Put mycorrhizae to use

These natural fungi can greatly improve plants' nutrient and water uptake

By Carolyn Scagel and Robert Linderman

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Mycorrhizal fungi and plant roots have had a partnership for more than 460 million years.

This association is thought to be responsible for the initial plant colonization of the Earth. Today this partnership is a key component to successful development of sustainable crop production systems.

Colonization of roots by mycorrhizal fungi results in a cooperative exchange between the plant and the fungus. The plant receives nutrients, water and hormones from the fungus in exchange for sugars and other substances from the plant.

The formation of mycorrhizae results in significant changes in the growth and physiology of the host plant.

There are several types of mycorrhizae. The type of mycorrhizae a plant forms generally depends on the plant species and fungus in the association.

The most common mycorrhizae in nursery crop plants are arbuscular (AM), ectomycorrhizae and ericoid. The main differences between these three types of mycorrhizae are how and where the fungi grow on and in roots.

AM and ericoid mycorrhizae are characterized by growth of hyphae (fine fungal strands) into feeder or fine root cells and into the soil or medium surrounding the roots.

AM is the most common type of mycorrhizal association in nursery crops. AM fungi form associations with most angiosperms (flowering plants) and some gymnosperms (*Taxus, Sequoia, Thuja* and *Chamaecyparis*), mosses and ferns. Ericoid mycorrhizae occur on the roots of ericaceous plants (*Rhododendron, Vaccinium,* etc.) except those in the Arbutoideae (such as *Arbutus, Arctostaphylos* and *Pyrola*).

Ectomycorrhizae commonly form a sheath (or mantle) of fungal material on the outside of the roots. Ectomycorrhizal fungal hyphae grow between root cells and grow into the soil or medium surrounding the roots. Ectomycorrhizae occur on most species in Betulaceae, Fagaceae, Pinaceae, Salicaceae and Myrtaceae. Many ectomycorrhizal fungi also form associations with species of *Arbutus, Arctostaphylos* and *Pyrola*.

Why they're important

Many benefits attributed to mycorrhizae are related to the hyphae that extend out from roots into the surrounding soil or medium. These hyphae increase the uptake and availability of nutrients and water to a plant. The extensive and dense hyphal network also modifies the soil or medium surrounding the root, resulting in protection against pathogens and improved soil.

Mycorrhizae are known for their effects on plant nutrition, especially improved phosphorus and nitrogen uptake. In most nursery production systems, nutrients and water are readily available to plants and enhanced uptake may not be as important as improved efficiency of nutrient and water use.

Mycorrhizal plants can use nutrients and water more efficiently than non-mycorrhizal plants, resulting in reduced nutrient runoff. Plants with mycorrhizae are able to withstand soil drought stress better than plants without mycorrhizae and can potentially decrease water use during production.

The ability of mycorrhizae to improve plant nutrition is partially a result of the fungus accessing sources of nutrients that are not

Important mycorrhizal product information

Any mycorrhizal product you purchase should contain this information:

- Purpose of product and how to use it.
- Content with species names, strain numbers and product control number of the manufacturing company.
- Guarantee of pathogen-free status.
- Mycorrhizal effectiveness rate in a standard test.
- Maximum dilution rate of the product.
- How to store the product and recommended dates of use.

readily available to a non-mycorrhizal plant. For example, mycorrhizae can improve access to organic nutrients in composts.

These fungi can also selectively absorb minerals and elements from soil that otherwise are immobile and therefore unavailable to non-mycorrhizal roots. Soil toxicity due to heavy metals and high salinity may be decreased by mycorrhizal fungi.

The influence of mycorrhizal fungi on root growth has implications during several phases of nursery crop production. These fungi can produce hormones such as auxins, ethylene, polyamines, and cytokinins. Mycorrhizal fungi can increase root initiation and growth resulting in improved production efficiency during rooting of cuttings or tissue culture plantlets. Their ability to improve root growth also affects stock quality by improving plant survival after transplanting. Reduced transplant shock is an important benefit to establishing mycorrhizae in the nursery.

The transfer of sugars from plants to mycorrhizal fungi can alter aspects of plant development that are important for quality and marketability characteristics of certain nursery crops. For example, mycorrhizal fungi can improve flower production.

If plants have mycorrhizae, the benefits can

Photos courtesy of USDA-ARS

Mycorrhizal hyphae (or hairs) penetrate the soil and help roots absorb water and nutrients.

Facts and fiction

FICTION:
- All plants need mycorrhizae.

FACTS:
- Almost all plants can form mycorrhizae.
- Some plants don't naturally form mycorrhizae.
- Plants can potentially survive and grow without mycorrhizae.
- The fungus is often completely dependent on the plant.

FICTION:
- You can tell a plant is mycorrhizal by looking at it.

FACTS:
- The only way to confirm whether a plant is colonized by AM or ericoid mycorrhizal fungi is by microscopic or DNA analysis.
- Most ectomycorrhizae can be seen on roots without a microscope. However some do not produce a mantle that is visible with the naked eye.
- If inoculation affects plant growth, do not assume the plant is mycorrhizal. Other organisms or components of the inoculum may cause a plant response without colonization by mycorrhizal fungi.

FICTION:
- Mycorrhizae will solve all my production problems.

FACTS:
- Proof of benefit by research does not necessarily translate to benefits detectable in all production system or landscape situations.
- Mycorrhizal benefits are most obvious under stress conditions.
- Benefits derived from mycorrhizae will depend on production goals.
- Benefits may not be greater than costs. Evaluate the cost and benefit of using mycorrhizal fungi just like any other potential change in production practices.

FICTION:
- Plants are mycorrhizal if they have been inoculated.
- Plants are naturally mycorrhizal if they have been grown in soil.

FACTS:
- Application of inoculum or growing plants in soil does not guarantee mycorrhizae formation.
- If mycorrhizae formation is a production goal, then process and quality control measures should exist to evaluate colonization success.

FICTION:
- Once plants have mycorrhizae, they retain them.
- The benefits from mycorrhizae that occur in the nursery will occur in the landscape.

FACTS:
- Changes in the environment and cultural factors that occur during different stages of production can alter the mycorrhizal status of the plant.
- Mycorrhizal fungi that perform well during early stages of production may not be the best fungi during later stages of production or in the landscape.

FICTION:
- Inoculation with mycorrhizal fungi does not affect plants.

FACTS:
- If inoculation results in colonization, plants are influenced by the association. However, the effect may not meet specific goals and objectives. Other production practices may mask potential benefits.

vary with the plant or fungal species, as well as environmental conditions. In many cases, the benefits of mycorrhizae are not recognizable unless non-mycorrhizal plants are compared to them.

Do you need them?

For a plant to become mycorrhizal, spores or hyphae (inoculum)

Mycorrhizae benefits

These benefits have been attributed to mycorrhizae under experimental conditions:

Nutrition
- Increased efficiency of nutrient use.
- Decreased nutrient runoff/leaching.

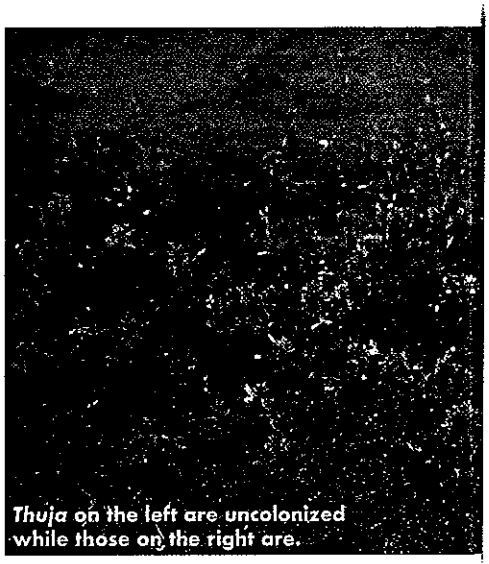
Disease
- Suppression of soilborne pathogens and disease.
- Increased plant health.
- Decreased use of pesticides.

Drought and salinity
- Increased efficiency of water use and drought tolerance.
- Decreased crop loss from salt stress.
- Increased acreage of farmable land.

Soil quality
- Improved soil structure and stability.
- Decreased erosion and topsoil loss.
- Enhanced nutrient retention.

Production efficiency and profitability
- Improved root growth and survival.
- Decreased production time.
- Enhanced marketability.

Product quality
- Altered phytochemical attributes.
- Increased flowering.
- Enhanced nutritional value.



Thuja on the left are uncolonized while those on the right are.

of the fungi need to be present in the soil or medium surrounding the roots. When roots and spores come in contact, spores germinate and hyphae penetrate the root tissue, initiating the mycorrhizal association.

Under certain nursery production conditions or in landscape situations inoculum may already be present and plants become mycorrhizal without assistance. The rate that natural colonization occurs depends on the amount and distribution of inoculum in the soil or growing medium.

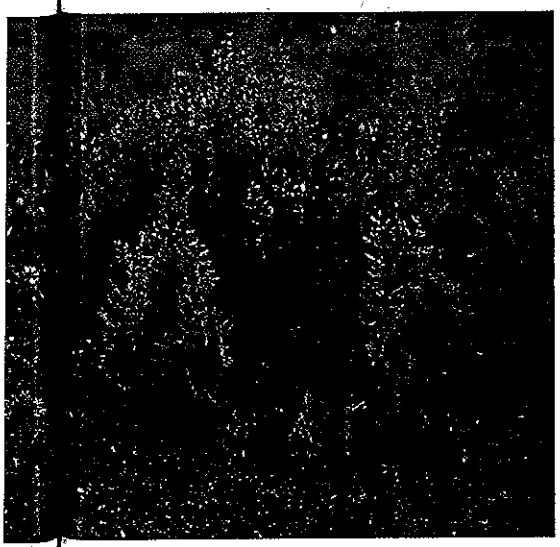
Once roots are colonized internally, the fungal partner must grow into the soil matrix, creating a direct interface between the fungal hyphae and the soil.

Inoculum of endomycorrhizal and ectomycorrhizal fungi is commercially available from several distributors, while there are only a few manufactures of inoculum of ericoid mycorrhizal fungi.

Application criteria and effectiveness of inoculum will vary with production systems, plant species and inoculum source.

Regardless of whether mycorrhizal fungi are introduced into a production system or whether there is a natural source of inoculum present, the ultimate success of inoculation or enhancement of natural colonization depends on environmental factors, cultural practices and viability or quality of the inoculum.

Sometimes the theoretical benefits of inoculation during nursery production are not realized or recognized. Reasons for successes and failures of mycorrhizal inoculants in nursery production include cultivar-specific responses to inoculation, optimal timing of application, cultural practices (such as using high rates of fertilizer), type and source of fertilizer and use of some pesticides.



When can you use them?

There are several opportunities to successfully inoculate crops during production. The benefits of having mycorrhizal fungi on plants are numerous and cumulative.

In most it's easier to see benefits from mycorrhizal formation when plants are inoculated in earlier crop stages. Furthermore, less inoculum is needed when plants are small. As the roots grow, the mycorrhizal fungus grows with the roots. Changes in the environmental and cultural factors that occur during different stages of production can alter the mycorrhizal status of a plant. Mycorrhizal fungi that perform well during early stages

Know the fungi

If your goal is to produce a mycorrhizal plant, then learning how to grow the fungus is as important as knowing how to grow the plant.

Mycorrhizae of Fungi [illegible]

of production may not be the best fungi during later stages of production.

What do you need?

You have to know what mycorrhizal fungi will form mycorrhizae on your crops. No comprehensive plant/fungi combination list exists.

Talk with inoculum suppliers, literature resources, extension personnel and researchers to determine the type of fungi best suited for your crop.

Many commercial formulations are available. Inoculum generally consists of a mixture of spores and hyphae either as pure inoculum or mixed with other components.

Some product formulations may be best suited for application to cuttings, others crops in later stages. Dry products are best applied incorporated into the medium.

Before making large financial investments, always test products on small scales using untreated plants for comparison.

A common question is whether one AM fungal species is better than several packaged together. Performance is often similar. However, the multiple-species products are often designed to have species that represent different adaptations to different soil conditions.

For example, fungi that are adapted to high-pH soils may function better in an alkaline soil than species that are better adapted to acid soils. Multi-species products, therefore, provide fungi that fit a wider range of soil conditions.

On the other hand, some species are broadly adapted to a wide range

Hit the Web

Those wanting more information on mycorrhizae can consult these Web sites:

http://cropsoil.psu.edu/sylvia/mycorrhiza.htm

www.ffp.csiro.au/research/mycorrhiza/index.html

http://res2.agr.gc.ca/ecorc/mycor/bio_sols_e.htm

http://mycorrhiza.ag.utk.edu

www.mycorrhizas.org

http://users.sunbeach.net/users/lec/types.html

http://invam.caf.wvu.edu/

www.deemy.de/Taxa/Images.cfm

www.mycorrhiza.org

Grapevines without mycorrhizae (on the left) show phosphorus deficiencies while the others thrive.

of soil conditions and could function as well as a mixture. In much of the published literature, single species are used with clear beneficial effects.

How can you use them?

1. Determine the specific goals or objectives for using mycorrhizal fungi in your production system (decreased fertilizer use, increased rooting, improved stock quality, drought tolerance, enhanced value-added product, improved transplanting success).

2. Evaluate the mycorrhizal status of crops under current production conditions. Your plants may already have mycorrhizae.

3. Work with commercial suppliers, extension personnel or other experts to determine whether cultural manipulation can improve mycorrhizal status or whether inoculation is needed.

4. If inoculation is needed, assess different products and determine host plant/fungus types required.

5. Test inoculum products on a small scale using non-inoculated plants for comparison.

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