

Mycorrhiza and its uses: Fact or Fiction

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Mycorrhizal Fungi

**unique, mutually beneficial
associations
of fungi with
plant roots!**



Types of Mycorrhizae

Seven Types

- *Ectomycorrhiza*
- *endomycorrhizas* aka arbuscular mycorrhizas
- Orchid mycorrhizas
- Ericoid mycorrhizas
- Ectendomycorrhizas - restricted mostly to the plant families *Pinus* (pine), *Picea* (spruce) and to a lesser extent *Larix*

Types of mycorrhizae

- Ectomycorrhizae predominate in temperate and boreal forests
 - Organic soils
- Arbuscular mycorrhizae is the dominant type in the tropics, and in grasslands and deserts of temperate latitudes
 - Mineral soils

Differences

- Ectomycorrhizal fungi do not penetrate the cell wall of the plant's root cells
- Arbuscular mycorrhizal (AM) fungi penetrate the cell wall
 - formerly called vesicular-arbuscular mycorrhizae
 - balloon-like (vesicles) or dichotomously-branching invaginations (arbuscules).

Ectomychorrizal Fungi

The fungal hyphae form a tissue-like sheath (mantle) on the surface of the nutrient-absorbing rootlets.



Ectomycorrhizae have been shown to degrade proteins in soil organic matter, obtaining a source of nitrogen that would otherwise be unavailable to plants.

Ectomychorrizal Fungi

- Hyphae extend into the soil, and also grow between the root cortical cells to form a 'Hartig net'.



Mantel

Hartig Net

Basidiomycetes
Ascomycotic
Endogone

Ectomychorrizal Fungi

- Colonize / infect 140 genera, in 43 plant families



Photos:
botit.botany.wisc.edu/toms_fungi/jul2004.html

Ectomychorrizal Fungi

Works for all *Abies* spp.,
Picea abies, *Pinus nigra*,
Pinus sylvestris, all
Populus spp.

Some trees form both AM
and Ecto



Not with *Aesculus hippocastaneum*, *Ligustrum vulgare*,
Rhamnus catharticus, *Sambucus nigra*

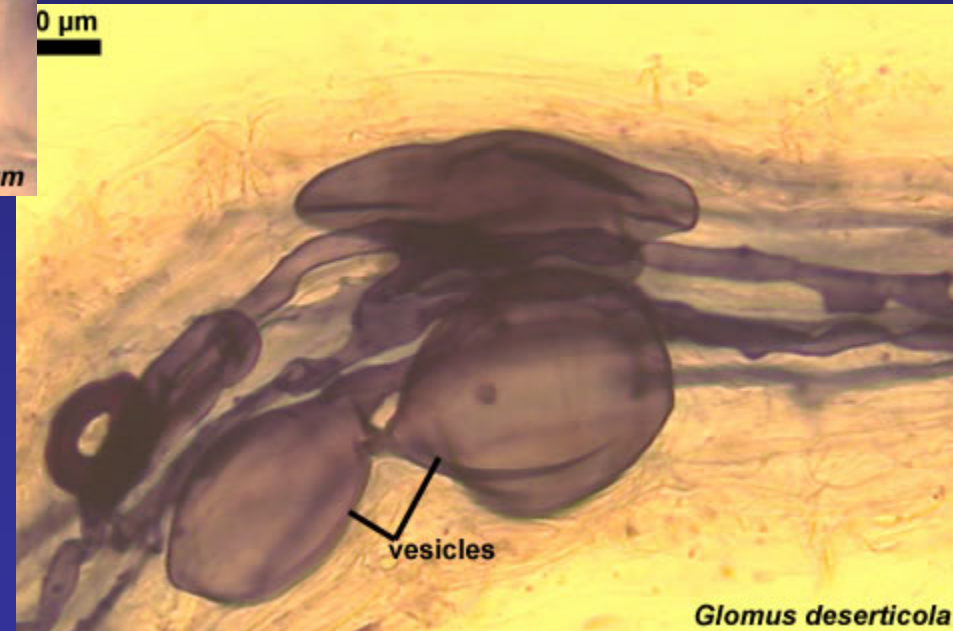
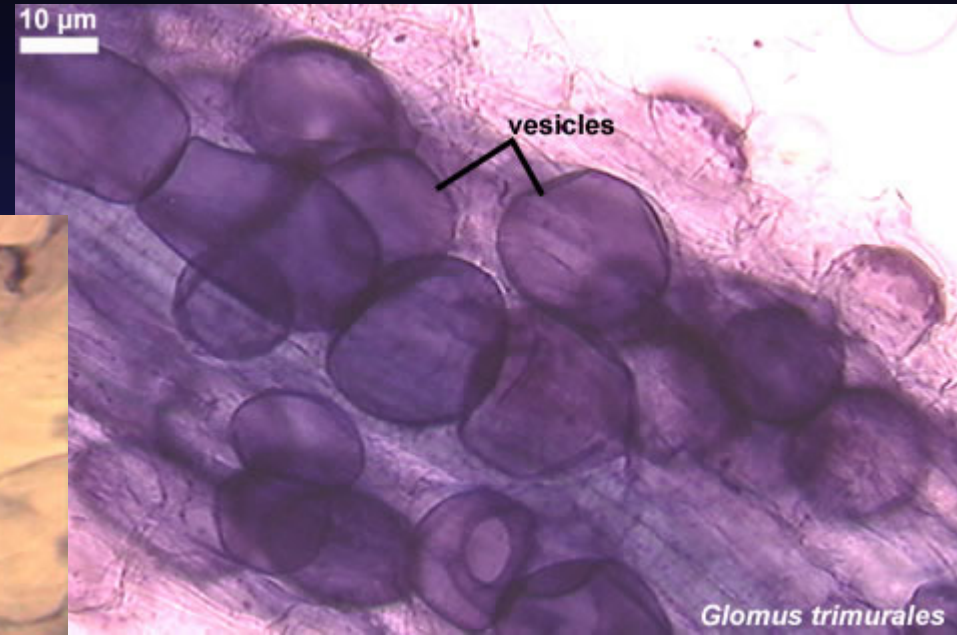
<http://www.nifg.org.uk/ecto.htm>

AM

- Arbuscular mycorrhizae are formed only by fungi in the division Glomeromycota
- Typically associated with the roots of herbaceous plants, but may also be associated with woody plants

New fossil evidence has pushed the date for the appearance of ARBUSCULAR MYCORRHIZAE back to 460 million years ago, predating vascular plants. Trends Ecol Evol. 2001 Feb 1;16(2):64-65.

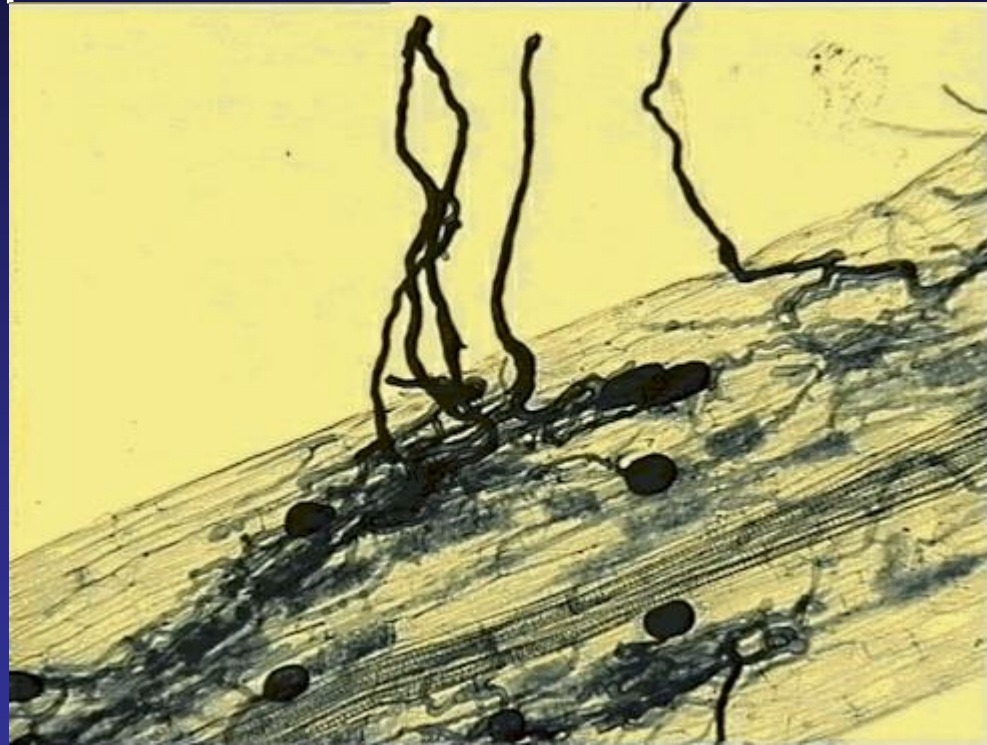
AM



Forms between the cell wall
and protoplasm

AM

- Hyphae originate from the colonized host plant root
 - Increase water and nutrient uptake
 - Small enough to invade smaller pores than roots
- Some hyphae invade neighboring plants



AM

- AM fungi help plants to capture nutrients such as phosphorus and micronutrients from the soil
- Found in 80% of vascular plant families of today

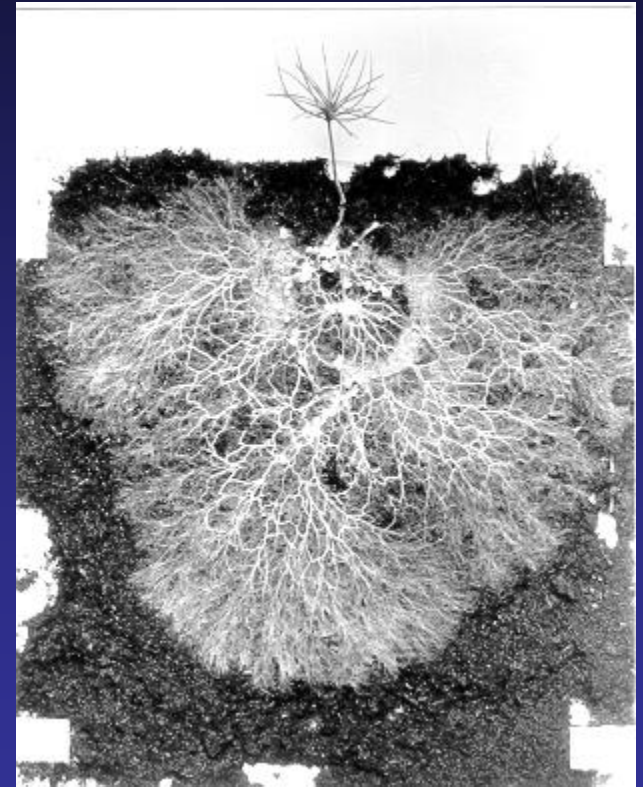
Endomycorrhizal Fungi (AM) are in Phylum Zygomycota

Mycorrhizal Fungi

79 % monocots

83% dicots

100% gymnosperms



Larch (*Larix*) seedling grown in peat

Root Hairs

Not all Plants have Root Hairs

Root hairs &
Mycorrhiza found
in the
upper 8 inches

Require
high levels
of
Oxygen

AM Fungi and Soil Depth

- The number of roots colonized decreased with soil depth.
 - Rillig, M.C. & Field, C.B. 2003. Arbuscular mycorrhizae respond to ... soil depth. *Plants and Soil* 254:383-391.
- with the number of infective propagules
 - An Z.Z., Grove, J.H., Hershman, D.E., Henson, G.T. 1990. Vertical distribution of ... *Soil Biology and Biochemistry* 22:715-719.

Mycorrhizal Fungi

Extends life of fine roots

Protects from pathogens



Marks & Kozłowski 1973

AM Fungi

- Can improve tolerance toward drought
 - Allen, M.F. and Boosalis, M.G. 1983. Effects of two species of vesicular-arbuscular ... *New Phytol* 93:67-76.
- AM plants fare better during droughts than non-AM plants
 - Augë and Moore. 2005. Arbuscular mycorrhizal symbiosis and plant drought resistance. In: Mehrota, editor. *Mycorrhiza: role and applications*. New Dehli: Allied Publishers Ltd. Pp. 136-162.

Mycorrhizal Fungi

- Produce
antibiotics
antifungal chemicals
- Physically protect root tip



Duehesne 94; Lindeman 94

Mycorrhizal fungi

enable plant to tolerate
toxic elements



Increase Nutrient
Uptake

Bradley, et. al., 1981
Jones & Hutchinson, 1986

Ectomychorrizal Fungi

- Alleviate growth depression of tree seedlings by excess:
 - Al
 - Schier and McQuattie. 1996. Response of ectomycorrhizal ... Can J. For Res. 26:2145-2152.
 - Ni
 - Jones and Hutchinson. 1988. Nickel toxicity in mycorrhizal birch seedlings... New Phytol 108:451-459.

Ectomychorrizal Fungi

- Alleviate growth depression of tree seedlings by excess:
 - Zn
 - Brown and Wilkins. 1985. Zinc tolerance of mycorrhizal *Betula*. *New Phytol* 99:101-106.
 - Cd
 - Jentschke, Winter & Godbold. 1999. Ectomycorrhizas and cadmium toxicity... *Tree Physiol* 19:23-30.

AM Fungi

- May have potential to reduce *Poa annua* in putting green turf while improving growth of *Agrostis* spp.

Gemma, J.N., Koske, R.E., Robert. E.M. & Jackson, N. 1997. Enhanced Establishment of bentgrasses by arbuscular mycorrhizal fungi. *Journal of Turfgrass Science*, 73: 9-14.

Root Age

- Only young roots can be infected by VAM fungi
 - Romer W., and Schilling, G. 1986. Phosphorus requirements of the wheat plant...Plant Soil 91:221-229.

AM

- Low incidence of mycorrhizal colonization in very arid or nutrient rich soils
 - Smith, S.E., Read D.J. Mycorrhizal Symbiosis. 2002. Academic Press: London.
- AM fungi are adapted to specific climatic and nutritional circumstances
 - Land, S. and Schöbeck, 1991. Influence of different soil types ... Mycorrhiza 1:39-44.

AM fungi are adapted to specific climatic and nutritional circumstances

- In arable soil investigated, only VAM fungi of the genus *Glomus* were recovered
- *Scutellospora*, *Acaulospora* and *Gigaspora* are more abundant in low-nutrient or nutrient-binding soils

Land, S. and Schöbeck, 1991. Influence of different soil types ... Mycorrhiza 1:39-44.

AM Fungi

- Are influenced by soil texture
 - Heavier soils inhibit germination or hyphal growth
- Tommerup, I.C. 1984. Effect of soil water potential on spore germination...*Trans.Br. Mycol. Soc.* 81:193-202.

Influence of Phosphorus

- Colonization by mycorrhizal fungi is significantly reduced at high soil phosphorus levels

Koide, R.T. & Li, M. 1990. On host regulation of the vesicular-arbuscular mycorrhizal symbiosis. *New Phytologist* 114:59-65

Amijee, F., Tinker, P.B. & Stribley, D.P. 1989. The development of endomycorrhizal root systems. VII. A detailed study of effects of soil phosphorus on colonization. *New Phytologist* 111: 435-446.

Influence of Phosphorus

- The development of mycorrhizal relationships were found to be the greatest when soil phosphorus levels were at 50 mg /kg (50 ppm)

Schubert, A.& Hayman, D.S. 1978. Plant growth responses to vesicular-arbuscular mycorrhizae. XVI. Effectiveness of different endophytes at different levels of soil phosphate. *New Phytologist* 103:79-80.

Influence of Phosphorus

- The mycorrhizae *Glomus fasciculatum* ceased to be effective when the soil level of phosphorus reached 133 parts per million (ppm)

Abbott, L.K. & Robson, A.D. 1977. Growth stimulation of subterranean clover with vesicular-arbuscular mycorrhizas. Australian Journal of Agricultural Research 28:639-649.

Abbott, L.K. & Robson, A.D. 1978. Growth of subterranean clover in relation to the formation of endomycorrhizas by introduced and indigenous fungi in a field soil. New Phytologist 81:575-585.

Influence of Phosphorus

- As the soil's phosphorus levels available to the plants increases, carbon drain on the plant by the AM fungi become parasitic
 - Grant, C. Bitman, S., Montreal, M., Plenchette, C., Morel, C.. "Soil and fertilizer phosphorus: effects on plant supply and mycorrhizal development". *Canadian Journal of Plant Science* **85**: 3-14.

Influence of Phosphorus

- A decrease in mycorrhizal colonization due to high soil phosphorus levels can lead to plant deficiencies in other micronutrients that have mycorrhizal mediated uptake such as copper
 - Timmer, L., Leyden, R. (1980). "The relationship of mycorrhizal infection to phosphorus-induced copper deficiency in sour orange seedlings". *New Phytologist* **85**: 15-23.

Soil Phosphorus Levels

- The benefits of mycorrhizae are greatest when at or below 50 ppm
- Mycorrhizal colonization of roots declines above 50 ppm
- Little if any infection occurs above 100 ppm P even when soil is inoculated with a mycorrhizae mix
 - Swift, C.E. Mycorrhiza and soil phosphorus levels.
<http://WesternSlopeGardening.org/mycorrhiza.html>

Snake Oil, Horticultural Myths, Horticultural Urban
Legends, and Persuaders in our Industry
Jim Downer

“The most creative and effectively marketed snake oil products often cite sound biological facts or knowledge and then attempt to link their product to this knowledge, but references to the published research about their product are always missing.”

A classical example is mycorrhizal inoculants for landscape trees

- Enhanced survival of newly planted landscape plants and accelerated growth **are claimed**
- However, increased vigor and growth have not been substantiated in replicated third party research trials.

Mycorrhizal fungal inoculation of street trees

- No effect on post-transplant stress, growth, or survival after 30 months for live oak (*Q. virginiana*) inoculated at transplant.

Gilman, E. 2001. Effect of nursery production method, irrigation, and inoculation with mycorrhizae-forming fungi on establishment of *Quercus virginiana*. Journal of Arboriculture 27:30-38.

Pin Oak

- Six months after treatments were applied:
 - no significant differences among the treatments in colonization or root dry weight
 - one year after inoculation, no significant increases among treatments in trunk diameter or leaf chlorophyll content.
- Mycorrhizal fungal inoculation of established street trees. 2003. Appleton, B., Koci, J., French S., Lestyan, M., and Harris, R. *Journal of Arboriculture* 29(2):107-110.

Willow Oaks

- Six months after treatments were applied, no significant differences in *Pisolithus tinctorius* (inoculated fungus) or other fungal colonization.
- Mycorrhizal fungal inoculation of established street trees. 2003. Appleton, B., Koci, J., French S., Lestyan, M., and Harris, R. *Journal of Arboriculture* 29(2):107-110.

Red Maple

- Six months after treatments applied, two mycorrhizal treatments significantly increased percentage of roots with VAM colonization
- Fertilizer plus mycorrhizal inoculant significantly increased root dry weight over the control and the mycorrhizal inoculant alone treatments
- Mycorrhizal fungal inoculation of established street trees. 2003. Appleton, B., Koci, J., French S., Lestyan, M., and Harris, R. *Journal of Arboriculture* 29(2):107-110.

Red Maples

- One year after inoculation
 - no significant increases in trunk diameter and no significant differences in leaf chlorophyll content.
 - the only significant root growth increase resulted from the two treatments containing fertilizer.
- Mycorrhizal fungal inoculation of established street trees. 2003. Appleton, B., Koci, J., French S., Lestyan, M., and Harris, R. *Journal of Arboriculture* 29(2):107-110.

Pine and Spruce

- Three year study
 - *Pinus sylvestris*, *Picea abies* seedlings
 - tested ECM fungi
- Results:
 - Limited ability to increase tree growth and survival
 - Formation in root systems is governed mainly by environmental factors.

Menkis, Vasiliauskas, Taylor, Stenlid and Finlay. 2007. Afforestation of abandoned farmland...Mycorrhiza 17:337-348.

Mycorrhizal inoculum potential: Turfgrass

- 5 of 8 commercial inocula failed to colonize roots when applied at the recommended rate - 0.4% to 8%
- 10X recommended rate – 8.6% to 72.5%

Tarbell & Koske. 2007. Evaluation of commercial arbuscular mycorrhizal inocula in a sand/peat medium. *Mycorrhiza*. 18(1):51-56.

Natural inoculation: Turfgrass

- Mycorrhizal fungi naturally colonize new greens turf without being added as inoculum.
- Inoculation of a new green at the time of seeding may not be necessary.
- AM fungi are ubiquitous in soils
 - Koske, Gemma and Jackson. 1995. USDA Green Section Record pp. 12-14.

Mycorrhiza and Strawberries

- Evaluated both commercially available strawberry cultivars and mycorrhizal inoculants for their influence on yield, and mycorrhizal colonization.
- None of the seven mycorrhizae products tested significantly influenced yield or colonization of the plants

Bull, C.T., Muramoto, J., Koike, S.T., Leap, J., Shennan, C., Goldman, P.H.
2005. EVALUATION OF STRAWBERRY CULTIVARS AND MYCORRHIZAL
INOCULANTS IN CALIFORNIA ORGANIC PRODUCTION FIELDS.

Mycorrhiza and Strawberries

- “Results suggest that indigenous inoculum from organic farms in this region is sufficient and the application of additional inoculum may not be of added benefit”

Bull, C.T., Muramoto, J., Koike, S.T., Leap, J., Shennan, C., Goldman, P.H. 2005. EVALUATION OF STRAWBERRY CULTIVARS AND MYCORRHIZAL INOCULANTS IN CALIFORNIA ORGANIC PRODUCTION FIELDS.

Agricultural Soils

- The ability to displace indigenous strains, even those less effective than the introduced, often prove to be difficult.
 - Abbot, Robson & Hall. 1983. Introduction of vesicular arbuscular mycorrhizal fungi into agricultural soils. Aust J. Agric. Res. 34:741-749.

Research Results

- What is “superior” for one crop may not be so for another crop
- What is superior under one set of environmental conditions may not be so under another
 - Menge. 1985. Developing widescale VA mycorrhizal inoculations: is it practical or necessary? In: Molina (ed). Proceedings of the 6th North American conference on Mycorrhizae. Forest Research Laboratory. Oregon State University, Corvallis, Ore., pp. 80-82.

Research Results

- Mycorrhizal colonization did not enhance plant growth.
- Only plants inoculated with the products that did not promote mycorrhizal colonization increased growth relative to the non-inoculated controls
 - suggesting the presence of other growth promoters in the inoculum products

Corkidi, Allen, Merhaut, Allen, Downer, Bohn, Evans. 2004. Assessing the infectivity of commercial mycorrhizal inoculants in plant nursery conditions. *of Environmental Horticulture*, 2004 (Vol. 22) (No. 3) 149-154

What should you know before committing to using these products?

- Are the recommendations anecdotal?
- Was this determined by research or a demonstration?
 - Peer reviewed journal or testimonial
- Who did the research?
- What was in the product in addition to mycorrhizal fungi?
 - Was nitrogen added or in the product?
 - Does the product contain a growth enhancing bacteria?
- What was the phosphorus level of the soil?

Thanks

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