycorrhizal roots are more resistant to root pathogens than non-mycorrhizal roots. The same is true of endomycorrhizal roots, but their improved disease resistance may have much to do with associated pathogen antagonists- bacteria and fungi that can suppress disease organisms. The pathogen antagonists seem to interact in a beneficial way with mycorrhizal fungi (Linderman 1994), which may be a necessary part of a reliable system. A reliable biocontrol program, like a modified fertilization program, may play an important role in meeting future regulatory requirements.

By and large, the motivation for a mycorrhizal program will be neither nursery nor field benefits, but increasing demand from customers. Our program in California created a demand, and as soon as mycorrhizal plants were specified for restoration jobs, other nurseries began claiming to provide them. Since it took us several years of trial and error to make the program reliable, we are a bit skeptical that our competitors began producing mycorrhizal plants overnight. Nevertheless, mycorrhizal restoration jobs are a reality now in California and it is hard to imagine that it will ever turn back.

How to Inoculate in the Nursery

Ectomycorrhizal inoculum is supplied as spores, spore suspensions, or vegetative inoculum. Spores can be dusted on the seedlings and washed into the soil, incorporated into the medium, or pelleted onto seed. Mixing spores into the seedbed or applying them in a root dip at outplanting are economical methods at those stages.

If you want to give this a preliminary try in outdoor bare-root beds, you may want to use the method suggested by Riffle and Maronek (1982). Collect some forest litter from near the final planting site, then broadcast and plow it in at the rate of 2-4 kg per square meter of soil surface.

Endomycorrhizal inoculum usually consists of roots, spores, mycelium, and the medium in which the host plants were grown. The inoculum must come into contact with the host plant roots, which generally means it has to be incorporated in some way. Inoculum is mixed into the bed or container mix or placed under the transplant. Some spore suspensions have been offered, along with advice to apply the suspension through a "fertigation" system. In the cases I know of, this has worked poorly because the large endomycorrhizal spores do not stay in suspension, and they do not reliably work their way into the medium. It is also important in such cases to be sure the dosage is high enough to deliver dozens (in small containers) or hundreds (larger containers) of propagules to each plant.

Likely Problems for a New Mycorrhizal Program

I have already reviewed some of the things that go wrong with attempts to produce mycorrhizal container plants: low light intensity, short photoperiod, low carbon dioxide, too much ethylene, toxic elements in the water supply, and the presence of root pathogens. It is likely that other problems will present themselves as more nurseries give this a try. For example, many sources of peat moss are inhibitory to the endomycorrhizal symbiosis.

One of the worst problems is the difficulty of figuring out whether you have succeeded. You cannot rely on the growth response to tell you, as noted above. Ectomycorrhizal roots are visible directly or with a hand lens in many cases, and it is probably important for any nurseryman to learn how to recognize them. Endomycorrhizal roots are much more difficult to distinguish. You will either have to send samples to a specialized laboratory, such as Soil Food Web, Inc., (Corvallis, OR) or you will have to build the capability in-house. One consultant I know has gained the interest of a local community college biology professor. Now the college has a continuing focus for laboratory work and the consultant has free verification of her mycorrhizal plants.

If you use field-collected inoculum, you may cause more problems than you solve. Diseases in the soil tend to be more specific to host plants than the mycorrhizal fungus, especially with endomycorrhizal plants, so it pays to collect wild material from an unrelated species if possible. This is easier with endomycorrhizal than with ectomycorrhizal fungi. I have run into insect problems more than root diseases, but any of these are very real possibilities.

Choose the Right Fungi for Your Situation

Not all mycorrhizal fungi are equal, and there are several distinct kinds of mycorrhiza. You have to know what kind of association your target species requires. You have to use fungi that are available to you and that work well in the nursery, but they have to be fungi that are well suited for the intended planting site.

There are seven kinds of mycorrhizal symbiosis (Smith and Read 1997), of which four are of those of interest to growers in the northwest. Endo, also known as arbuscular or vesicular-arbuscular, is the most widespread, and applies to grasses, herbs, shrubs, and trees not listed under some other kind of mycorrhiza. The fungi that form endomycorrhizae are not very closely related to other kinds of fungi, and hard to distinguish from other kinds of soil-borne fungi. Even so, they make up most of the microbial biomass in most ecosystems. There are several commercial suppliers of endomycorrhizal fungi.

Ectomycorrhiza is widespread in forest trees, including Douglas fir, pines, spruces, hemlocks, oaks, birches, and a few others. Willows, cottonwoods, and alders are both endo- and ectomycorrhizal. Not included in this group are such endomycorrhizal host trees as redwoods, cedars, junipers, and cypresses. The fungi that form ectomycorrhizae include forest mushrooms and truffles, as well as a range of less conspicuous fungi. Ectomycorrhizal fungi are available commercially.

Arbutoid mycorrhizae are found in *Arctostaphylos* and *Arbutus*, and are in some ways similar to ectomycorrhizae. Ericoid mycorrhizae are found in most ericads, and are quite different from other types. I am not aware of commercial sources of fungi for either arbutoid or ericoid mycorrhizae.

Watch for a list of mycorrhiza types required by western native plant species, planned as a continuing feature in Hortus West.

Trappe (1977) has advised us to choose the fungi for the field site, not for the nursery. The ideal inoculum would be a mixture of species that are native to the site on which the material will be planted (Perry et al. 1987). This is a formidable undertaking for a nursery, although we have done it a few times. You can do it by inoculating with wild-collected soil or litter from the planting site, although Tree of Life grows cultures specifically for the purpose.

There is currently a lot of research about specific effects of native mycorrhizal fungi. The plant diversity of ecosystems is strongly tied to the diversity of fungi in the soil (Moutoglis et al. 1998), an effect that may only make itself known under conditions of competition between plant species. Some fungi are much better than others at improving soil structure, because some produce more soil-binding products than others (R. M. Miller, pers. comm.). We know that plants do not have absolute requirements for particular fungal species, but rather preferences that appear in certain as-yet poorly understood conditions.

If practical considerations prevent the use of local native fungi, it is considered better to inoculate with a mixture of fungi rather than a single species. Even so, the single-species inoculum that has been by far our best seller has worked very well in the field. The site-specific fungi have proven in practice to be about the same or in one case worse than the single species. This may have to do with the fact that the soil at the planting site has been changed so drastically by disturbance that the native fungi are no longer suited for that site.

Coming Developments

The most important trends are toward mixtures rather than single species, and toward lower cost of inoculating large land areas. Site-specific fungal mixtures are only available on special order, but we are beginning to provide regional mixes, divided by geographic area within southern California. We plan to keep producing our "generic" fungus, since experience indicates that on newly graded sites it may give better results than the native mixtures.

Is it Worth the Trouble?

A key question for nursery growers will be whether this is worth the expense and start-up time. If your main interest is in getting plants out the gate, and you already have a system that works, it would be best for now to stick with it. If you are interested in mycorrhizal inoculation, or if you have persistent problems that might be related to this, it would be worth trying some in-house tests. The easiest and most fruitful place to try this would be in fumigated nursery beds. Container production will be more difficult and will take time, but customer demand and regulatory pressure might have everyone doing this in a few years.

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