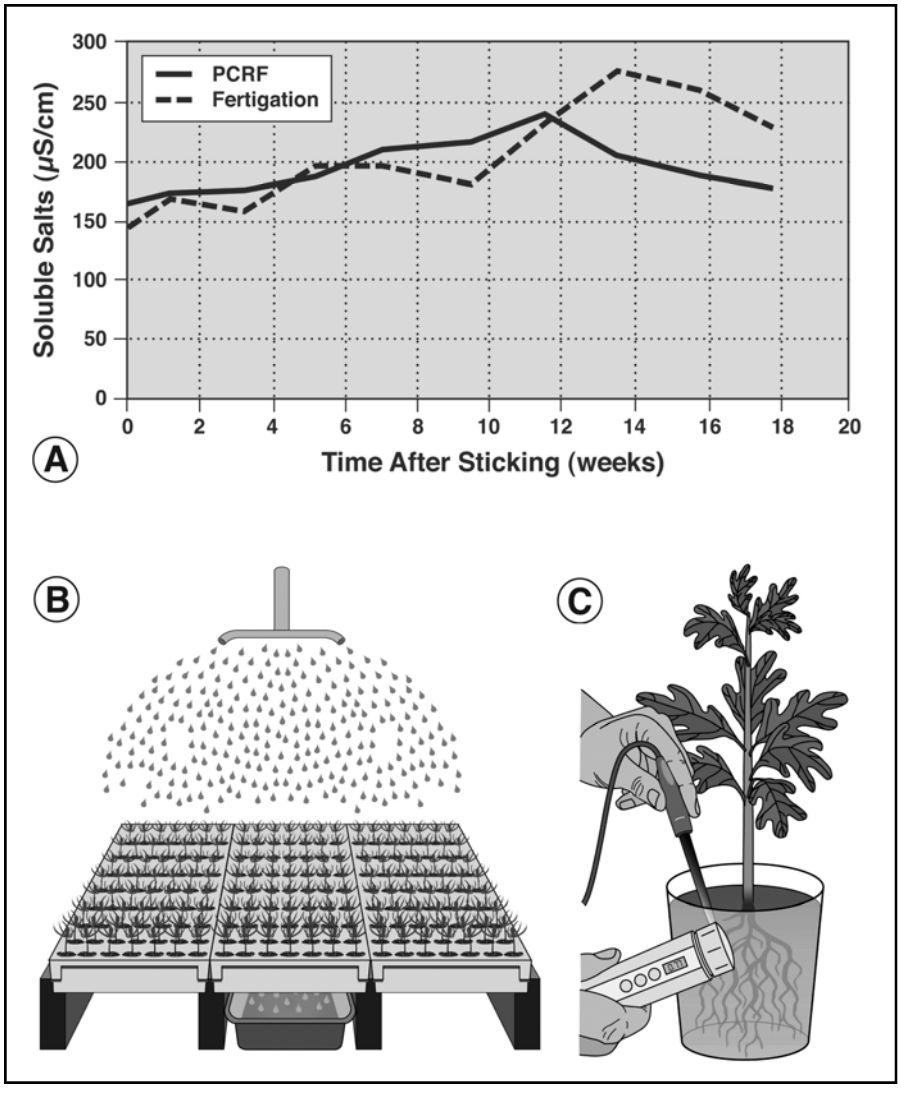
United States Department of Agriculture

Forest Service

Forest Nursery Notes

Winter 2009

Volume 29, Issue 1



Inoculate with Mycorrhizae, Rebuild Your Soil, and Help Stop Global Warming
by Thomas D. Landis and Michael A. Amaranthus

Mycorrhizal fungi form symbiotic partnerships with most plant families and all forest trees. Just to review, "myco" means "fungus" and "rhizae" means "root", and so the word "mycorrhizae" means "fungus-roots." In these mutually beneficial partnerships, root of the host plant provide a convenient substrate for the fungus, and also supply food in the form of simple carbohydrates. In exchange for this free room-and-board, the mycorrhizal fungus provides several benefits to the host plant.

Three types of mycorrhizal fungi are important to forest, conservation and native plants. (Wilkinson 2008):

Ectomycorrhizae - These fungi form partnerships with many temperate forest plants, especially pines, oaks, beeches, spruces, alder, hemlocks and firs.

Arbuscular Mycorrhizae (aka endomycorrhizae) - These fungi are found on a wide variety of wild and cultivated plants: most grasses, tropical plants, and understory species; some temperate tree species, including maples, dogwoods, redwoods, junipers and cedars.

Ericoid Mycorrhizae. These fungi form partnerships with plants in the families of heath (Epacridaceae); crowberry (Empetraceae); sedge Cyperaceae); and most of the rhododendrons (Ericaceae).

In this article, we're concerned with arbuscular mycorrhizae which we'll abbreviate as AM.

We've discussed the many benefits of inoculating your nursery stock with mycorrhizae several times in past FNN issues but we've just become aware of a new reason why you should. First, however, let's review the other reasons:

Potential Benefits of Inoculating Plants with Mycorrhizae

1. Increased water and nutrient uptake - Mycorrhizal fungi help plants absorb mineral nutrients, especially phosphorus and several micronutrients such as zinc and copper. Mycorrhizae increase the root surface area, and the fungal hyphae access water and nutrients beyond the normal root zone (Figure 1A).

2. Stress and disease protection - Mycorrhizal fungi protect the plant host in several ways. With some fungi, the mantle completely covers fragile root tips and acts as a physical barrier from dryness, pests, and toxic soil contaminants. Some fungal partners produce antibiotics that provide chemical protection against root pathogens.

3. Increased nursery vigor and growth - Plants that require AM associations perform better if they are inoculated in the nursery. This effect is often difficult to demonstrate under ideal nursery conditions but becomes obvious where soil fumigation has eliminated mycorrhizal fungi from the seedbed. If they are not purposefully inoculated with AM, nursery plants will eventually become naturally inoculated but growth will vary considerably from plant to plant creating a "mosaic" pattern in the seedbeds or nursery containers.

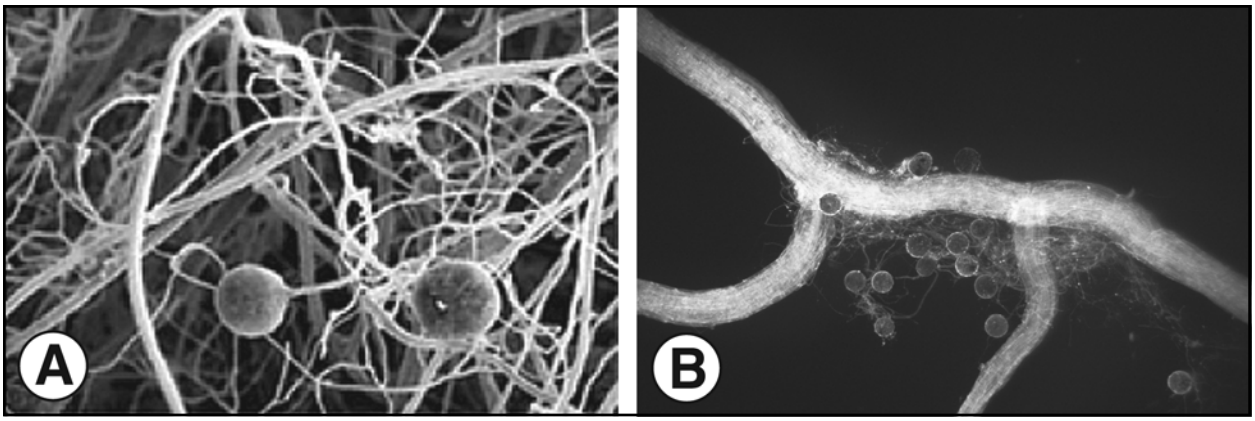


Figure 1 - The fungal partner of arbuscular mycorrhizae on grass roots sends out hyphae into the soil, greatly increasing access to water and nutrients. The round structures are spores (A). A microscopic view shows an arbuscular mycorrhizal fungus growing on a corn root (B). The shiny coating is glomalin, a glue-like substance which gives soils their structure (B- Photo k9968-1 courtesy of ARS)

4. Reduced transplant shock - Since we are able to supply all plants needs in the nursery, many of the above benefits are not readily obvious. The real payoff for having inoculated your nursery stock will often show up after outplanting. Non-mycorrhizal plants often become stunted and chlorotic ("yellow") after they are outplanted, especially on restoration sites where soil conditions are less than optimal.

5. Glomalin: the newest mycorrhizal benefit - In 1996, pioneering research by Sara Wright of the USDA-Agricultural Research Service showed AM produce a sticky glycoprotein called glomalin (Comis 2002). Wright named glomalin after Glomales, the taxonomic order to which AM belong (Amaranthus and others 2009).

From a soil management standpoint, the most important property of glomalin is this stickiness " (Figure 1B) which gives soils their "tilth. Tilth is one of those terms that's hard to describe on paper but you can feel it from the seat of your tractor. The best definition that we could find for tilth is "a sensory measure of the soil's ability to be worked easily, to hold water, to smell sweet, to crumble easily into large aggregates, and to resist wind and water erosion" (Podoll 2009). You probably remember from college that some of the best soils in the world developed under grasslands (Grieve 1980), and now you know why. Soils formed under grasses are very high in organic matter due to their massive fibrous roots and annual annual senescence and decomposition of their shoots. Grassland soils are also known for their excellent structure and, since all grasses have AM, we now know that structure can be attributed to glomalin.

From an ecological standpoint, one of the fascinating properties of glomalin is that it contains 30 to 40% carbon; in fact, glomalin can comprise one-third of all carbon in the soil and can persist for 40 years. We are all familiar of the deleterious connection between greenhouse gases and global warming. It has been estimated that up to a third of all of the increase in global CO_2 that has been generated since the industrial revolution can be attributed to carbon losses through poor agricultural practices. Because of glomalin's high carbon content, grass crops and natural grasslands are now being recognized as potentially valuable for offsetting carbon dioxide emissions from industry and vehicles. In fact, some private markets have already started offering carbon credits for grassland owners (Amaranthus and others 2009).

Rebuild Your Soil with Cover Crops and Green Manure crops

So, what does all this have to do with you? All bareroot nurseries are only as good as their soil, and harvesting during the winter is one of the most destructive things that you could do to a soil. Growing cover crops and green manure crops are the best ways to rebuild it. Just to review, cover crops are primarily used to prevent wind and water erosion whenever the land is fallow, whereas green manure crops are grown specifically to add organic matter to the soil (Rose and others 1995). Bareroot managers typically choose cover or green manure crops for their organic matter additions or resistance to root pathogens but now there's another consideration - glomalin. By inoculating the seeds of your cover crop with the spores of AM fungi, you could increase tilth in your nursery soil.

Choose grasses - The species that you use for a green manure and cover crop is critical. Perennial grasses and deep-rooted legumes are the best for soil building. Shallow rooted legumes and annual grasses are next in line, and grain legumes like soybeans are the most destructive of soil tilth. Lush green crops decay quickly after incorporation and much of the biomass is lost to the atmosphere as CO_2 (Podoll 2009). Perennial grass crops are most effective in soil building because they grow more root mass and the AM have more opportunity to form glomalin.

Inoculate with arbuscular mycorrhizae - So, it makes sense to inoculate your cover crops and green manure crops with AM. In a recent study, tall fescue grass plants (*Schedonorus phoenix*) were grown in pots with and without mycorrhizal inoculation and carbon and glomalin levels were monitored (Amaranthus and others 2009). At the end of one year, the inoculated grasses had significantly higher carbon and glomalin levels than the controls. The curvilinear relationship between mycorrhizal colonization and glomalin levels is intriguing - if you can achieve greater than around 30% AM colonization, then the amount of glomalin produced increases exponentially (Figure 2).

Sources of Arbuscular Mycorrhizal Inoculum

1. MycoApply® is a mixture of the active spores of several species of AM fungi: *Glomus intraradices, Glomus aggregatum, Glomus mosseae and Glomus etunicatum*. For more information, contact:

Mycorrhizal Applications, Inc.
TEL: 866.476.7800
FAX: 541.476.1581
E-mail: info@mycorrhizae.com
Website: www.mycorrhizae.com

2. BioVam is a mycorrhizal soil biotic that contains a mixture of ectomycorrhiza, endomycorrhiza, several species of bacteria, and 2 species of *Trichoderma* fungi. For more information, contact:

T&J Enterprises
TEL: 800-998-8692
E-mail: thomas@tandjenterprises.com
Website: www.tandjenterprises.com

3. Plant Revolution Inc. has several forms of mycorrhizal inoculum in their Plant Success product line. For more information, contact:

Josh Eagan
TEL: 714.545.5335
FAX: 714.545.5345
Email: info@plantrevolution.com
Website: www.plantrevolution.com

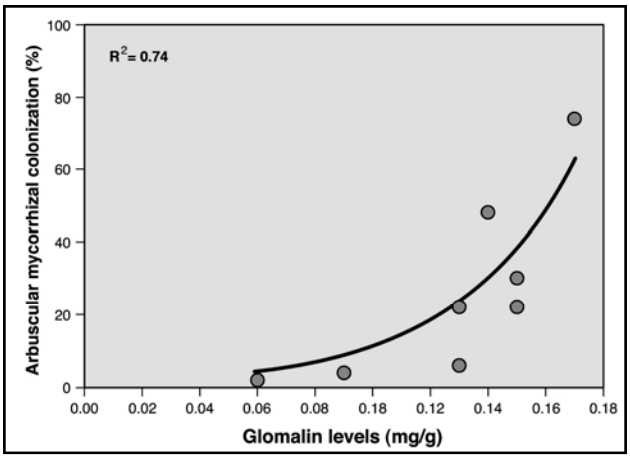


Figure 2 - When tall fescue plants were inoculated with arbuscular mycorrhizae, the more effective the colonization, the more glomalin was produced (modified from Amaranthus and others 2009).

4. Bio-organics™ offers an inoculum blend with 8 AM species: *Glomus aggregatum, G. clarum, G. desert-icola, G. intraradices, G. monosporus, G. mosseae, Gigaspora margarita, and Paraglomus brasilianum*. For more information, contact:

Don Chapman
TEL: 1.888.332.7676
E-mail: moreinfo@bio-organics.com
Website: www.bio-organics.com

Inoculating Grass Seed - Grass seed can be inoculated with AM in several different ways. Powder, granular or liquid formulations can be applied directly into the planting furrow during sowing. One especially effective application technique is to coat seeds with AM powders or liquids which ensures that inoculum is in close proximity to the germinating seeds. Exudates produced by the young roots stimulate the mycorrhizal spores to germinate and colonize nearby roots. Smart Seed™ with MYCO Advantage™ from Pennington Seed features improved selections of turfgrass inoculated with a mixture of AM spores from MycoApply. They offer a specialized grass mixture for the erosion market called Slopemaster™ which contains MYCO Advantage™, and also looking into inoculating their forage and annual grass seed products (Pennington 2009).

Summary

The benefits of inoculating nursery stock with mycorrhizal fungi are well documented, but the newly discovered relationship between arbuscular mycorrhizae and glomalin is particularly interesting. Arbuscular mycorrhizae are found on a wide variety of plants from around the world, and produce glomalin on their roots. This sticky protein is responsible for giving soils their tilth, which is critical to nursery soil management and reforestation, conservation, and restoration planting projects. Perennial grasses are most effective in soil building because they grow more root mass and the AM have more opportunity to form glomalin. Because it contains 30 to 40% carbon and ties it up for decades, glomalin can help counteract the buildup of greenhouse gases and lessen the effects of global warming. We're sure that we'll be hearing more about the glomalin connection in coming years but it makes sense to start inoculating cover and green manure crops as well as nursery stock.

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