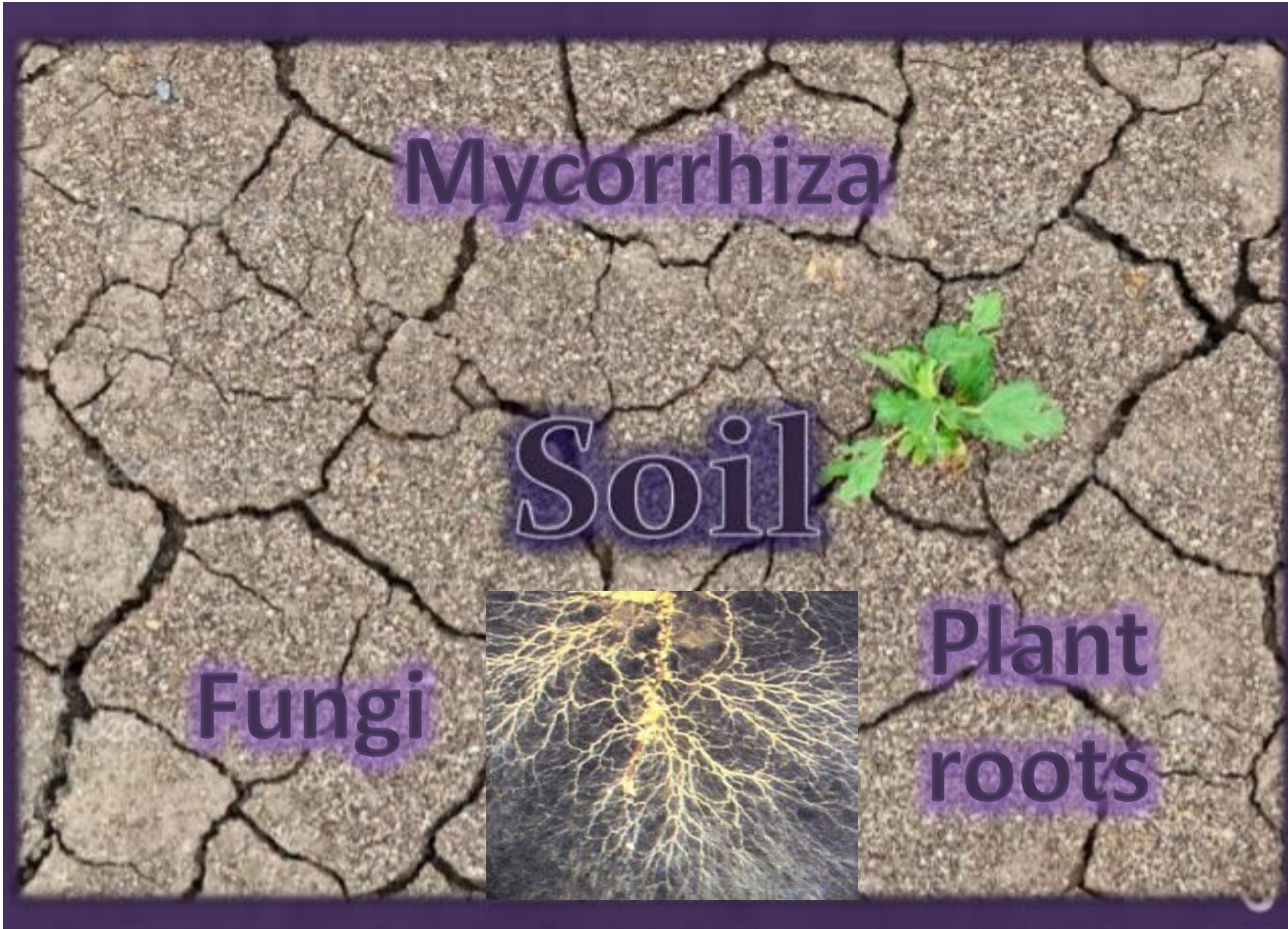
Prof. Dr. Ali Irfan ILBAS, Erciyes University



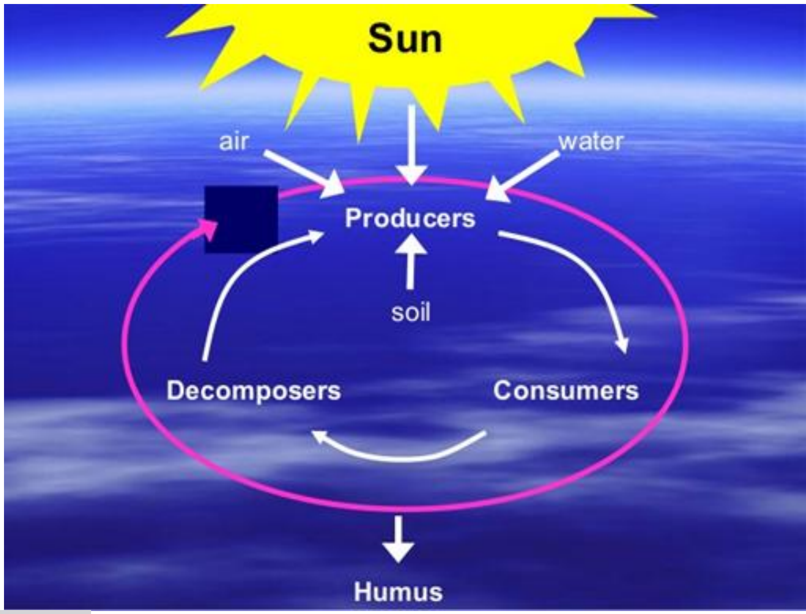
Abundance of soil organisms

Organism	Number per gram soil (~1 tsp)	Biomass[1] (lbs per acre 6”)
Earthworms	–	100 – 1,500
Mites	1-10	5 – 150
Nematodes	10 – 100	10 – 150
Protozoa	up to 100 thousand	20 – 200
Algae	up to 100 thousand	10 – 500
Fungi	up to 1 million	1,000 – 15,000
Actinomycetes	up to 100 million	400 – 5,000
Bacteria	up to 1 billion	400 – 5,000

[1] Biomass is the weight of living organisms

Types of Microbes in Soils

- ✓ Prokaryotic Bacteria, Actinomycetes
- ✓ Fungi
- ✓ Algae
- ✓ Protozoa
- ✓ Viruses



Microbial Number and Biomass in Cultivated Field Soil (15 cm)

Microbos	Number /g	Biomass(g/m^3)
Bacteria	10^8	160
Fungi	10^5	200
Actinomycets	10^5 - 10^6	160
Algae	10^4 - 10^5	32
Protozoa	10^4	38

A cup of soil contains...

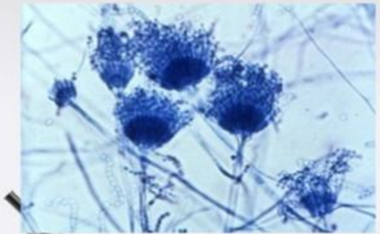
Microflora, or "microbes"
- Bacteria 200 billion
- Fungi** 100,000 meters

microfauna
- Protozoa 20 million
- Nematodes 100,000

macro- and mesofauna
- Arthropods 50,000
- Earthworms <1

** Fungi are actually their own separate kingdom

Fungi



Fungi

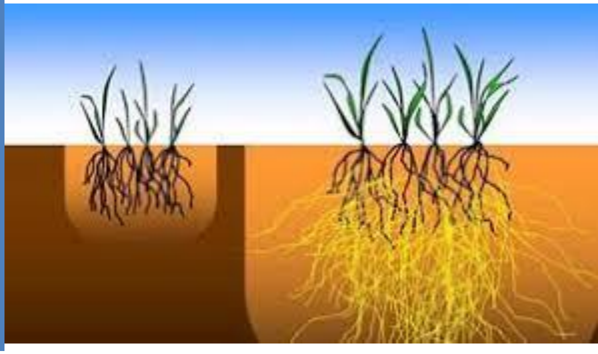
- ✓Grow as long threads (hyphae)
  - ✓Push through soil particles, roots, rocks
- ✓Often group into masses called myce
  (look like roots)
- ✓Higher fungi have *basidium* :
- ✓ club-shaped structure ,
- ✓bearing fruiting body

Role of Fungi in Soil

- Orgnic matter degradation: Degrade starch, hemicellulose, cellulose, lignin
- Ammonification; Degrade proteins, nucleic acids and release NH_3
- Control of other organisms; Some fungi kill nematodes
- Pathogenicity; Many fungi associated with plant disease- *ythium, Sclerotinia, Puccinia*
- Formation of mycorrhizae; symbiotic relationship-*Glomus*

What is Mycorrhiza?

- The word Mycorrhizae was first used by german researcher A.B Frank in 1885 and originates from the Greek mycos, meaning “fungus” and “rhiza” meaning “root”.
- Mycorrhiza is a symbiotic mutualistic associations between soil fungi and plant roots.
- it is neither the fungus nor the root but rather the structures from these two partners.
- Both sides get benefits from this association.



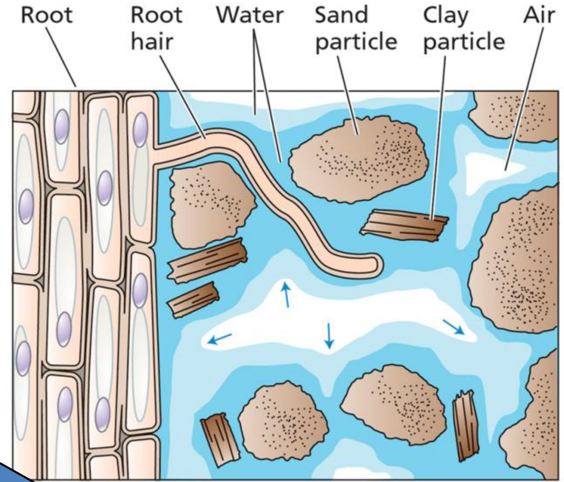
Basic Interactions between Fungi and Plant Roots

- Mycorrhizae are highly evolved, mutualistic associations between soil fungi and plant roots. Since the association is mutualistic, both organisms benefit from the associations.

- The fungus receives carbohydrates (sugars) and growth factors from the plant.
- Benefits to fungus provided with source of C and energy. Plants provided C appears in fungus. Sucrose from plant converted into trehalose, mannitol by fungus. Estimates that up to 10% (or more) of photosynthate produced by trees is passed to mycorrhizae and other rhizosphere organisms

- Host plant receives mineral nutrients and water and other many benefits directly or indirectly.
-
- In this association, the fungus takes over the role of the plant's root hairs and Acts as an extension of the root systems.
- This asoociation are members of the fungus kingdom (Basidomycetes, Ascomycetes and Zygomycetes) and most vascular plants, more than 95% terrestial plants.

Why mycorrhiza?



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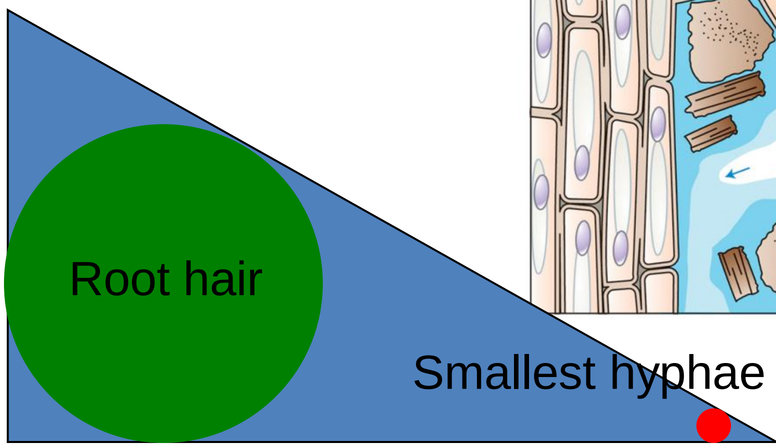


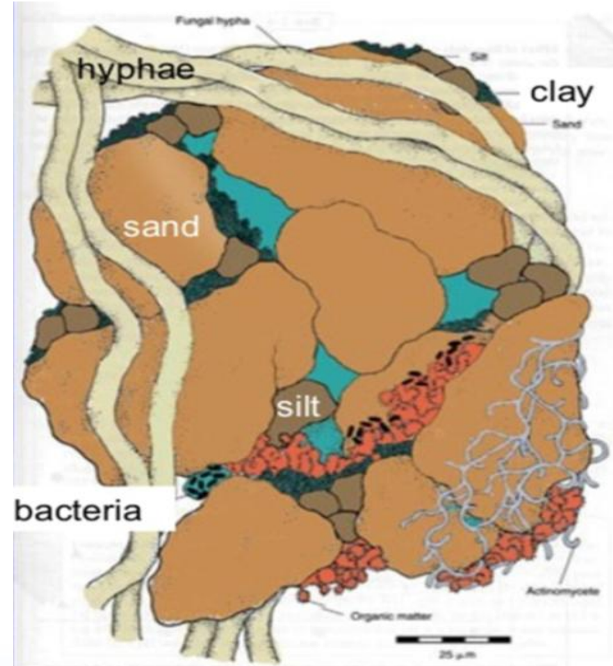
- Roots and root hairs cannot enter the smallest pores
- Hyphae is 1/10th of root hair
- Increased surface area
- Extension beyond depletion zone
- Breakdown of organic matter

How do Mycorrhizae Help the Plants?

- Mycorrhizal fungi increase the surface absorbing area of roots by as much as 50 times, thereby greatly improving the ability of plants to utilize soil resources such as nutrients and water.
- Mycorrhizal fungi also release powerful enzymes into the soil that solublize hard to capture nutrients such as phosphorous, nitrogen, iron and other "tightly bound" soil nutrients.
- Because of increasing access to nutrients, water and oxygen for the plant, plant vigor, drought resistance and fruiting/flowering also increase.

Cont’d

- Mycorrhizal plants are far less susceptible to drought stress when compared to non-mycorrhizal plants.
- Mycorrhizal fungi also improve soil structure. Mycorrhizal filaments (hyphae) produce organic “glues” (extracellular polysaccharides and glycoprotiens, such as Glomalin) that bind soils into aggregates and overall improve soil structure and porosity. Soil porosity and soil structure positively influence the growth of plants by promoting aeration, water movement into soil, root growth, and distribution.
- Increases tolerance of plant to drought, high temperatures, pH extremes, heavy metals. Many common desert plants are heavily mycorrhizal.
- Increases resistance to infection by root pathogens – provides a physical barrier

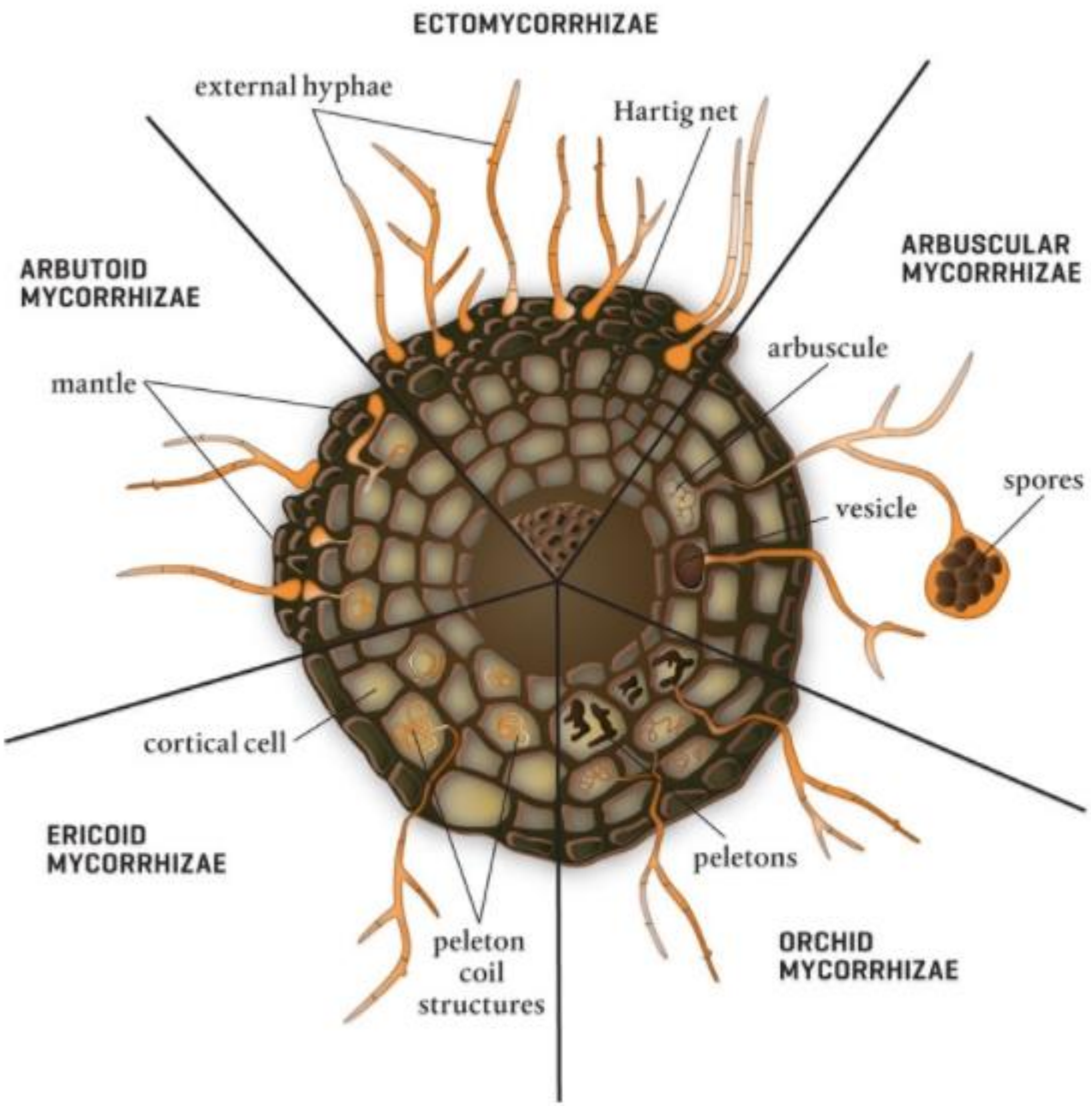


Mycorrhizal fungi
Soil structure benefit

Mycorrhizal fungi present
- Soil structure stabilized and strengthened
- Structure is maintained when immersed in water

Mycorrhizal fungi absent
- Soil structure is weak
- Structure is not maintained when immersed in water

Types of Mycorrhizal Associations



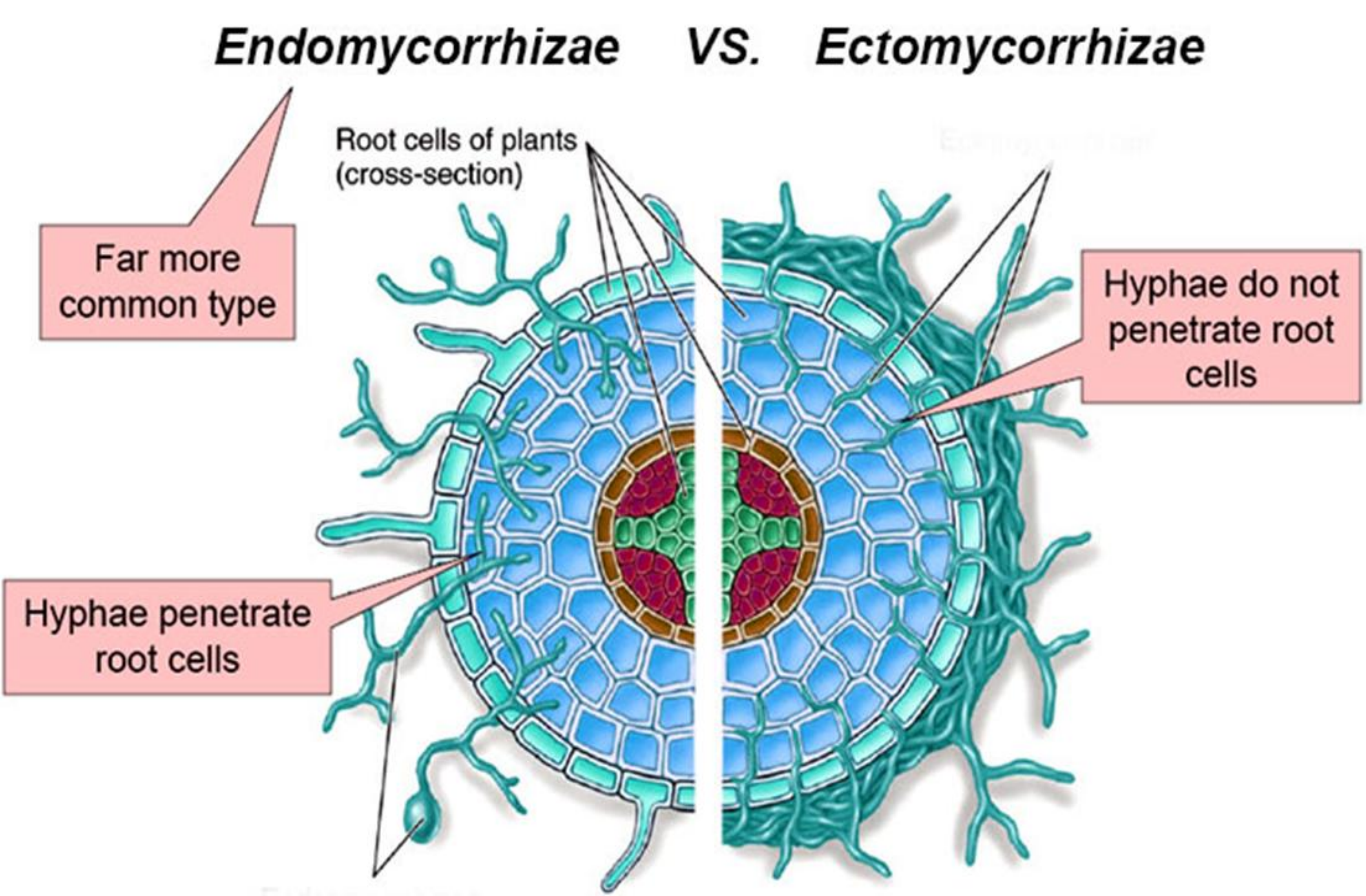
- Ectomycorrhiza (extracellular)
- Endomycorrhizas (Intracellular)
  - Arbutroid
  - Ericoid
  - Orchid
  - Monotropoid

The two types are differentiated by the fact that the hyphae of ectomycorrhizal fungi do not penetrate individual cells within the root, endomycorrhizal fungi penetrate the cell wall and invaginate the cell membrane.

Differences Between Endomycorrhiza and Ectomycorrhiza

Endomycorrhizal fungi form the inside of the root cells, and the hyphae extend outside the root.

Endomycorrhizal fungi form association mostly with green leafy plants and most commercially produced plants. Examples: Most Vegetables, Grasses, Flowers, Shrubs, Fruit Trees, and Ornamentals. Approximately 85% of terrestrial plant species on Earth are endomycorrhizal.



Ectomycorrhizal Fungi form their structure out of the root cells, extracellularly.

Ectomycorrhizal fungi form association mainly with Conifers and Hardwoods, and are required mostly for woody plants/trees and forest trees. Approximately 10% of terrestrial plant species on Earth are ectomycorrhizal.

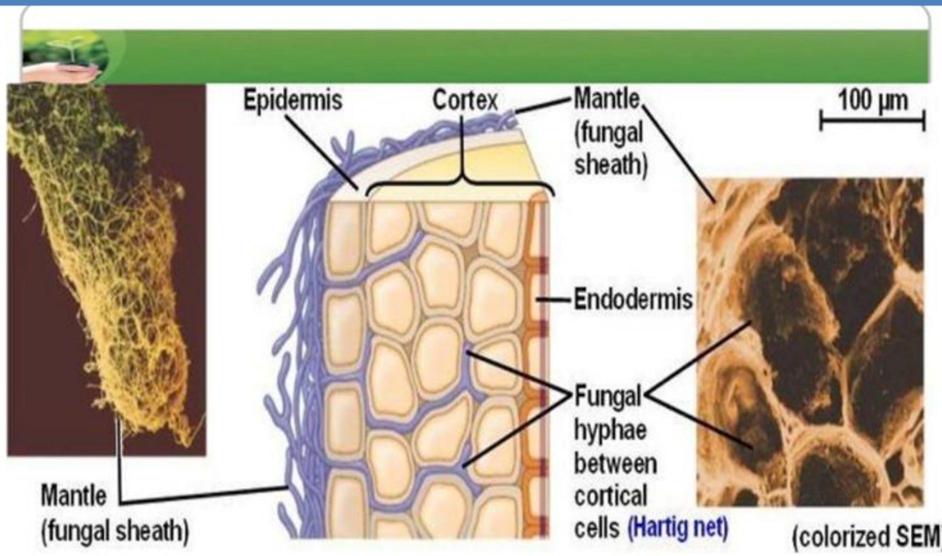
Ectomycorrhiza

- Ectomycorrhiza, or EcM, are typically formed between the roots of around 10% of plant families, mostly woody plants including the birch, dipterocarp, eucalyptus, oak, pine, and rose families, orchids, and fungi belonging to the Basidiomycota, Ascomycota, and Zygomycota.
- Some EcM fungi, such as many Leccinum and Suillus, are symbiotic with only one particular genus of plant, while other fungi, such as the Amanita, are generalists that form mycorrhiza with many different plants.
- Trees with EcM are dominant in coniferous forests, especially in cold boreal or alpine regions
- EcM trees and shrubs common in many broad-leaved forests in temperate or Mediterranean regions
- Also occur in some tropical or subtropical savanna or rain forests habitats

Ectomycorrhiza

- Most noticeable and easily recognized.
- Plant roots are enclosed by a sheath of fungal hyphae – fungal mycelium penetrates between cells in cortex of the root.
- Fungal tissue may account for up to 40% mass of root. Hyphae also extend out into the soil – extramatrical hyphae
- Ectomycorrhizae contains a fungal sheath Parenchyma of root cortex is surrounded by hyphae – Hartig net

Ectomycorrhiza



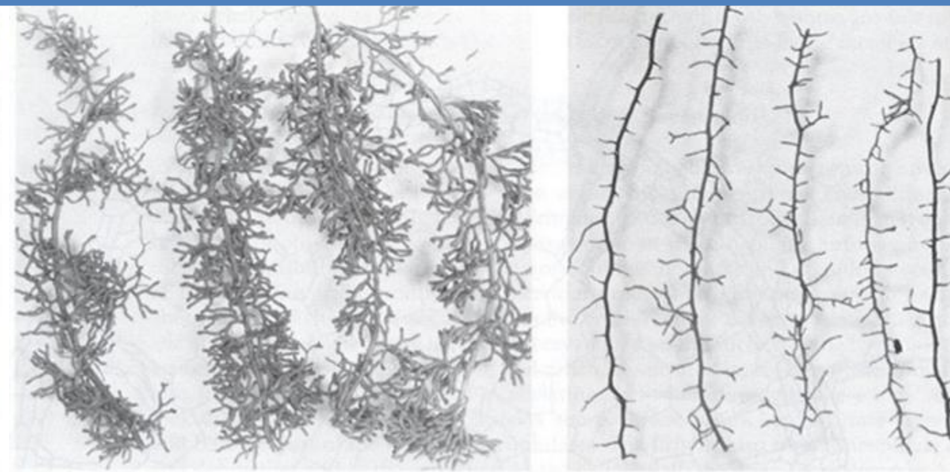
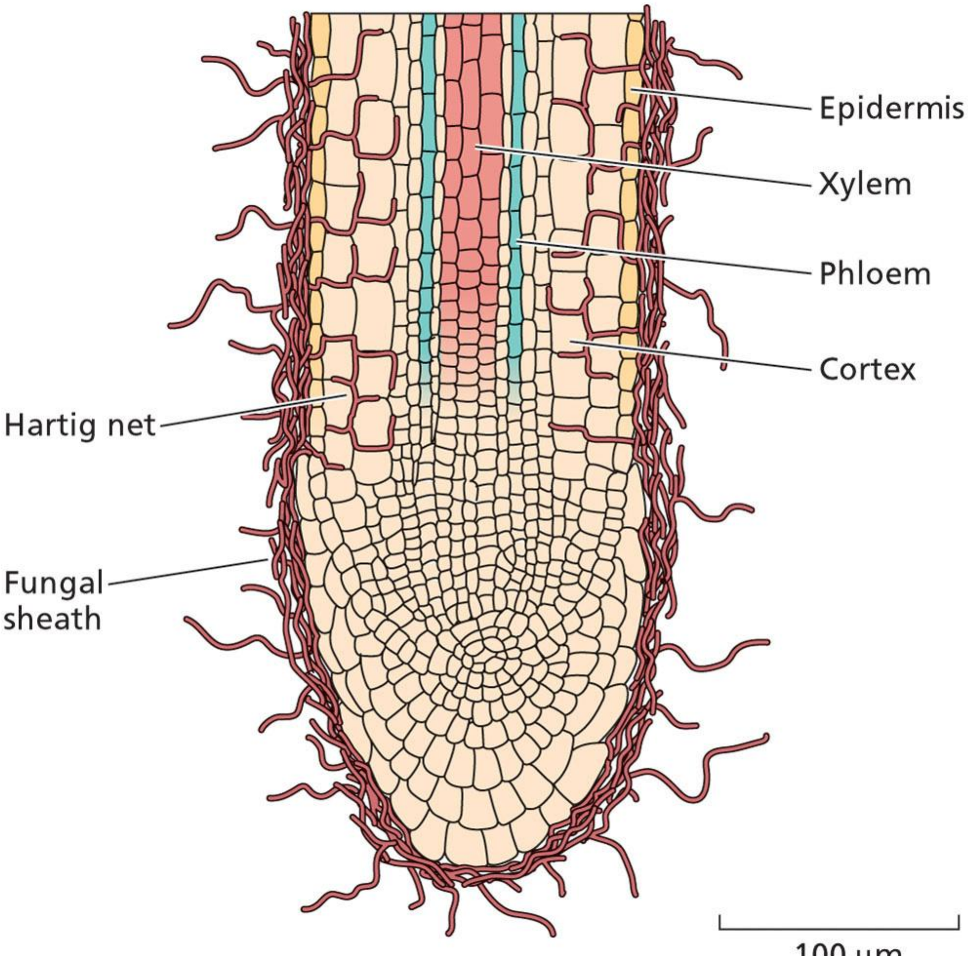


Figure 16-7 Roots of pine seedlings with (left) and without (right) the ectomycorrhizal fungus *Pisolithus tinctorius*. These are roots from the seedlings shown in Fig. 16-8. [Courtesy D. H. Marx, U.S. Department of Agriculture, Forest Service.]

- ***Eucalyptus maculata*** **and** ***Astraeus pteridis*** **association synthesised under sterile conditions with relatively unbranched ECM and attached mycelial strands (star).**



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Ectomycorrhiza

Inside root

• Intercellular hyphae

• Does not enter cells

Outside root

• Thick layer of hyphae around root
    • Fungal sheath
• Lateral roots become stunted

• Hyphae
    • Mass about equal to root mass

Forms extensive network of hyphae even connecting different plants

2. Ectomycorrhiza (EM)

• Ascomycetes and Basiodiomycetes – form large fruiting bodies

• 5000 species interact with 2000 plant species

• Interaction with trees: angiosperms and all Pinaceae

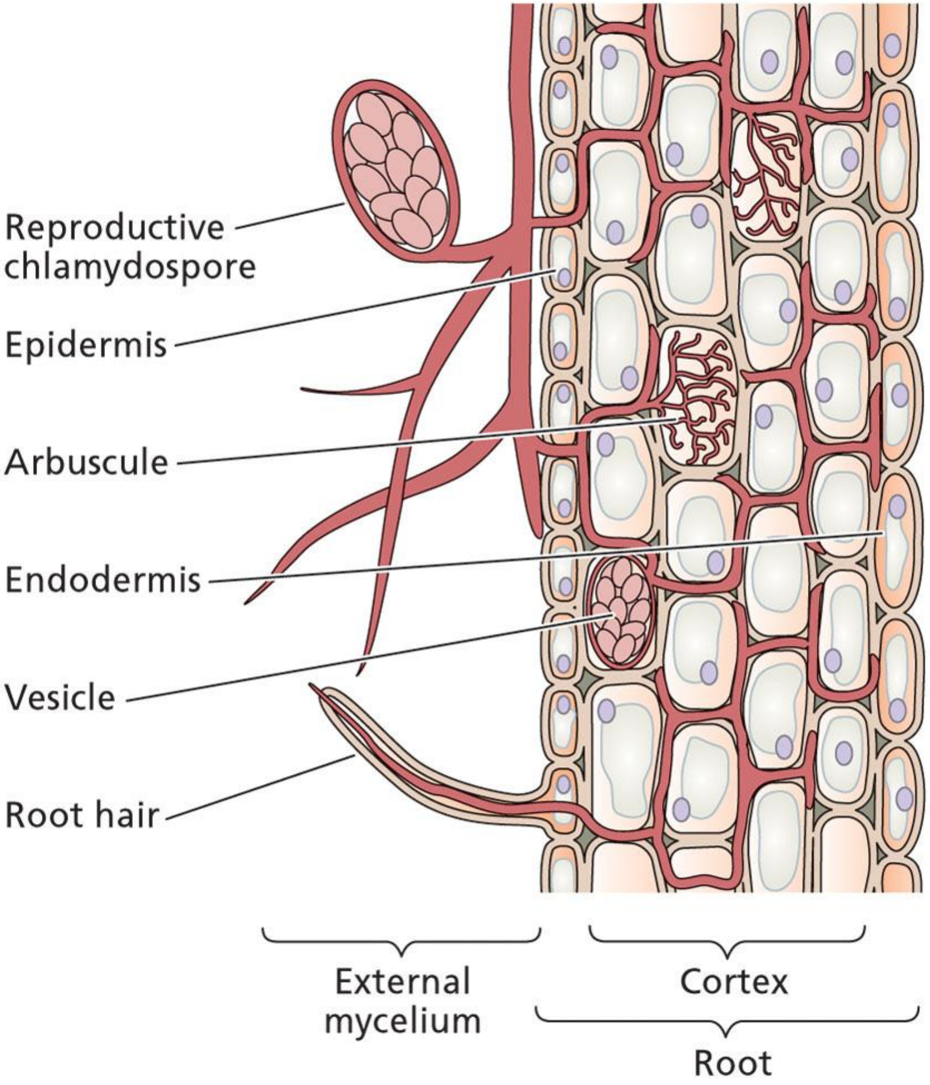
Endomycorrhiza

Vesicular Arbuscular Mycorrhiza

Inside root
- Intercellular mycelium
- Intracellular arbuscule
    - tree-like haustorium
- Vesicle with reserves

Outside root
- Spores (multinucleate)
- Hyphae
    - •thick runners
    - •filamentous hyphae

Form extensive network of hyphae even connecting different plants



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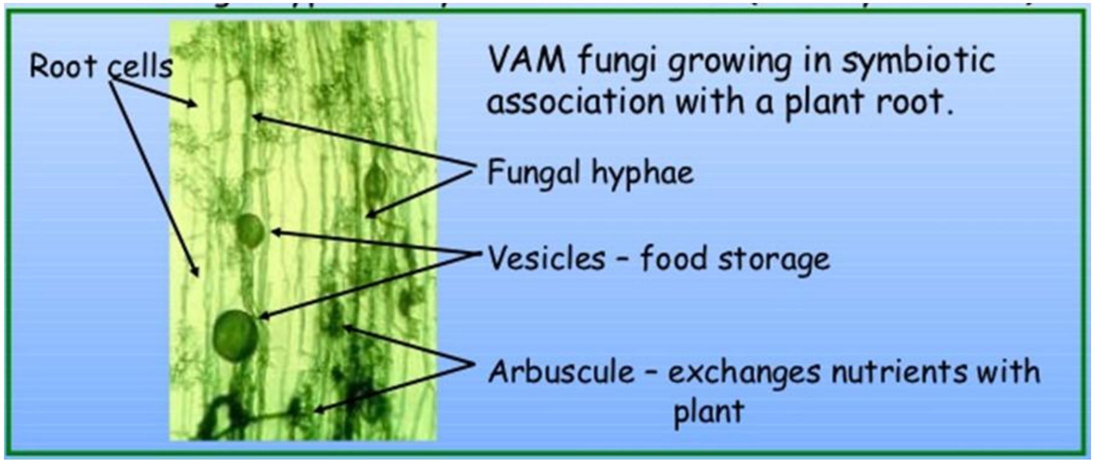
Endomycorrhiza

Endomycorrhizas are variable and have been further classified as

- Arbuscular mycorrhiza
- Ericoid mycorrhiza
- Arbutoid mycorrhiza
- Monotropoid mycorrhiza
- Orchid mycorrhiza

- Arbuscular mycorrhizas, or AM (formerly known as vesicular-arbuscular mycorrhizas, or VAM), are mycorrhizas whose hyphae enter into the plant cells, producing structures that are either balloon-like (vesicles) or dichotomously branching invaginations (arbuscules).

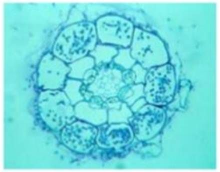


Arbutoid mycorrhizae

- Plant are also Ericaceae – *Arbutus*, *Arctostaphylose*, *Pyrola*
- Fungi are basidiomycetes that also fo ectomycorrhizae
- Fungi form sheath and Hartig net, hy also penetrate outer coritcal cells

Ericoid mycorrhizae

- Plants are Ericaceae – *Erica*, *Vaccinium* - heathland plants
- Fungi are Ascomycota and Deuteromycota
- Form loose network on surface & hyphal coils inside epidermal cells of hair roots where nutrient exchange is thought to take place
- Shown to supply N to plant – fungi secrete proteinases

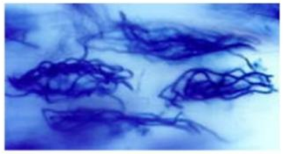


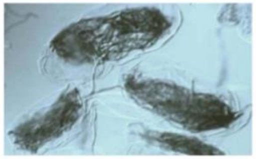
Monotropoid mycorrhizae

- Plants are nonchlorophyllous – *Monotropa*
- Fungi are basidiomycetes – boletes that form ectomycorrhizae with other plants (conifers)
- Plant depends on its mycorrhizal fungus - for its organic nutrients as well as inorganic nutrients

Orchid mycorrhizae

- Not clear about benefits to fungus – may obtain amino acids and vitamins from orchid





Endomycorrhiza VAM-AM

- Vesicular Arbuscular mycorrhizae VAM is a type of mycorrhiza in which the fungus penetrates the cortical cells of the roots of a vascular plant. characterized by the formation of unique structures, arbuscules and vesicles by fungi of the phylum Glomeromycota (VAM fungi). VAM fungi help plants to capture nutrients such as phosphorus, sulfur, nitrogen and micronutrients from the soil. It is believed that the development of the arbuscular mycorrhizal symbiosis played a crucial role in the initial colonisation of land by plants and in the evolution of the vascular plants.
- VAM fungi help plants to capture nutrients such as phosphorus, sulfur, nitrogen and micronutrients from the soil. It is believed that the development of the arbuscular mycorrhizal symbiosis played a crucial role in the initial colonisation of land by plants and in the evolution of the vascular plants.

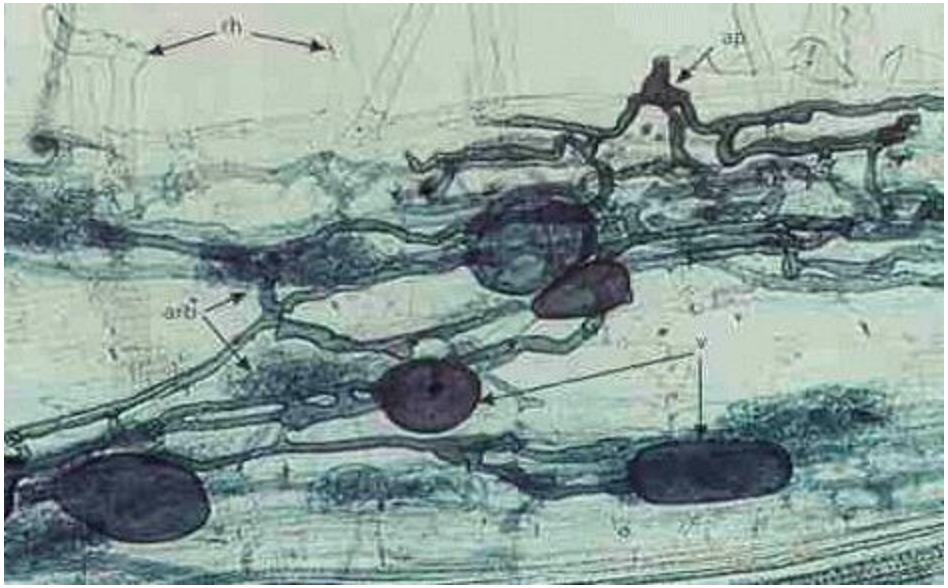
Endomycorrhiza VAM-AM

- Vesicular Arbuscular mycorrhizae-VAM appear to be the most common type of mycorrhizal association with respect to the number of plant species.
- Found in species in all divisions of terrestrial plants – widely distributed in annuals, perennials, temperate and tropical trees, crop and wild plants. Estimated to occur on 300,000 plant species.

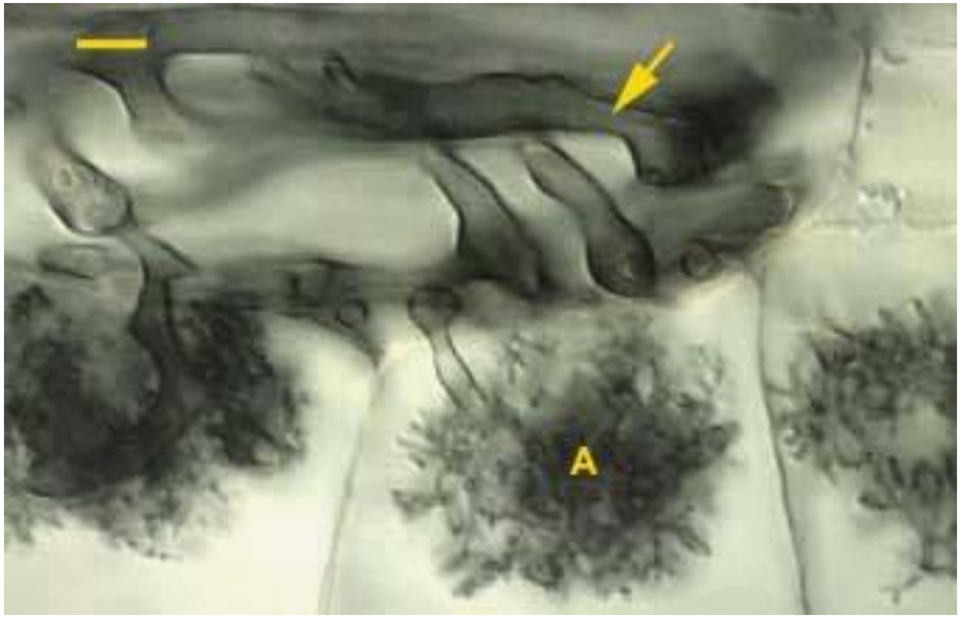
Endomycorrhiza VAM-AM

- To detect, must clear and stain root to observe fungal structures.
- Fungi form both extracellular and intracellular hyphae.
- Intracellular hyphae analogous to haustoria – called arbuscules – tree like branching pattern. Thought to be site of nutrient exchange between fungus and plant
- Arbuscules develops internal side of cell.
- Vesicles is mean that intercellular hyphae may also form large swellings – vesicles – at ends of hyphae or intercalary
- Vesicles rich in lipids and thought to be involved in storage

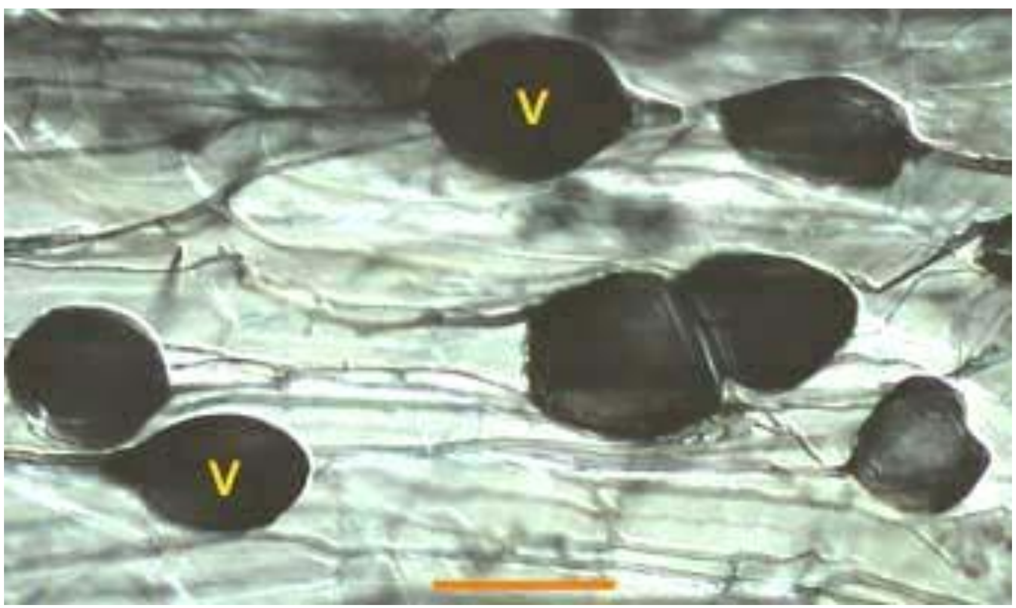
Arbuscule of Glomus mosseae



What are AM Fungi, formerly called VAM?



Arbuscules (A) and convoluted hyphae (arrow) in the inner cortex of an *Asarum canadense* root. Arbuscules only form in the innermost cortex cell layer next to the endodermis in this species.



Vesicles (V) produced by a *Glomus* species in a leek root. This root also contains many intercellular hyphae. (Bar = 100 um)

http://www.ffp.csiro.au/research/mycorrhiza/ecm.html

Arbuscular mycorrhizal fungi

- Arbuscular mycorrhizal fungi are in the Zygomycota in the Glomales – or newly proposed phylum Glomeromycota. Include 130 species in 6 genera.
- All are obligate biotrophs.
- Form large spores that superficially resemble zygospores, but not formed from fusion of gametangia.
- Well known genus is *Glomus*
- Spore diameters range from 50 to 400 µm

- Specificity: Few species of fungi and many species of plants – very low specificity.
- One fungal species may form association with many different plant species.
- It is much different than biotrophic parasites that have a limited host range.

Arbuscular mycorrhizae

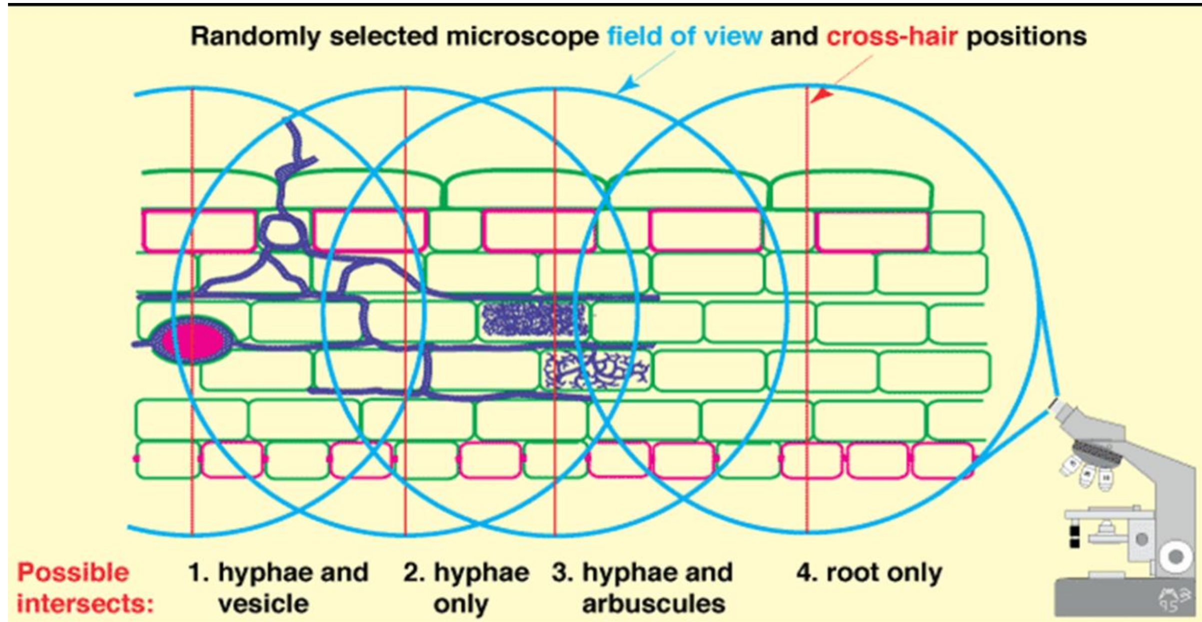
Fossils of spores found that are as old as first land plants – 460 mya

Determination of AM Fungus Infection

Fungi are obligate biotrophs – cannot be grown in axenic culture – so difficult to conduct experiments. Arbuscular mycorrhiza is not as well characterized as ectomycorrhiza.

Root is not altered in morphology – difficult to determine when roots are infected.

To determine mycorrihizal root colonization, root tissues were cleared with strong alkali and then stained with trypan blue to reveal the fungus and followed by microscopic examination.



http://mycorrhizas.info/method.html

Root length is estimated using grid intersection

Ectomycorrhizal colonization is estimated by using the proportion of those intersections which crossed ectomycorrhizal root tips compared to colonized root

To estimate Arbuscular mycorrhizal percentage <1mm diameter roots are cut into 2mm section and stained, slides are prepared and examined at 400x magnification and the presence or absence of arbuscular mycorrhizal features is noted

What Plants Form Mycorrhiza with AM Fungi?

- Approximately 95% of the world's plant species form mycorrhiza. Endomycorrhiz share is 10%, Endomycorrhiza share 85%.
- Endomycorrhizal Plants: About 85% of Plants—Mostly Green, Leafy Plants and most Commercially Produced Plants.
- A list of the types of mycorrhizal plants was given as following.

Endomycorrhizal Type Field Crops Family, Genus and Common Name (s)

Poaceae
- Avena, Oat
- Hordeum, Barley
- Miscanthus, Miscanthus
- Oryza, Rice
- Panicum, Panicum
- Poa, Meadow grass
- Triticum, Wheat
- Zea Maize, Corn

Astereaceae
- Helianthus, Sunflower

Linaceae
- Linum, Flax

Malvaceae
- Gossypium Cotton

Fabaceae
- Arachis, Peanut
- Cicer, Chickpea
- Glycine, Soybean
- Glycyrrhiza, Liquorice
- Lens, Lentil plant
- Medicago, Alfalfa
- Phaseolus, Bean
- Pisum, Peas
- Trifolium, Clover

Solanaceae
- Nicotiana Tobacco
- Solanum, Potato

Lamiaceae
- Melissa, Balm
- Mentha, Mint
- Lavandula, Lavender
- Ocimum, Basil
- Origanum, Oregano
- Salvia, Sage
- Thymus, Thyme

Lauraceae
- Cinnamomum, Cinnamon
- Laurus, Laurus

NON-Micorrhizal

Amaranthaceae
- Beta, Sugar beet

Brassicaceae
- Brassica, Rapeseed

Non-mycorrhizal Plants

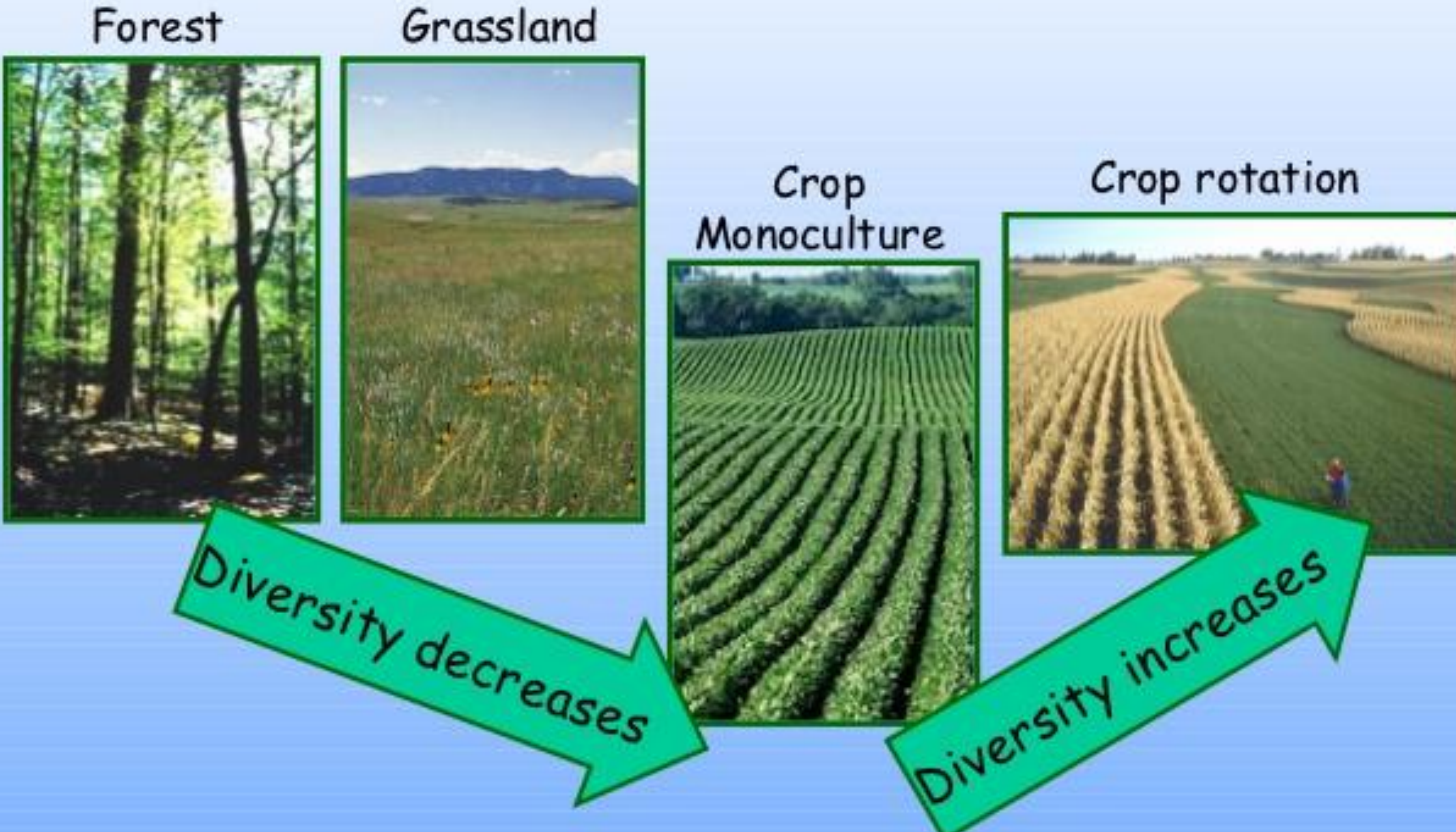
5% of plants are "Non-mycorrhizal". Some of them were given as fallowing.

- Brassica Family: Broccoli, Brussels, Cabbage Cauliflower, Collards, Kale, Rutabaga
- Ericaceae Family: Azalea, Blueberry, Cranberry, Heath Huckleberry, Lingonberries Rhododendron
- Others: Beet, Carnation, Mustard, Orchids, Protea, Rush, Sedge, Spinach

Effective Factors on Mycorrhiza

- Physical
  - Temperature
  - Radiation
  - Moisture
- Chemical
  - pH
  - Salinity
  - N
  - P
  - Organic matter
  - Micro nutrients
  - Soil fertility
  - Pesticide
- Biotic
- Agricultural practices

Effects of soil management practices on soil organisms



Effects of soil management practices on soil organisms

Increased intensity of tillage tends to decrease microbial diversity and microbial biomass

Effects of soil management practices on soil organisms

Application of lime or fertilizer to infertile soils tends to increase microbial activity and biomass

Addition of organic materials such as manure tends to increase microbial biomass and activity

Effects of soil management practices on soil organisms

Maintaining high soil organic matter levels and residue cover on the soil surface (no till systems) tends to increase microbial diversity and activity

Pesticide applications have variable effects on microbial populations

Pesticide effects on non-target soil organisms

- Herbicides
  - Minimal known effects soil microbes or soil animals
  - Some may harm certain algae
- Insecticides
  - Some effects on non-target soil insects
  - Some effects on earthworms
- Fungicides and soil fumigants
  - Significant effects on a wide array of fungi and soil animals.

Exp. Mycorrhizal Inoculants are Commercialized in Abroad

MycoApply® agricultural soil health products contain a diverse combination of beneficial mycorrhizal fungi species.

It help improve nutrient efficiency, drought tolerance, and maximize yield potential. These beneficial fungi rapidly establish a symbiotic relationship with the plant, producing hyphae that can access small soil spaces that root hairs can't. These hyphae expand beyond the root zone, increasing the root surface area by as much as 50 times and produce enzymes which release tightly bound nutrients in the soil to make these insoluble nutrients available to your crops. Keep your advantage – nurture your soil today to ensure that future harvests are just as bountiful. https://mycorrhizae.com

Exp. Mycorrhizal Inoculants are Commercialized in Turkey

- Ürün ile ilgili detaylı bilgi
- MİKORİZA MANTARLARI Bitki kökleri ile simbiyotik yaşam şekli gösteren mikroiza mantarları bitkinin su ve besin alım kapasitesini arttırır.Bitkinin tüm yaşamı boyunca bitki kökleri ile sürdürdüğü ortak yaşam devam eder.
- Garanti edilen İçerik: % 23,5 toplam canlı organizma
- Glomus intraradices……………………………21
  Glomus aggregatum……………………………20
  Glomus mosseage………………………………20
  Glomus clarum……………………………………1
  Glomus monosporus……………………………1
  Glomus deserticola………………………………1
  Glomus brasilianum………………………………1
  Glomus etunicatum………………………………1
  Gigaspora margarita……………………………1
- Suda çözünür toz formülasyona sahiptir.
- Örtüaltı ve açıkalan sebze, süs bitkileri, meyve vb. tüm bitkisel üretimde kullanılabilir. Tek yıllık bitkilerde erken gelişim dönemlerinde, çok yıllık bitkilerde ise 4 yaşına kadar önerilir. Tüm bitkilerde sadece bir kez uygulanır.
- Sipariş bilgileri
- **Fiyat:** 250 TL/paket
- **Minimum Sipariş:** 1 paket
- 2-2.5 gr per 1 kg seed

Application Timing and Effectiveness

- **While plants can be treated at any time during their life cycle, It is recommend that mycorrhizae are applied as early as possible in the plant's life cycle.**
- **It may be applied at seeding, propagation, or transplanting times**
- **This timing is also decrease cost and treated soil volume and amount of requiring product per plant than application in later stages would require.**
- **The mycorrhizal fungi will remain in a symbiotic relationship with the plant for the entire life of the plant.**
- **The mycorrhizae go to work immediately after application to a growing plant root, but it can take 8-12 weeks for benefits to be visible.**

Application Methoda of Mycorrhizal Fungi Inoculant?

Application is easy and requires no special equipment.

The goal is to create physical contact between the mycorrhizal inoculant and the plant root.

Application ways:

- **Sprinkling onto roots during transplanting**
- **Applying into seed beds**
- **Blending into potting soil**
- **Watering in via existing irrigation systems**
- **Drenching into porous media**
- **Appling as a root dip or plug dip**
- **Injecting into the root zone of existing plants**

Pay Attention When Applying Mycorrhiza

- **Don't keep inoculant uper than 40-60 C, higher temperature can kill the mycorrhizal fungi.**
- **Mycorrhizal inoculants have to store the bag product in a cool and dry location and keep the bag closed to keep the moisture out.**
- **Some fungicides can also damage mycorrhizal fungi. Maybe, a mycorrhiza friendly fungicide can be selected.**
- **Mycorrhizal fungi actually attach and become part of the plant, they are not free living soil organisms, they require that symbiotic relationship. When plants die, or a field is tilled and resowing seeds and seedlings, It is is needed to a renewe application.**

Cont’d

- **High levels of available Phosphorous can slow there progress.**
- **if there is already an over abundance of phosphorous available to the plant, the mycorrhiza won’t be performing some of their other important tasks like water uptake, P and other nutrient extraction as well.**
- **Available phosphorous level should be kept at a low to moderate level.**
- **The result of our study shows that effects of mycorrhizal inoculation (*Glomus fasciculatum*) on soybean growth and yield increased in poor P conditions.**
- **Positive effects of mycorrhiza will be visible sooner in more stressful growing conditions, as this is when the mycorrhiza can bring the most benefits to the plants.**
- **Since initial stress conditions will restrict plant growth, farmers do not want exposure their crops under stress in early stage.**

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ORIGINAL PAPER

Melanie Landwehr · Ulrich Hildebrandt
Petra Wilde · Kerstin Nawrath · Tibor Tóth
Borbála Biró · Hermann Bothe

The arbuscular mycorrhizal fungus *Glomus geosporum* in European saline, sodic and gypsum soils

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Abstract Plants of saline and sodic soils of the Hungarian steppe and of gypsum rock in the German Harz mountains, thus soils of high ionic strength and electric conductivity, were examined for their colonization by arbuscular mycorrhizal fungi (AMF). Roots of several plants of the saline and sodic soils such as *Artemisia maritima*, *Aster tripolium* or *Plantago maritima* are strongly colonized and show typical AMF structures (arbuscules, vesicles) whereas others like the members of the Chenopodiaceae, *Salicornia europaea*, *Suaeda maritima* or *Camphorosma annua*, are not. The vegetation of the gypsum rock is totally different, but several plants are also strongly colonized there. The number of spores in samples from the saline and sodic soils examined is rather variable, but high on average, although with an apparent low species diversity. Spore numbers in the soil adjacent to the roots of plants often, but not always, correlate with the degree of AMF colonization of the plants. As in German salt marshes [Hildebrandt et al. (2001)], the dominant AMF in the Hungarian saline and sodic soils is *Glomus geosporum*. All these isolates provided nearly identical restriction fragment length polymorphism (RFLP) patterns of the internal transcribed spacer (ITS) region of spore DNA amplified by polymerase chain reaction (PCR). Cloning and sequencing of several PCR products of the ITS regions indicated that ecotypes of the *G. geosporum*/*Glomus caledonium* clade might exist at the different habitats. A phylogenetic dendrogram constructed from the ITS or 5.8S rDNA sequences was nearly identical to the one published for 18S rDNA data (Schwarzott et al. 2001). It is tempting to speculate that specific ecotypes may be particularly adapted to the peculiar saline or sodic conditions in such soils. They could have an enormous potential in conferring salt resistance to plants.

Keywords Arbuscular mycorrhizal fungi · Halophytes · Restriction fragment length polymorphism analysis · Salt resistance · *Glomus geosporum*

M. Landwehr · U. Hildebrandt · P. Wilde · K. Nawrath · T. Tóth
B. Biró · H. Bothe (✉)
Botanisches Institut der Universität zu Köln, Gyrhofstrasse 15, 50923 Cologne, Germany
e-mail: Hermann.Bothe@uni-koeln.de
Tel.: +49-221-4702760, Fax: +49-221-4705181

T. Tóth · B. Biró
Research Institute for Soil Science and Agricultural Chemistry (RISSAC), Hungarian Academy of Sciences, Herman O. ut. 15, 1525 Budapest, P.O. Box 35, Hungary

Introduction

The older reviews (Juniper and Abbot 1993; Peat and Fitter 1993) state that high salinity in soils has adverse effects on the colonization of plants by AMF. However, there are reports from all over the world scattered amongst the literature that plants of salt marshes can be colonized by AMF (Mason 1928; Boullard 1959; Kahn 1974; Hoefnagels et al. 1993; Brown and Bledsoe 1996). Even families which are generally considered as non-mycorrhizal like the Chenopodiaceae *Salicornia europaea* and *Suaeda maritima* have been reported to show significant colonization by AMF under high salt stress (Kim and Weber 1985; Rozema et al. 1986; Van Duin et al. 1989; Sengupta and Chaudhari 1990). In a detailed study, this laboratory (Hildebrandt et al. 2001) screened plants of several salt marshes both of the North and Baltic Sea and of German inland salt habitats for their colonization by AMF. Members of the Asteraceae, *Aster tripolium* and *Artemisia maritima*, the plantains *Plantago maritima* and *P. coronopus* and *Oenanthe lachenalii* of the Apiaceae showed a high degree of mycorrhizal colonization, and low, though distinct, signs of AMF were scored in samples of the grasses *Puccinellia maritima* and *P. distans* and even of *Salicornia europaea* of the Chenopodiaceae, at inland salt marshes, whereas other species like the grass *Spartina anglica*, the Juncaceae *Juncus gerardii*, and the Juncaginaceae, *Triglochin maritimum*, were non-mycorrhizal. The soils of all salt marshes investigated contained spores of AMF in high numbers. Their distribution was patchy and highly vari-

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ORIGINAL ARTICLE

Glomus fasciculatum inoculation improves soybean production

A.I. ILBAS[1] & S. SAHIN[2]

[1]*Department of Biology, Faculty of Yozgat Arts and Science, Erciyes University, Yozgat, Turkey and* [2]*Department of Biology, Institute of Science, Erciyes University, Kayseri, Turkey*

Abstract
The effects on soybean yield components of inoculation with arbuscular mycorrhizal fungus (AMF) *Glomus fasciculatum* were investigated at different phosphorus levels. The level of root AMF colonization decreased a little when P levels increased. Mycorrhizal inoculation and increasing levels of P application had positive effects on yield components such as stem and root length, shoot and root dry weight, stem diameter, 1000-grain weight and seed yield per plant but not on legume numbers per plant. Both mycorrhiza inoculation and P treatments affected P and N concentrations of grain and roots of soybean. Mycorrhizal fungi decreased the need of P addition in growth medium by contributing to the demand of optimum phosphorus for growth of soybean.

Keywords: *Glycine max (L.) Merr., mycorrhiza, phosphorus.*

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Arbuscular mycorrhiza enhances nutrient uptake in chickpea

M. Farzaneh[1,2], H. Vierheilig[1,3], A. Lössl[1], H.P. Kaul[1]

[1]*Department of Crop Sciences, University of Natural Resources and Life Sciences, Vienna, Austria*
[2]*Institute of Agronomy and Plant Breeding, Shahid Chamran University, Ahvaz, Iran*
[3]*Departament of Soil Microbiology and Symbiotic Systems, CSIC, Experimental Station of El Zaidin, Granada, Spain*

ABSTRACT

Arbuscular mycorrhiza fungi (AMF) colonize roots of host plants and promote plant growth due to improved uptake of nutrients. While the effects on P uptake are well known, the relevance of AMF for the uptake of other nutrients is less investigated. In the present paper we studied contents of N, P, K, Ca, Mg, Fe, Mn, Cu, and Zn in the legume chickpea in pot experiments during two seasons. Beside the control, the following treatment combinations: (i) the inoculation with the commercial AMF product 'Symbivit®'; (ii) soil sterilization before inoculation, and (iii) mineral nitrogen application. A moderate level of AMF colonization (18–55% of roots), enhanced the nutrient uptake of chickpea. With P, Mn, and in 2006 also with K, Cu, and Fe the nutrient concentrations were also elevated, even along with a simultaneous increase in plant biomass. Soil sterilization or fertilization with N showed no significant effect on nutrient uptake and biomass production.

Further Research Topics

- Select specialized inoculant or mixing inoculants for determined plants
- Application timing and application rates
- Using fungicide and other pesticides before or after mycorrhizal inoculation
- Be required of reusing, and spit using, and reaplication
- Proving inoculation, getting benefits in time and effective period
- Using with other biological products, e.g. nitrogen fixing bacteria
- Keeping conditions and shelf life of mycorrhizal inoculant
- Production of commercialized inoculants, properly
- Abundance of available P in the growing medium
- Effects of other edaphic, biotic and abiotic factors and their interaction with mycorrhizal association
- Molecular studies, disposing and reproducing, and extracting important chemical compounds associated to Mycorrhiza

It was pleasure for me meeting to you!

Thank you very much for your kind invitation!

We will be glad to see you in Turkey!