Mycorrhizal Applications, LLC


## 44TH ANNUAL MEETING

# MULCH & SOIL COUNCIL

### OCTOBER 20-22 2015

# UNDERSTANDING THE BENEFITS OF MYCORRHIZAE IN MANUFACTURED SOILS

*ADDING LIFE & VALUE TO SOIL AND MULCH PRODUCTS*

*JEFF ANDERSON - MYCORRHIZAL APPLICATIONS*

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Applications, Inc.
710

# WITH THE RECENT ACQUISITION BY VALENT BIOSCIENCES OUR FAMILY EXPANDS TO 700 EMPLOYEES IN 95 COUNTRIES.


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# MYCORRHIZAE

"fungus"-"roots"

are naturally-occurring beneficial soil fungi that form *symbiotic* relationships with plants. They grow from the roots and essentially become living extensions of the root system, where they dramatically expand access to moisture and nutrients in the soil environment. In return, the host plant feeds the fungi sugars and other organic substances that it produces by photosynthesis.

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# MYCORRHIZAE

have been an essential factor in plant survival and optimum growth since plants first colonized dry land about 460 million years ago. Today, about 95% of all terrestrial plant species world-wide will host one or more mycorrhizal associations.

Seedling
in glass box
with
mycorrhizal
filaments

A powerful network for transportation of water and nutrients to the plant

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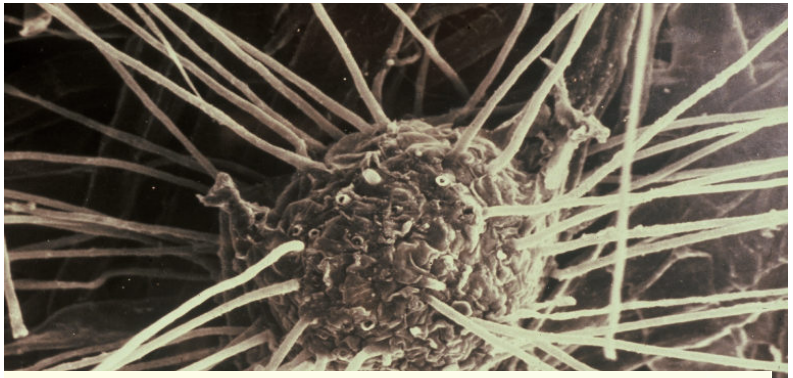
# WHAT?

# WHERE?

# HOW?



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In natural ecosystems, over 90% of the world's terrestrial plants depend on ***mycorrhizal fungi*** for survival, efficient nutrient and water uptake and optimum growth

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# NATURAL AREAS ARE FULL OF MYCORRHIZAL FUNGI

- Conserve nutrients and water
- Limit offsite erosion and nutrient loss
- Control diseases
- Protection against environmental extremes

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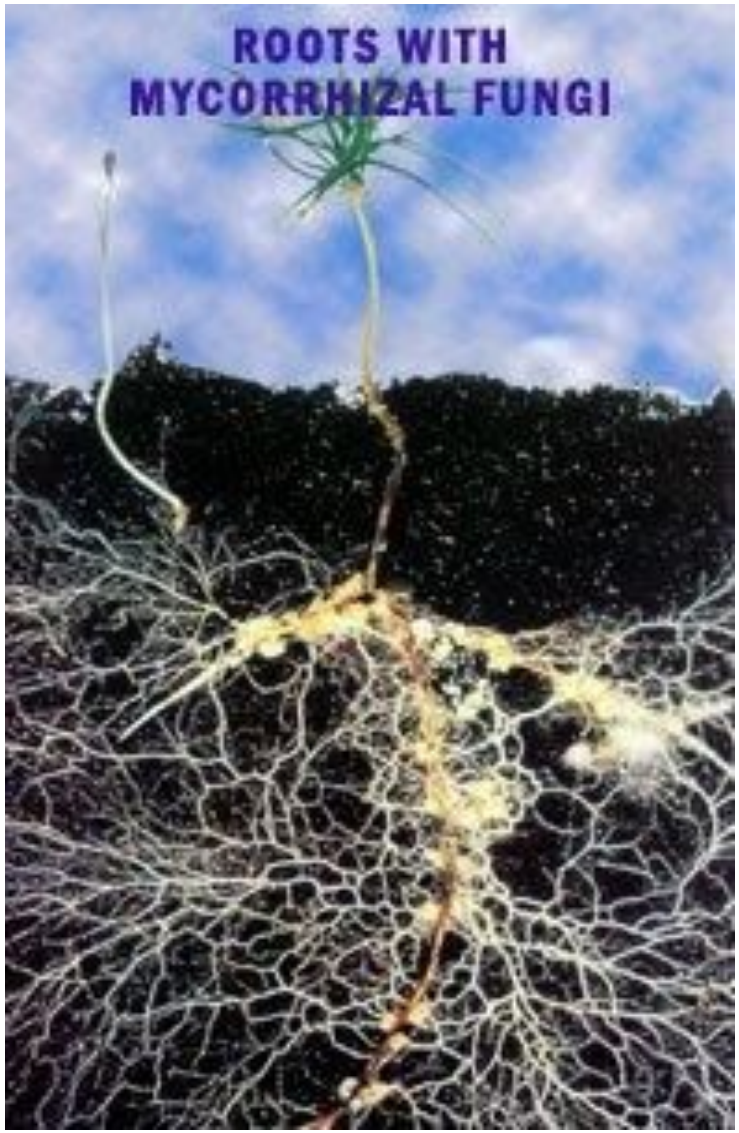


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hnology and people™

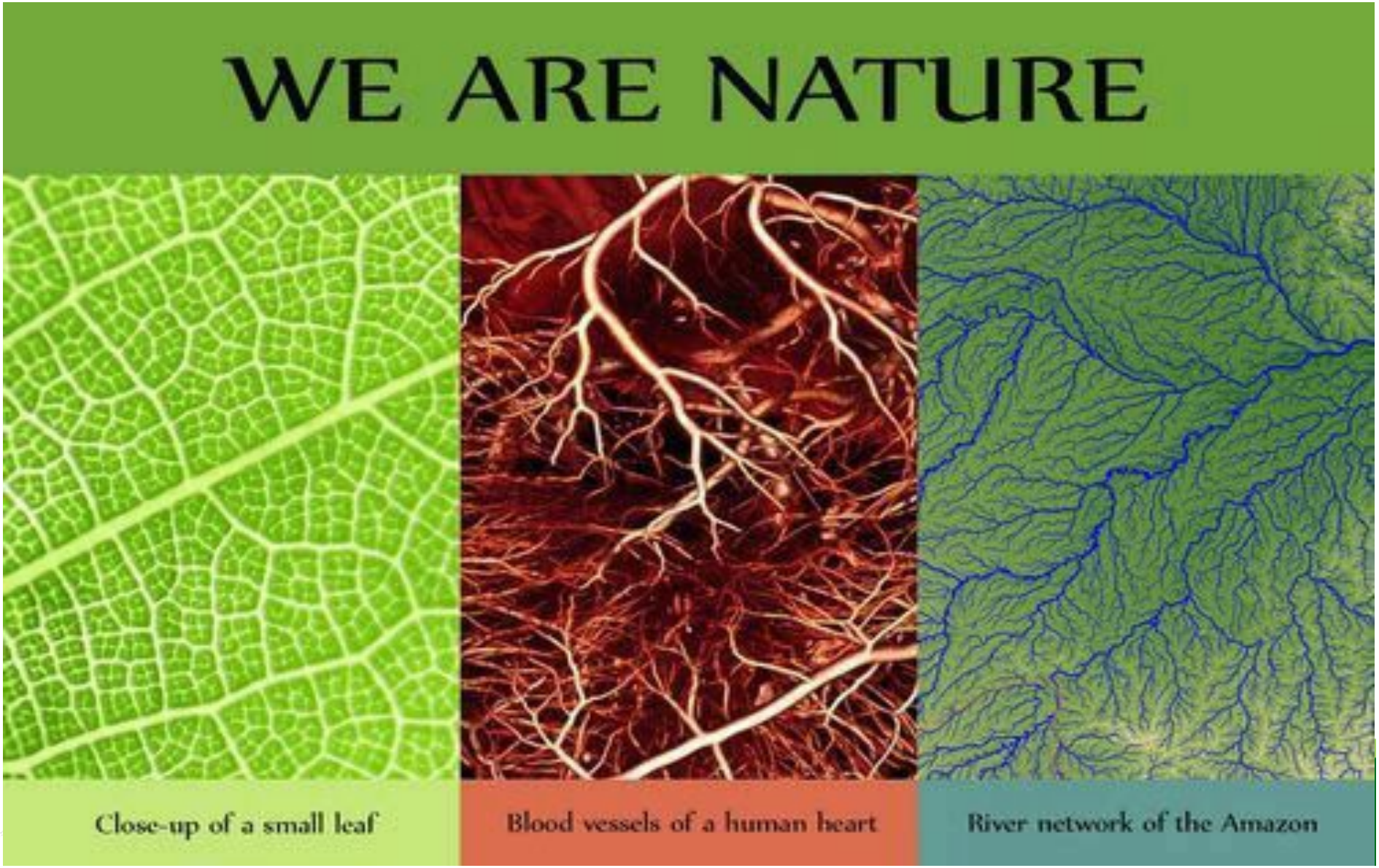
# COMPARISON OF NATURAL SOILS VS INTENSIVELY DISTURBED LANDS

| Natural | Intensive Disturbance |
| --- | --- |
| Teeming with life | Biologically challenged |
| Nutrients in organic form | Nutrients in chemical forms |
| No leaching losses | Considerable leaching losses |
| Deep aerobic zone | Thin aerobic zone |
| Little disease pressure | Severe disease pressure |
| Decreasing $ inputs | Increasing $ inputs |

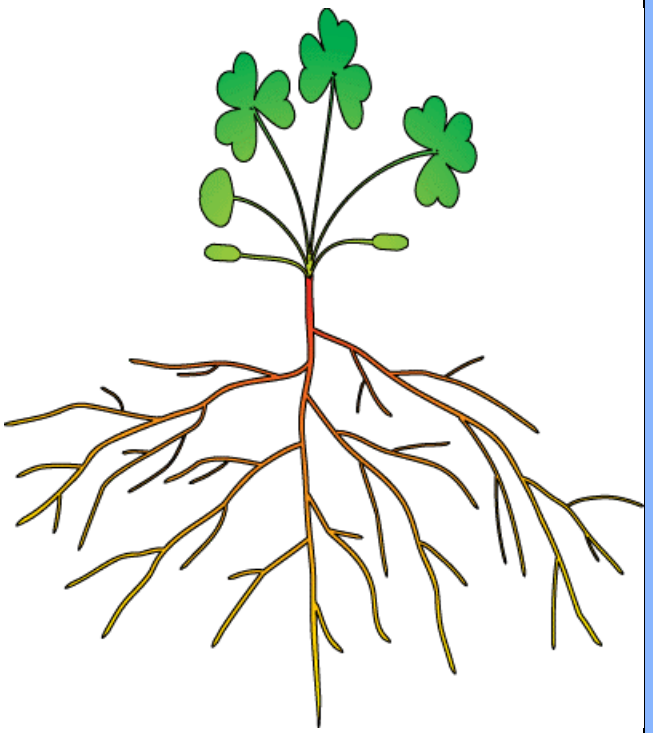
# Mycorrhizal Challenges:

- Soil excavation or tillage
- Extended periods of fallow
- Soil fumigation
- Isolation from natural mycorrhizae sources
- Erosion
- Fungicides (*some, but not all*)
- Chemical fertilizers
- Compaction
- Some plants are non-mycorrhizal
- Soil-less medias and nursery mixes

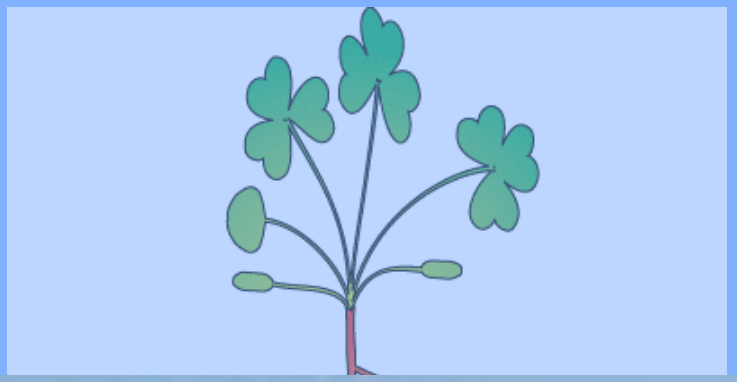
# Exploring the power of Bio-Possibilities in manufactured soils

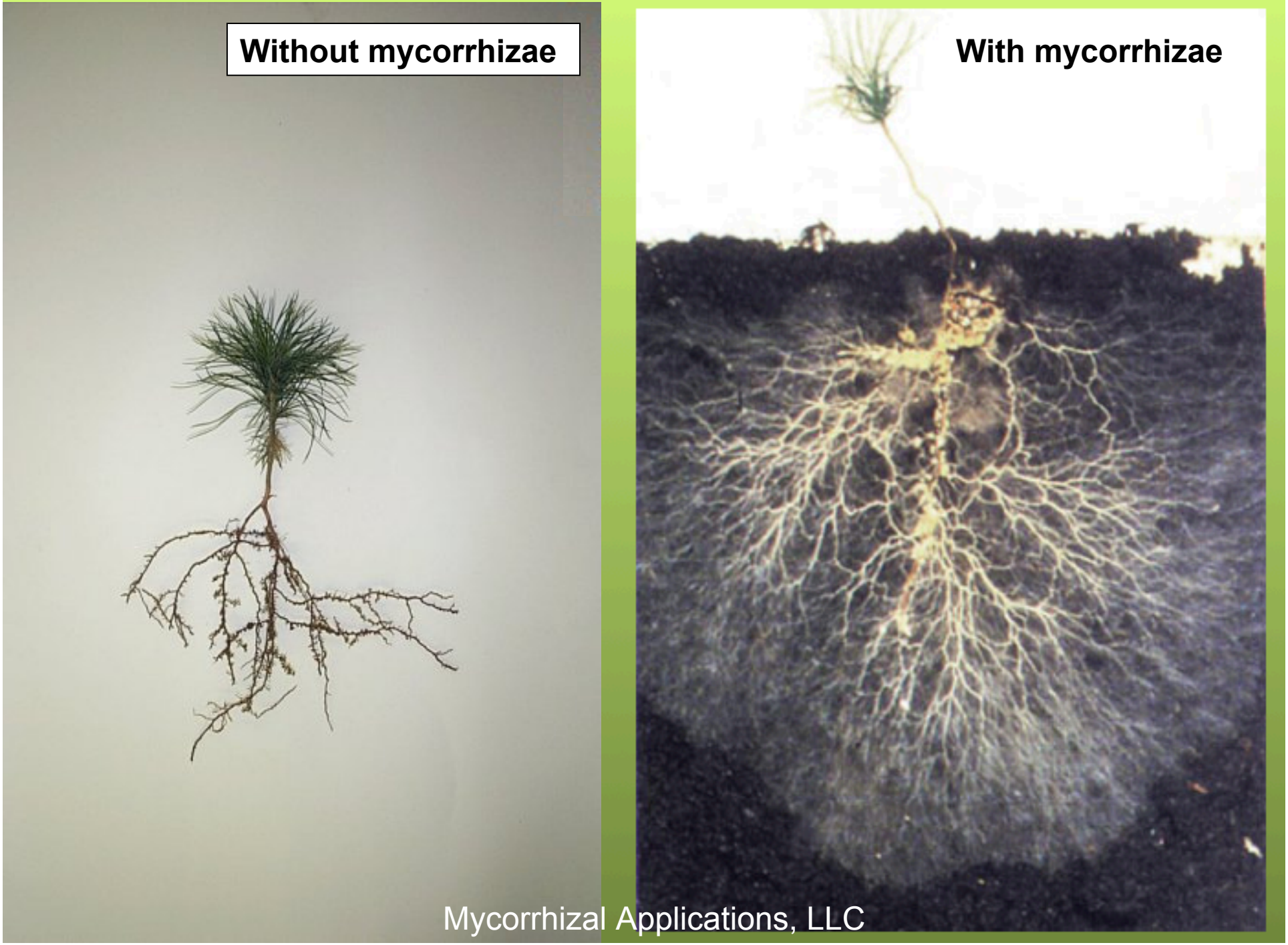


## YOUR PLANT



## YOUR PLANT *WITH* MYCORRHIZAE




Without mycorrhizae
With mycorrhizae
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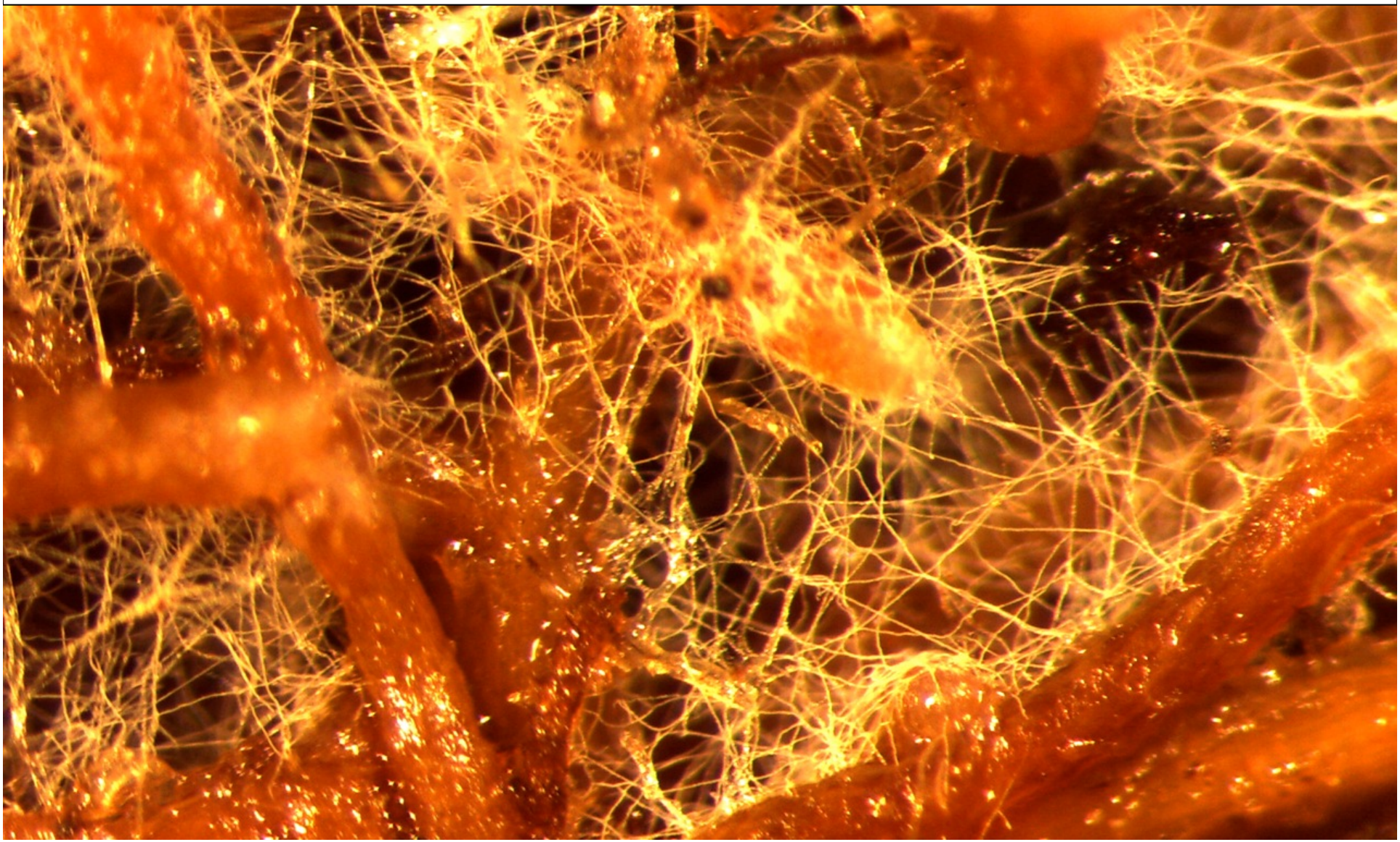
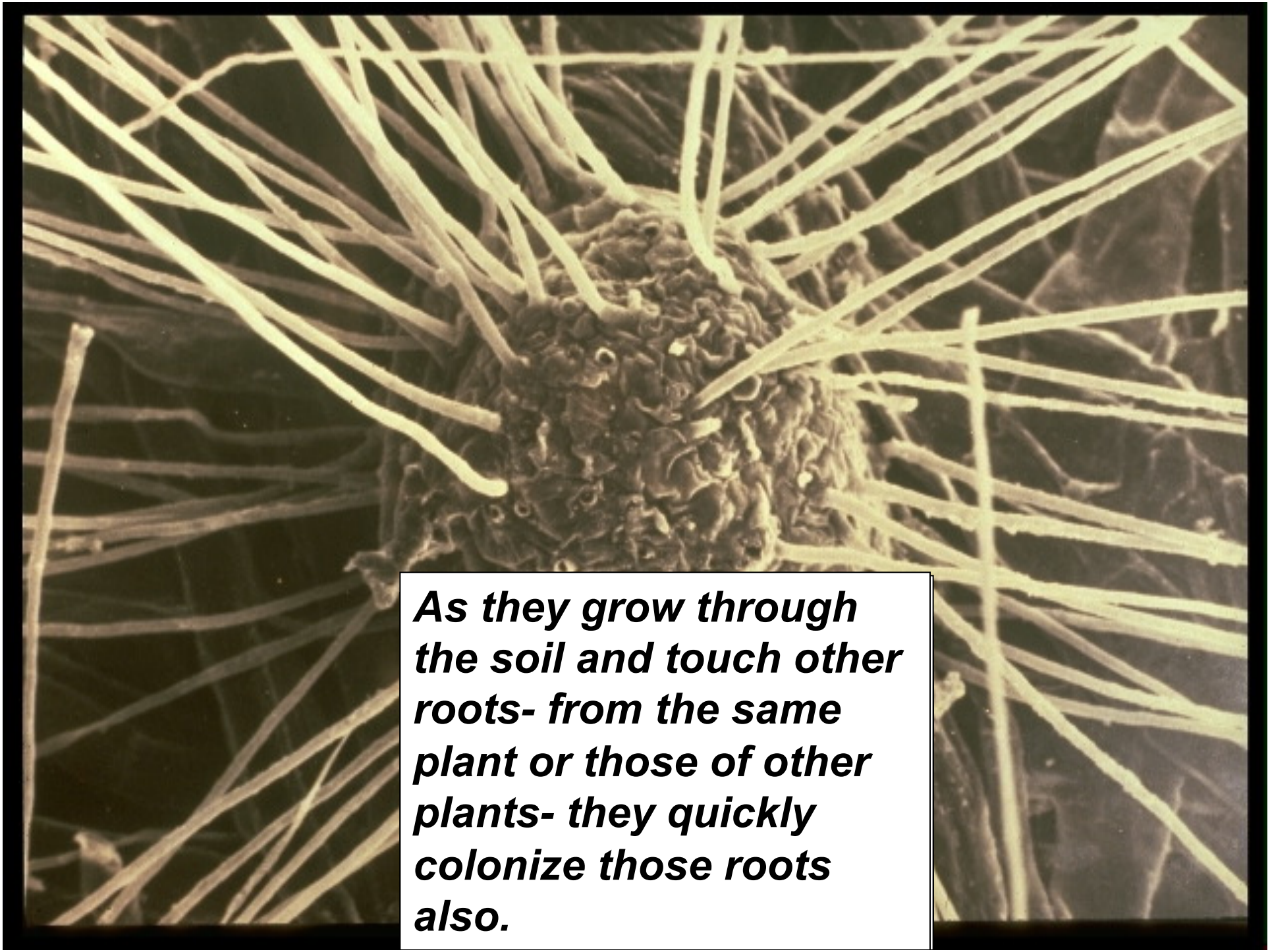
**In undisturbed natural environments, the network of fungal filaments can total several miles in just one spoonful of healthy soil!!**




As they grow through the soil and touch other roots- from the same plant or those of other plants- they quickly colonize those roots also.

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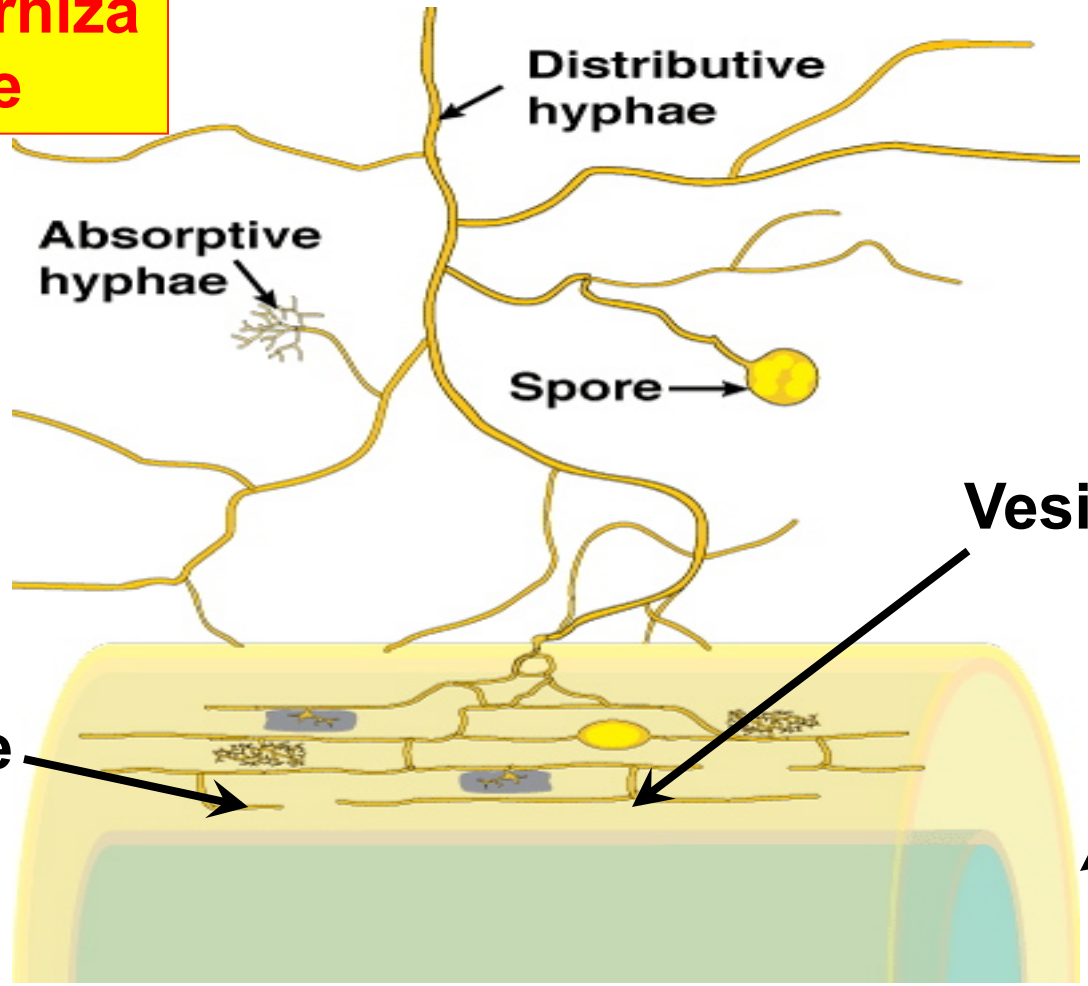
# *Endo* mycorrhiza Structure

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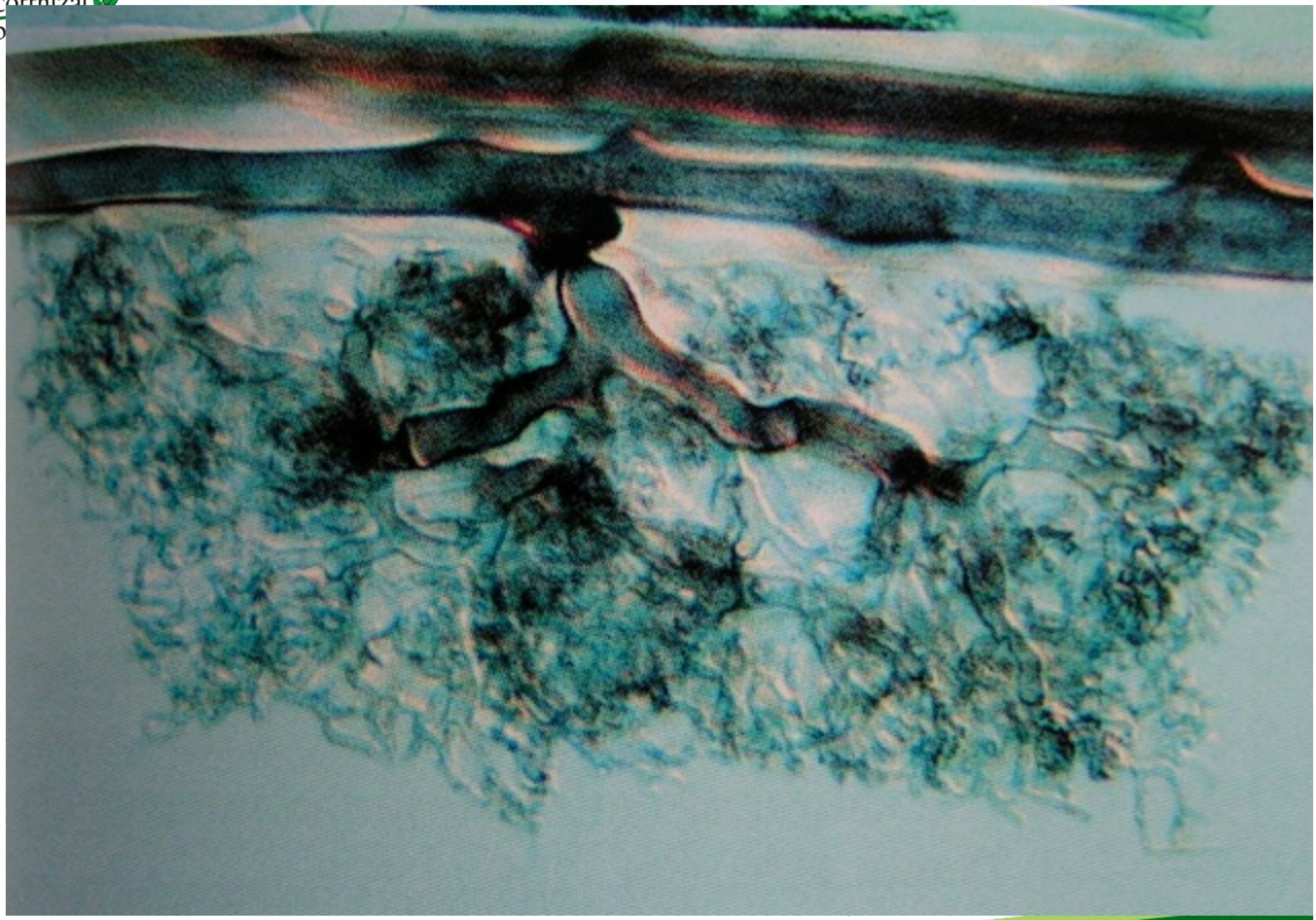
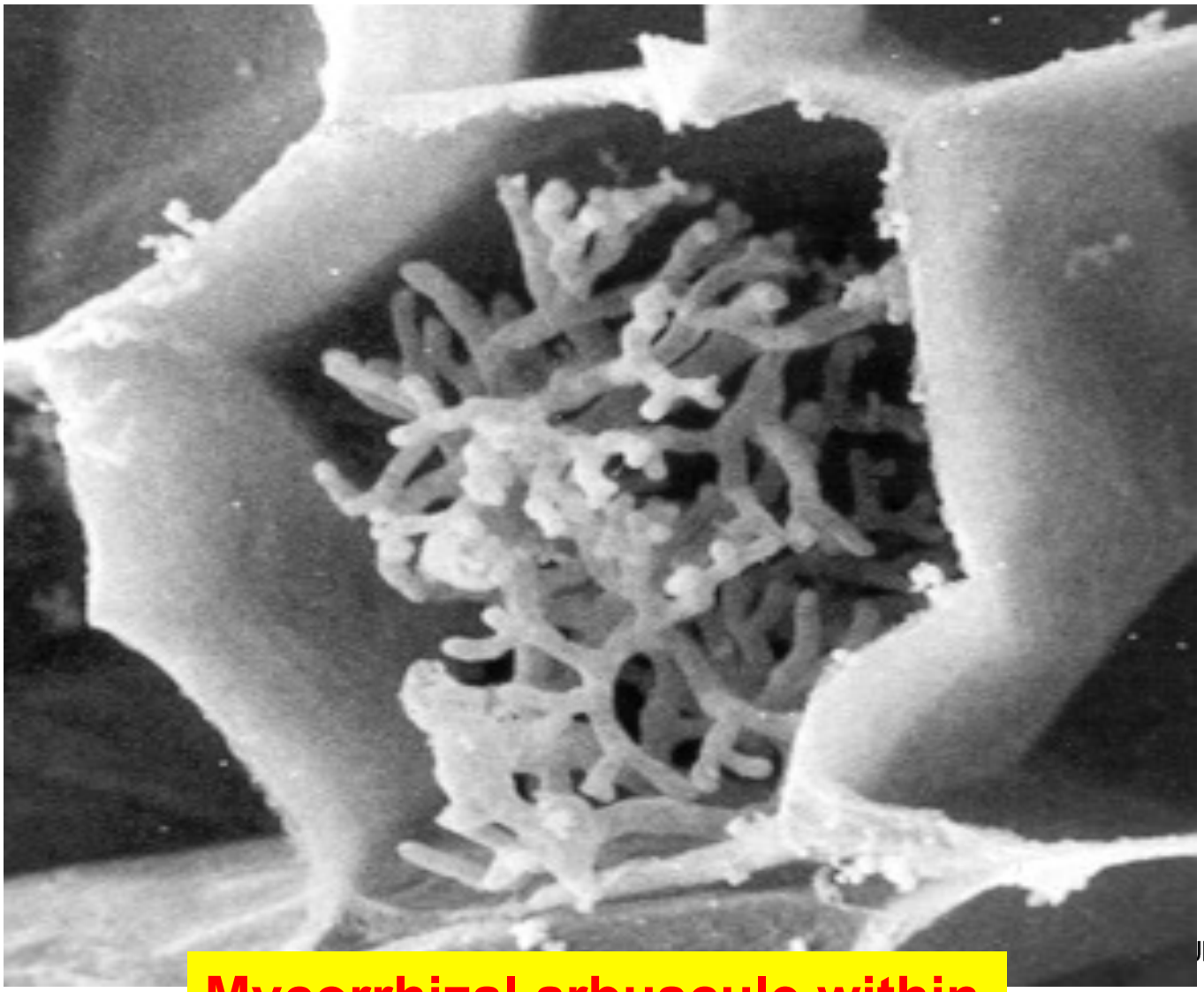
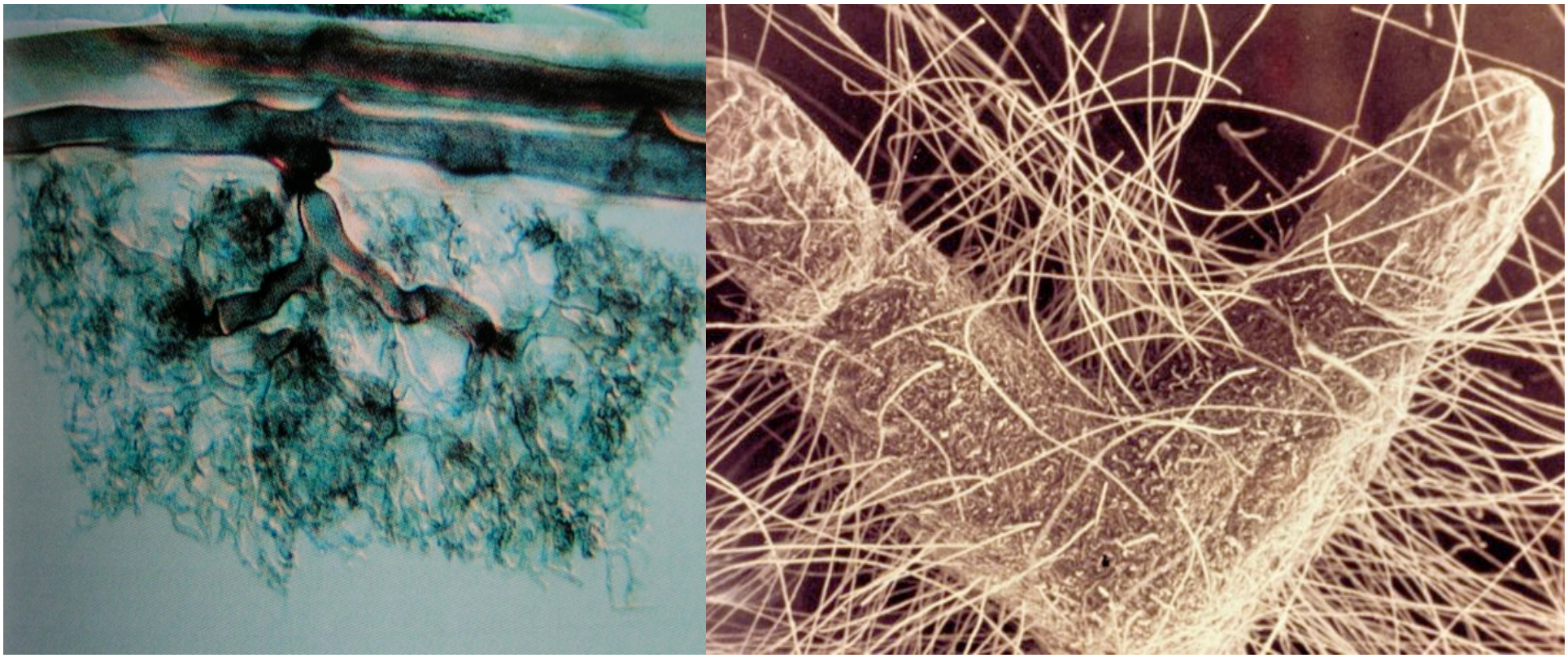




**Mycorrhizal arbuscule within a root cell at attachment site**

# One of the most successful biological success stories in the history of the earth



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# “We know more about the celestial bodies than the soil beneath our feet.” Leanardo da Vinci

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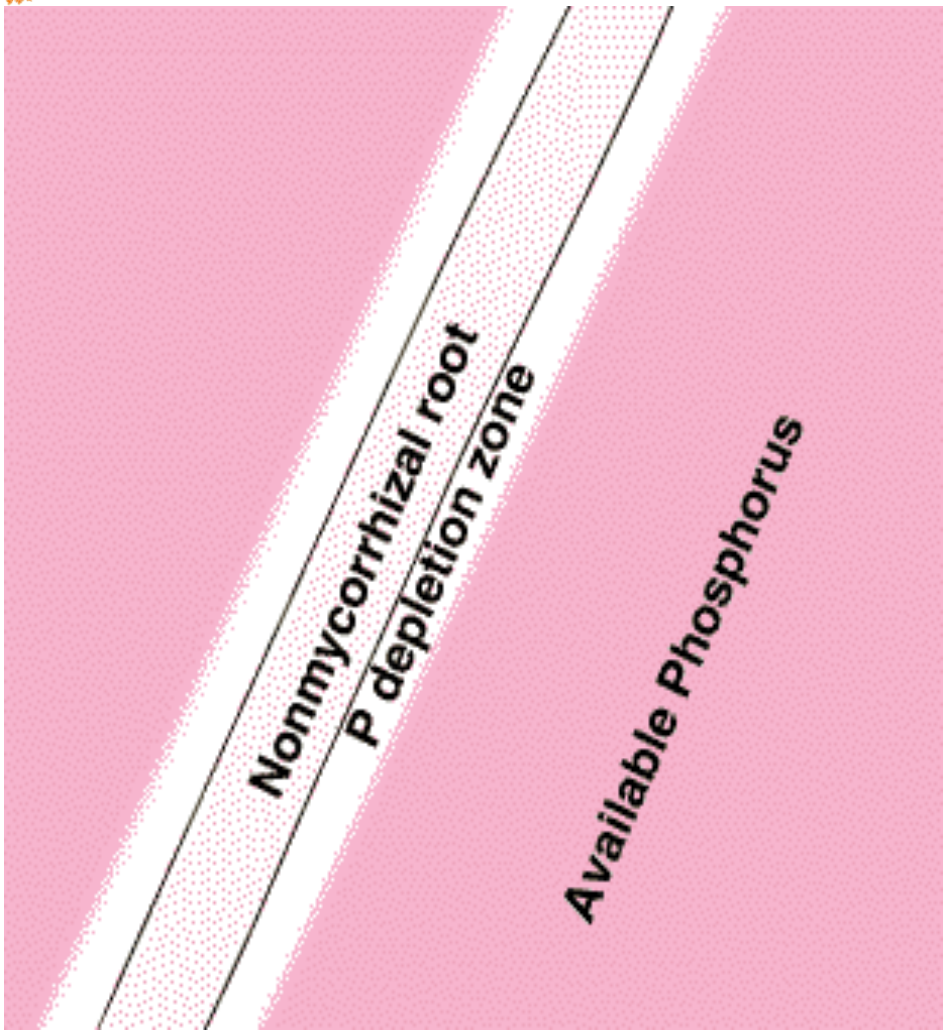
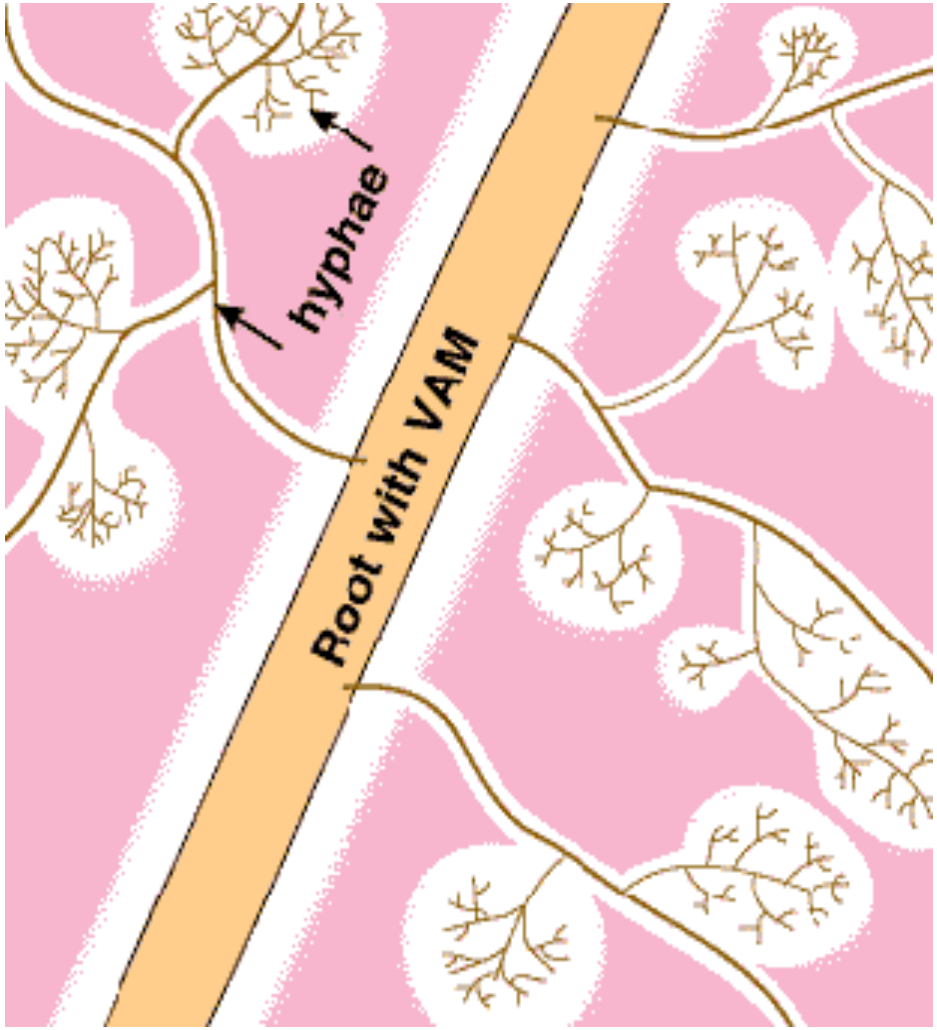
# PHOSPHORUS NUTRITION

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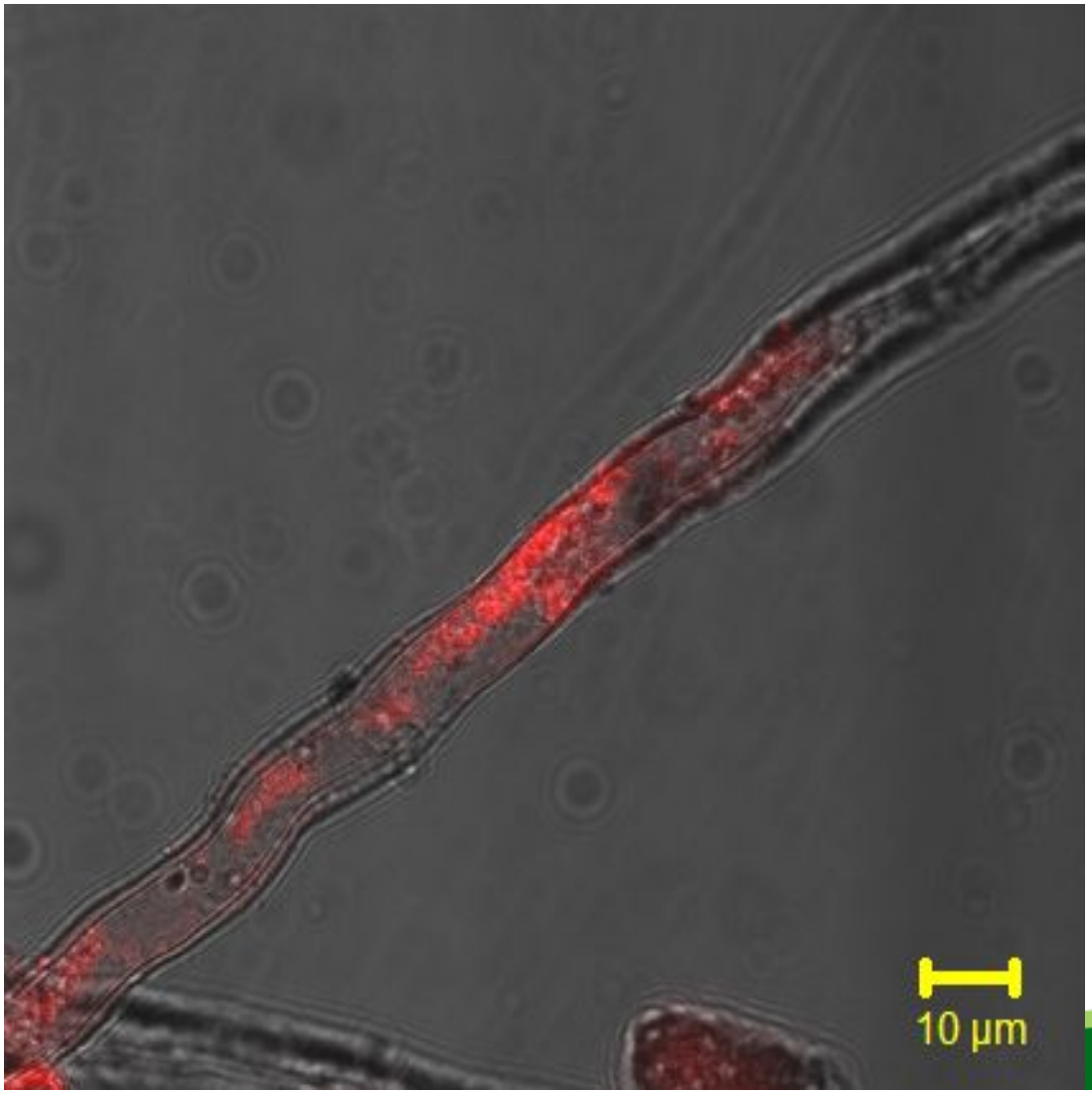
# *Journal of Ecology*




Inoculated plants absorbed organic forms of nitrogen

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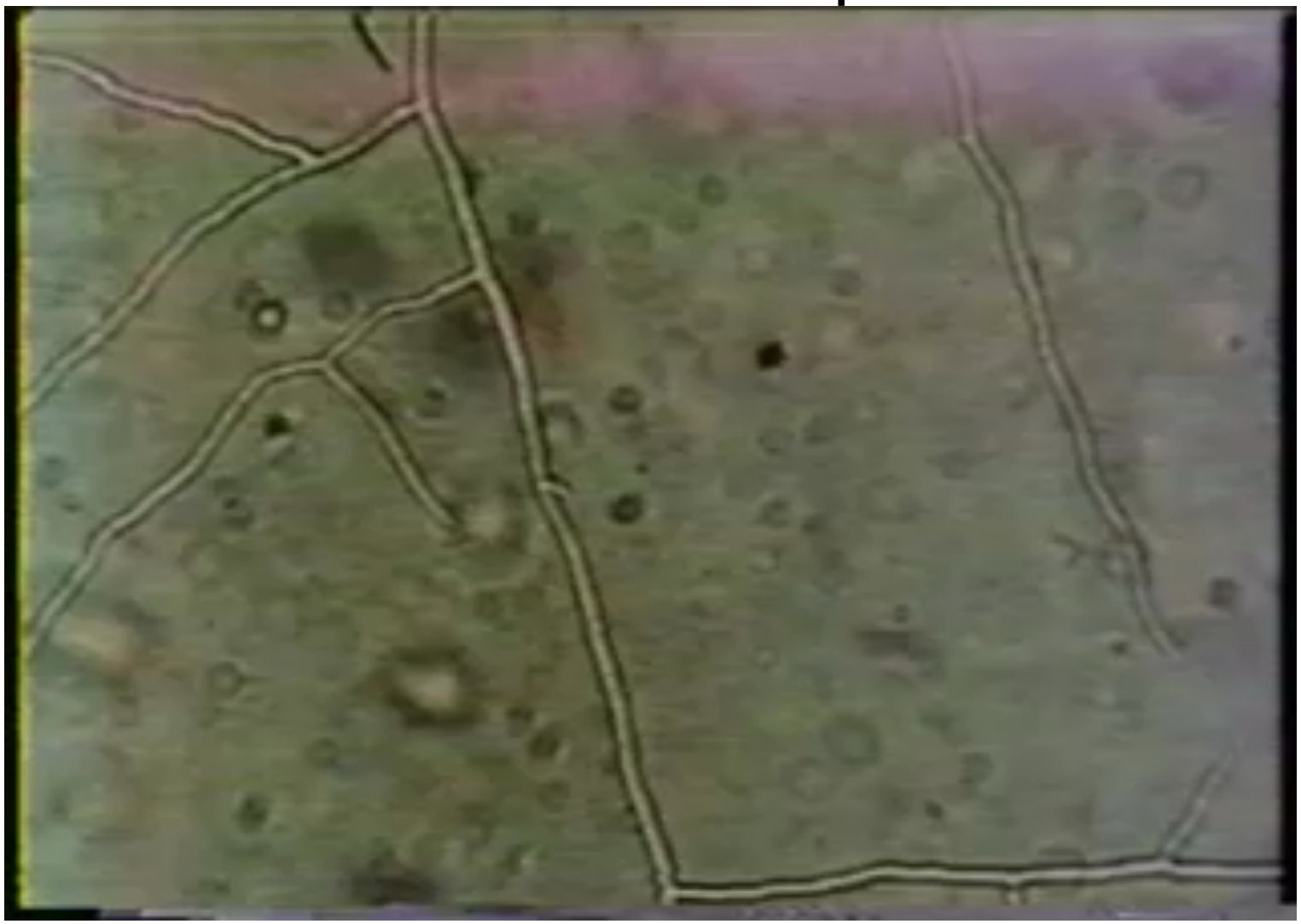
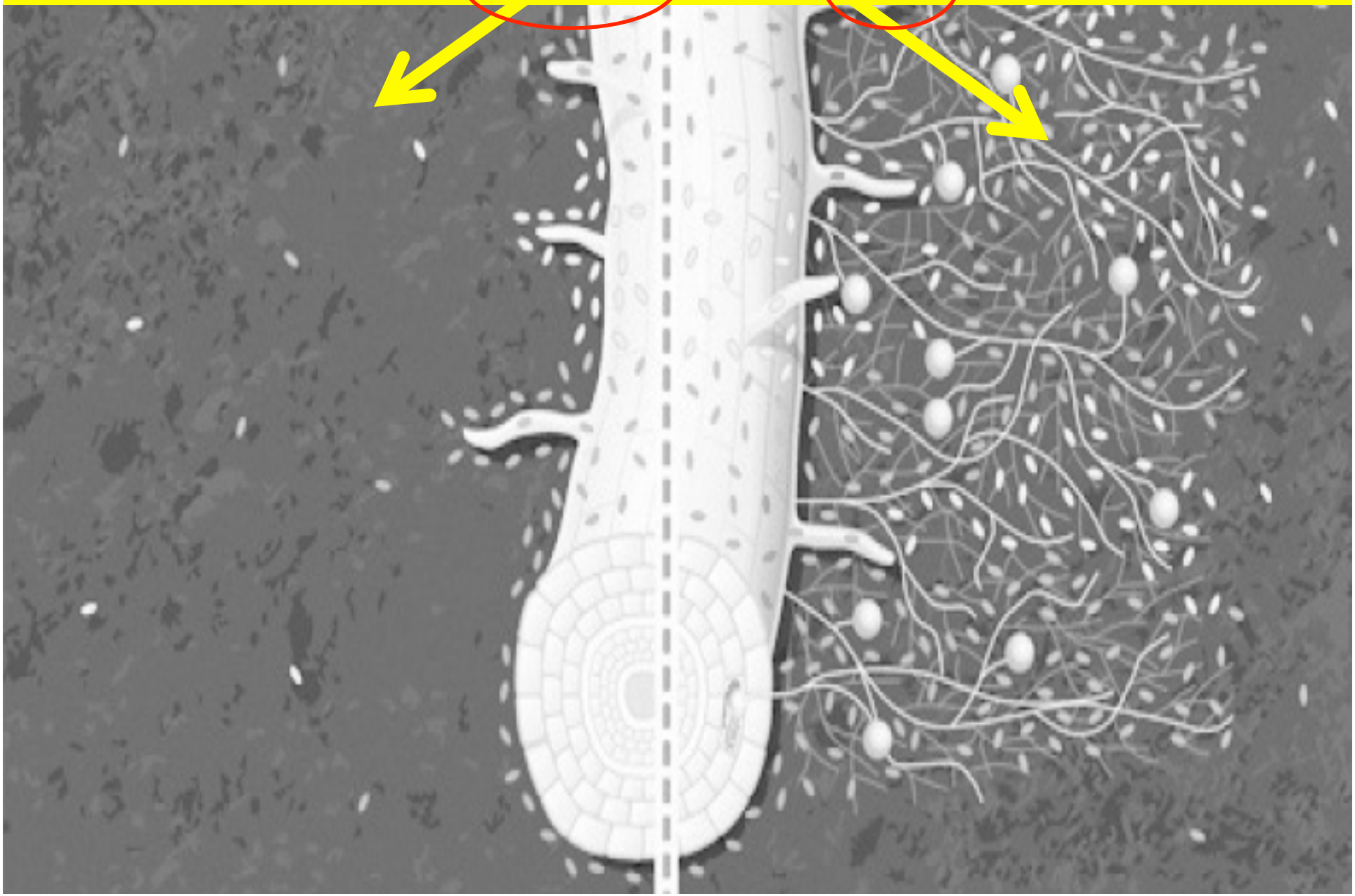
# Filaments access/transport nutrients



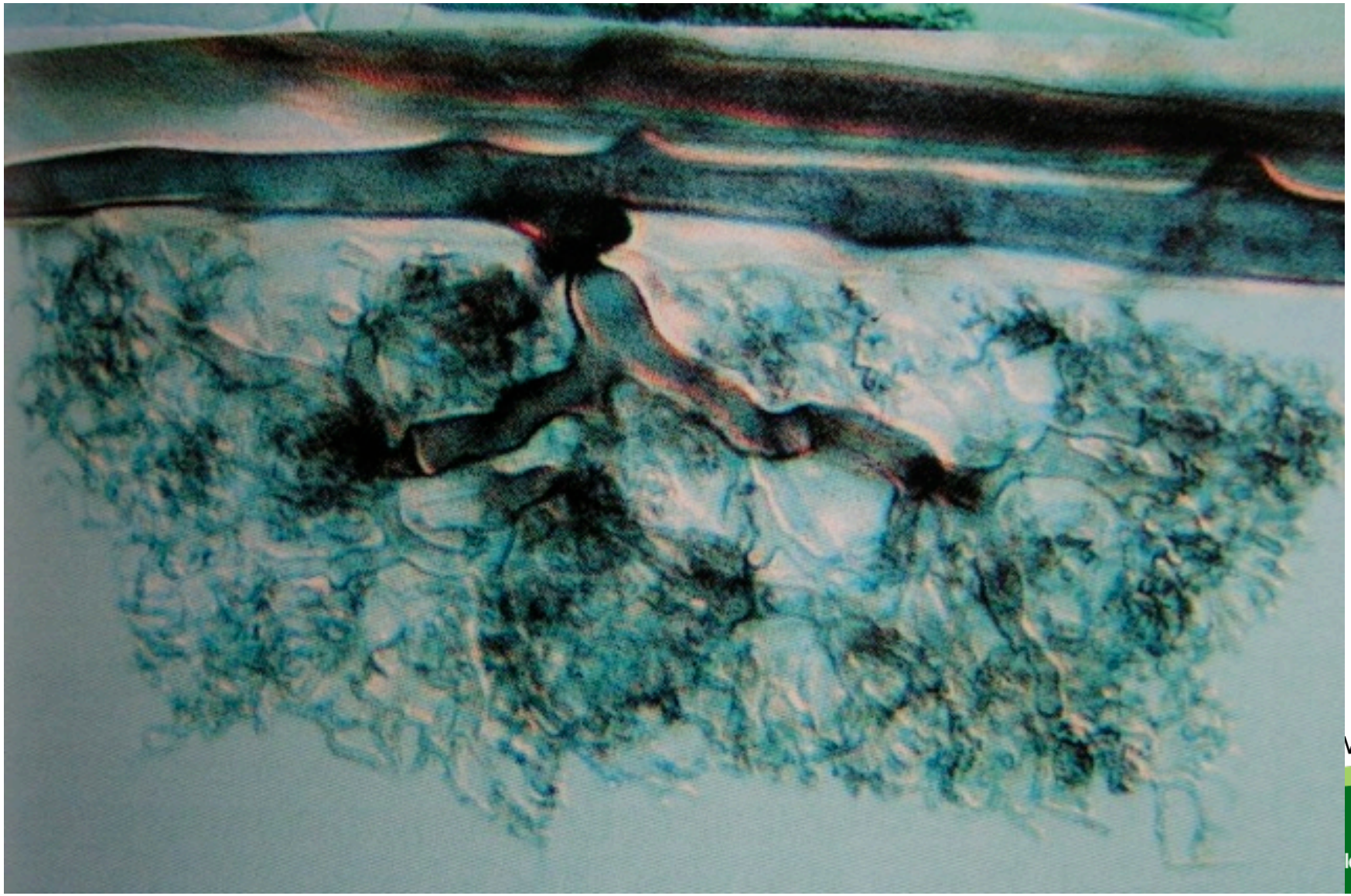
**This electron microscope photo shows bacteria and other beneficial microbes thriving on the surfaces of mycorrhizal hyphae**

**The surfaces of mycorrhizal hyphae are the favorite environment for a huge spectrum of beneficial micro-organisms in the soil**

# Diagram of a root showing beneficial soil bacterial activity in the rhizosphere without and with mycorrhizae

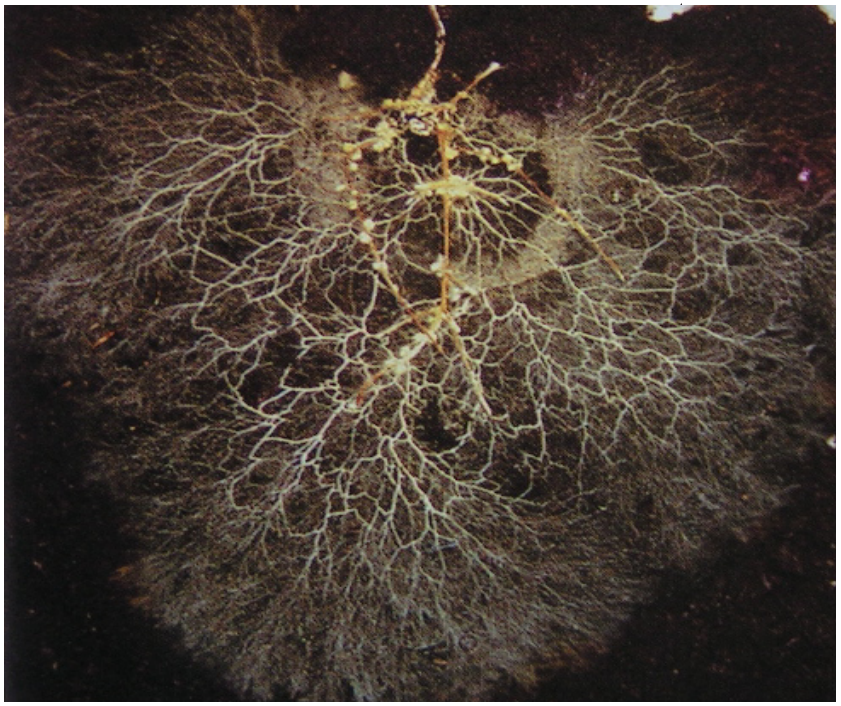


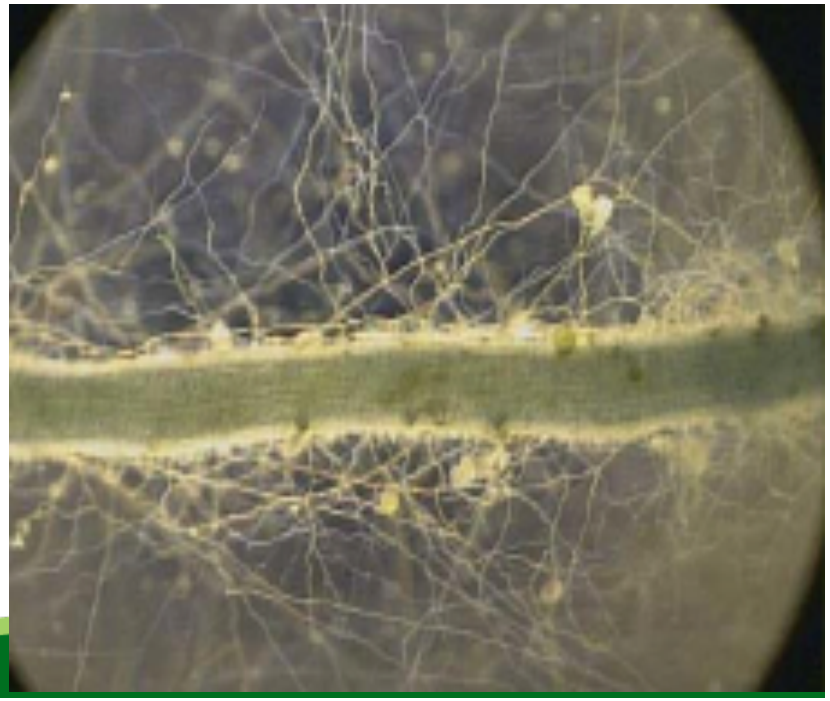
# Endo or Arbuscular Mycorrhizae-80% of plants

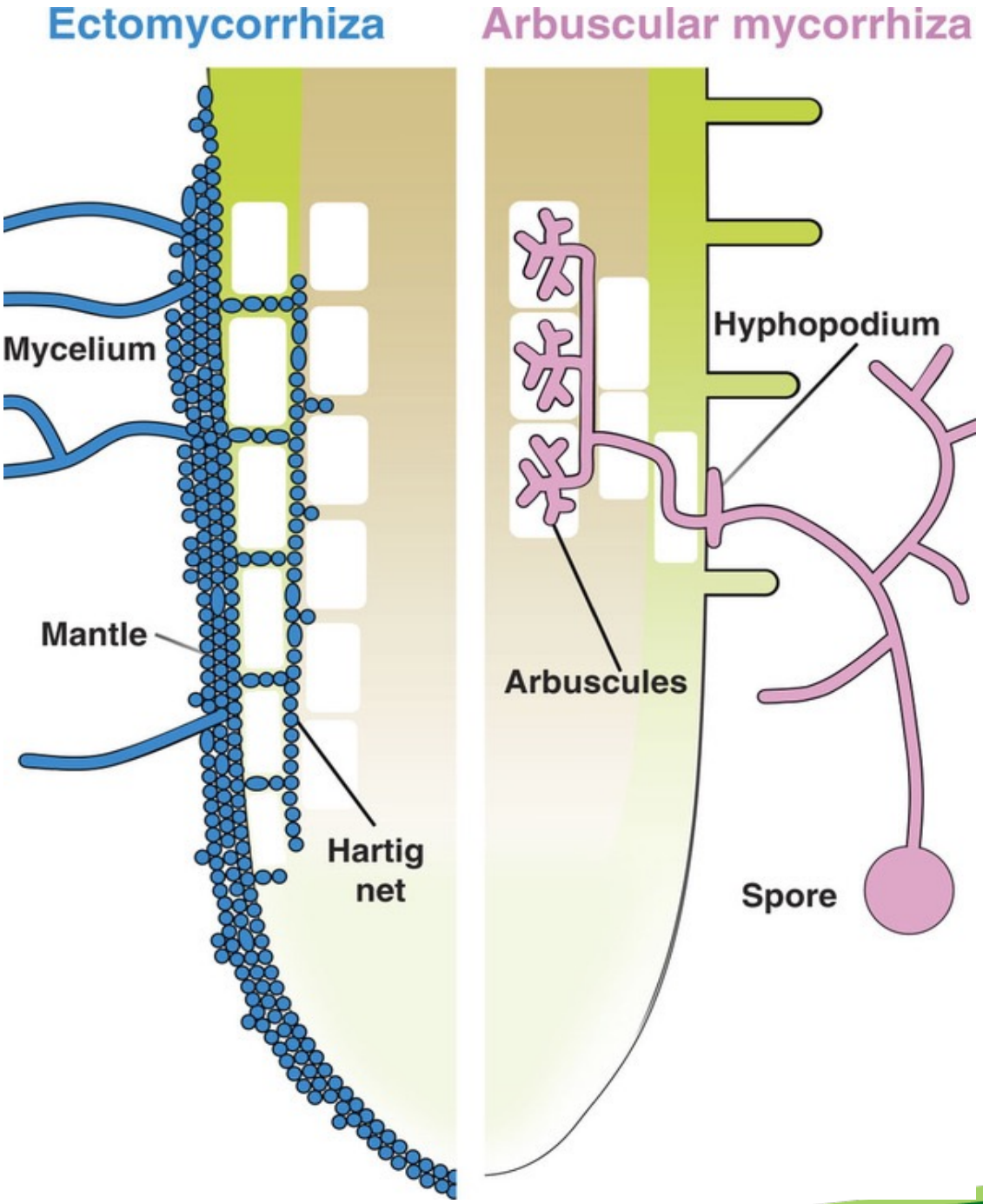


# Ecto and Endo Mycorrhizae

90% of the world's Plant families are dominated by these two types of mycorrhizae







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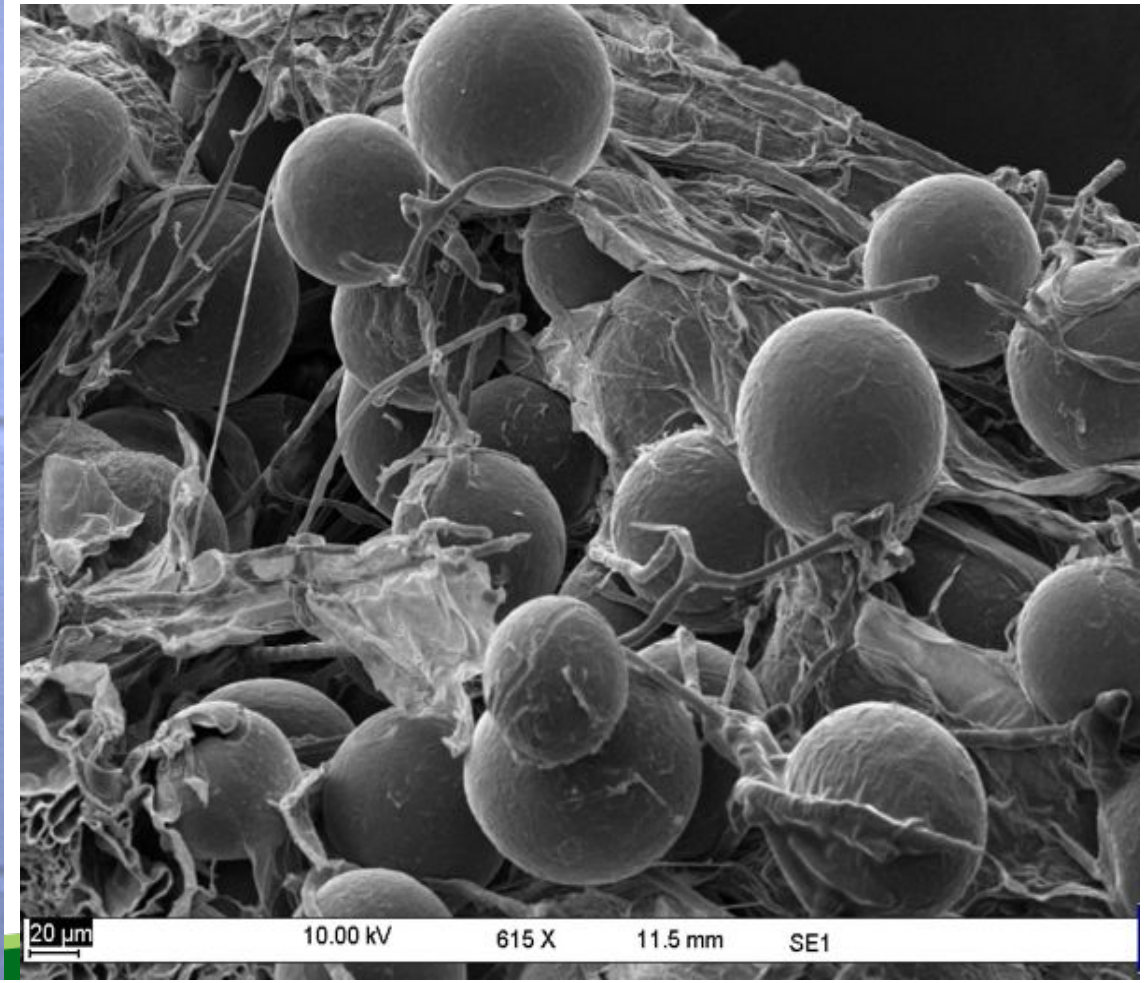
# ECTO FRUITING BODIES VS ENDO



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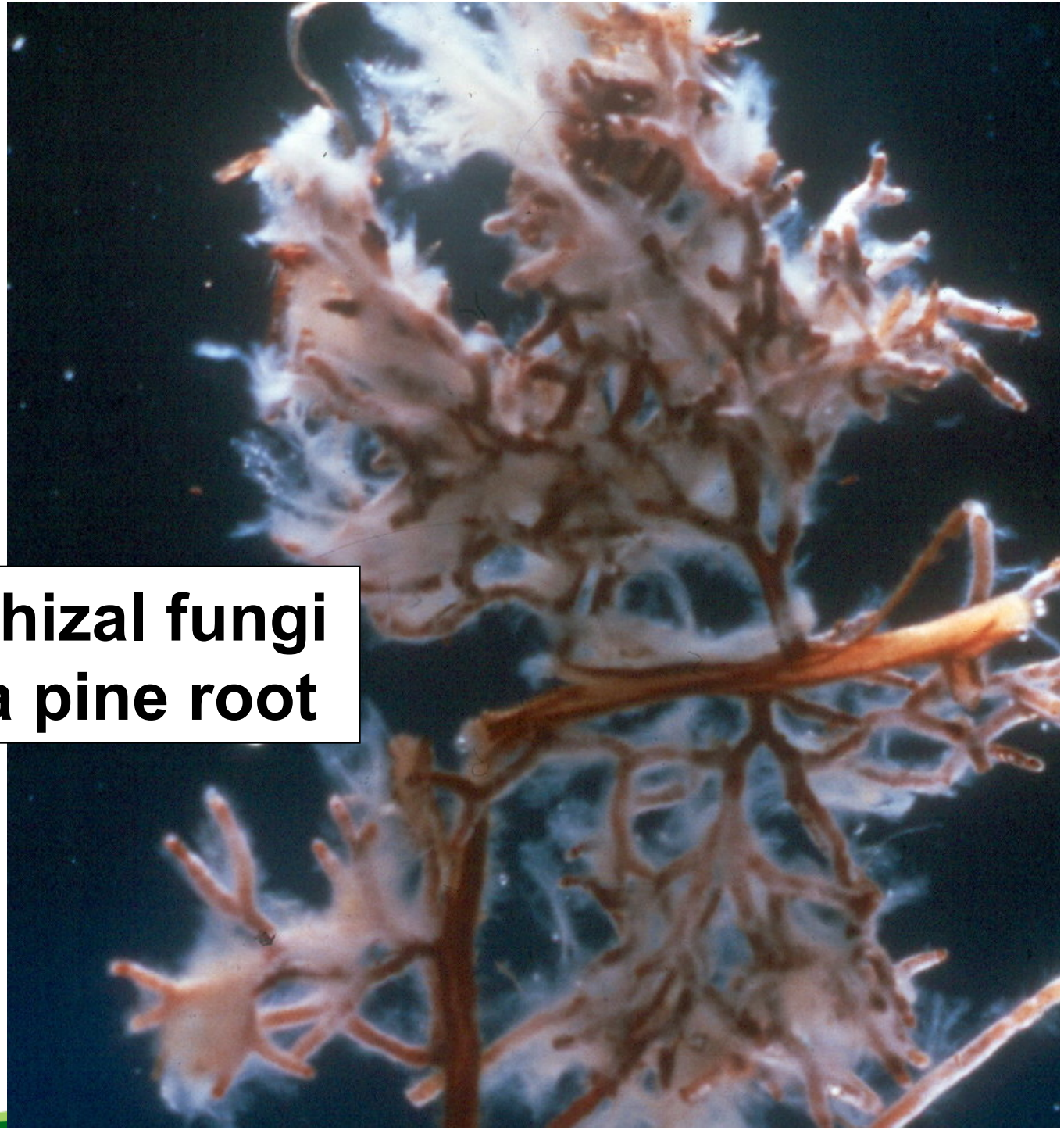

**ecto mycorrhizal fungi colonizing a pine root**

# Common plants that respond to *Ecto mycorrhizae*:

Poplar
Spruce
Willow (Endo & Ecto)
Linden
Madrone
Manzanita
Oak
Pecan
Pine
Filbert
Fir
Hazelnut
Hickory
Hemlock
Larch
Birch
Chestnut
Chinquapin
Cottonwood (Endo & Ecto)
Douglas fir
Eucalyptus
Alder (Endo & Ecto)
Arborvitae
Arctostaphylos
Aspen (Endo & Ecto)
Basswood
Beech

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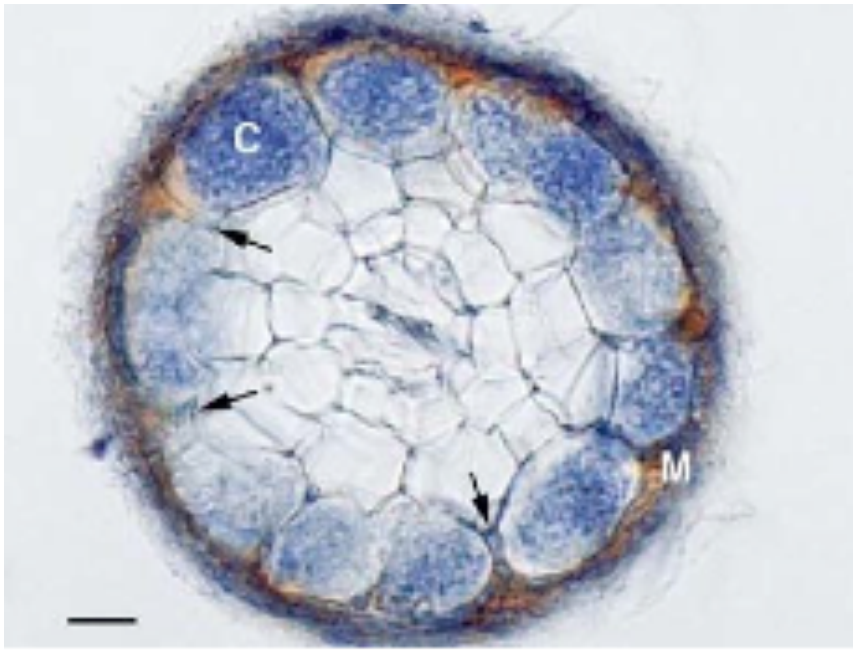
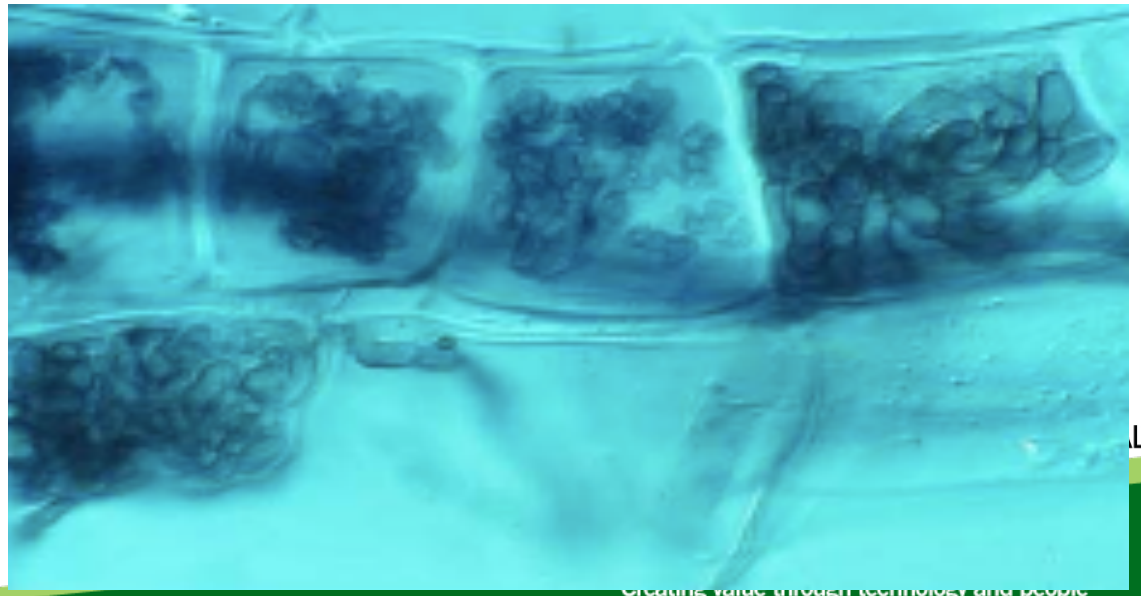
# Orchid




# Ericoid



# Common plants that ***do not*** respond to commercially available mycorrhizal inoculants:

- ✓ Sedges
- ✓ Rushes
- ✓ Orchids
- ✓ Protea
- ✓ Mustard
- ✓ Cabbages & Kales
- ✓ Beets
- ✓ Radish
- ✓ Spinach
- ✓ Ericaceous Plants (Azaleas, Rhododendrons, Blueberries, etc.)
- ✓ Many weed species

# SOME OF THE PRIMARY PLANT BENEFITS DERIVED FROM MYCORRHIZAL FUNGI:

- Improved root development

# 6 MONTH TURF GROWTH TEST

WITHOUT MYCORRHIZAE

WITH MYCORRHIZAE

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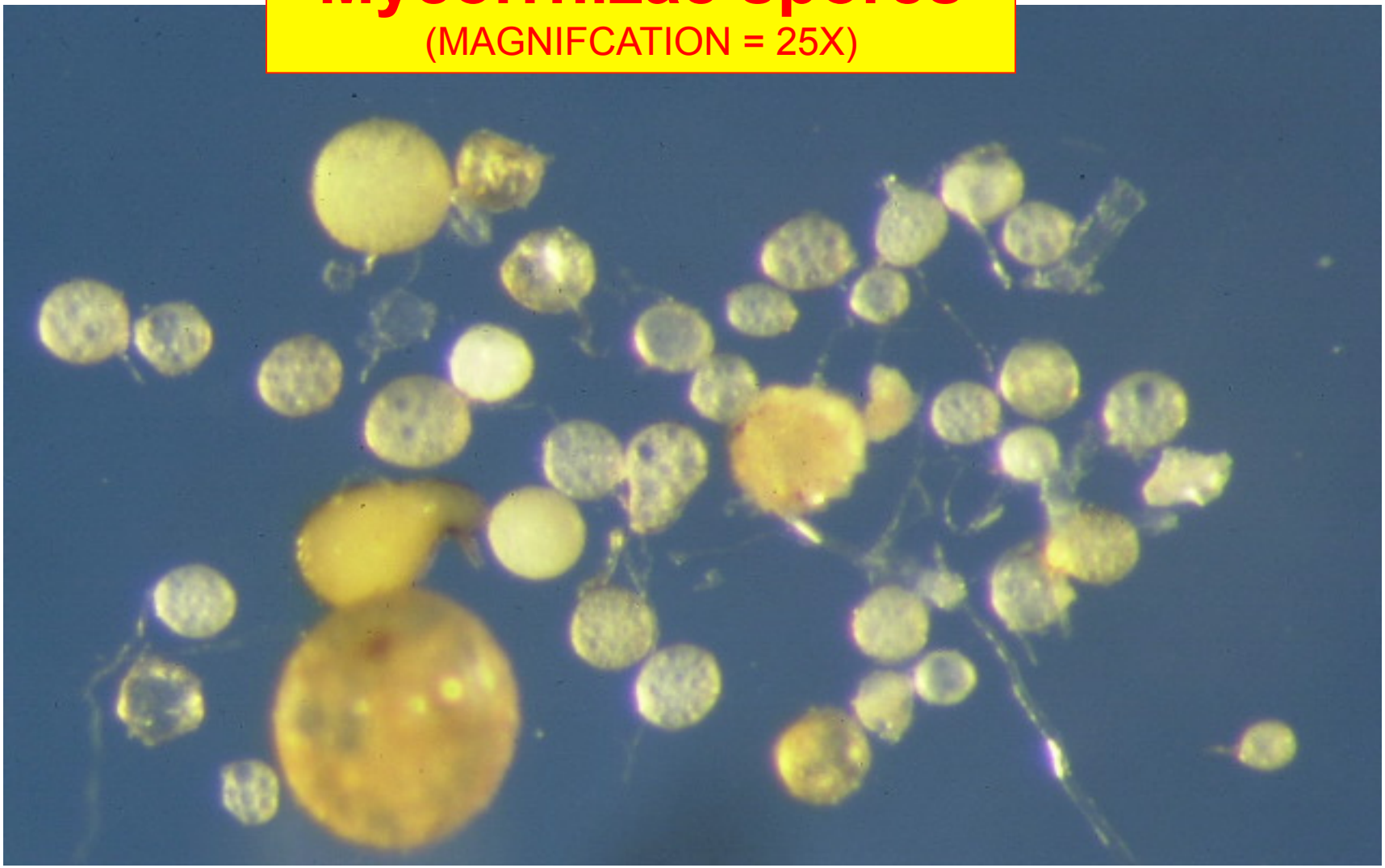
# Mycorrhizae spores

(MAGNIFCATION = 25X)



Dromant mycorrhizal spores break dormancy and begin colonizing root hair tissue *only when in the near proximity of a living root.* Moisture, soil type or temperature play no role in activating the spores.

# Dormant spores of mycorrhizal fungi

(MAGNIFCATION = 25X)


**Root colonization by spores is activated *only* by contact with or very close proximity to living root tissue.**

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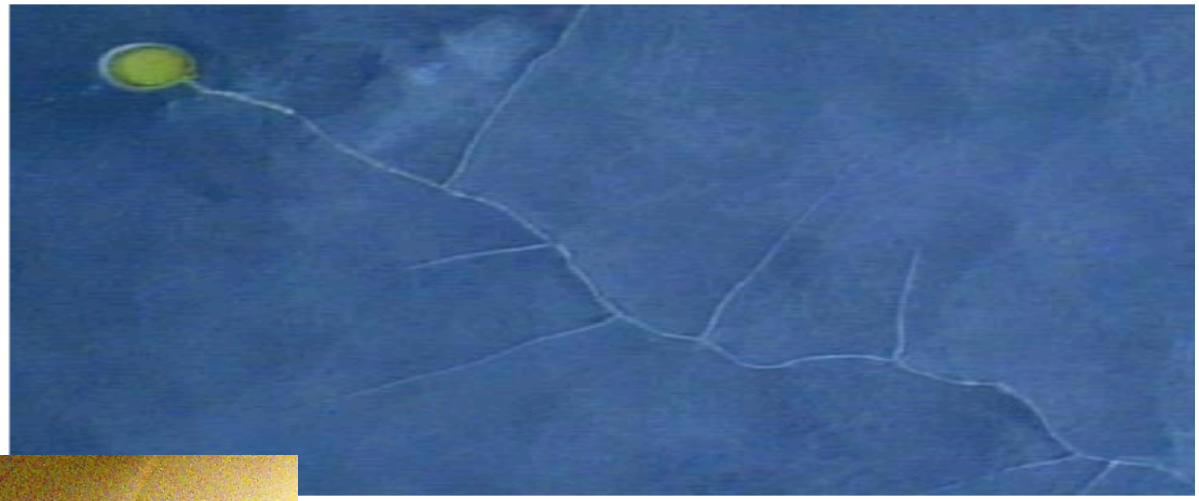
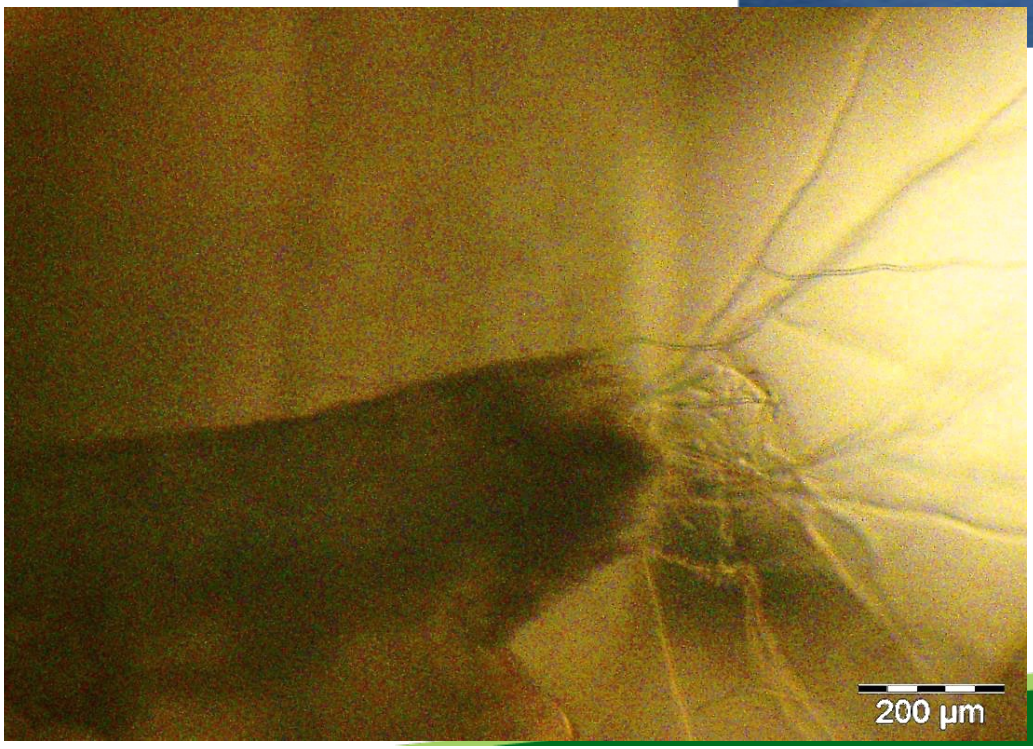
# ROOT ACTIVITY SIGNALS THE RELATIONSHIP

**Spore germination (signal)**



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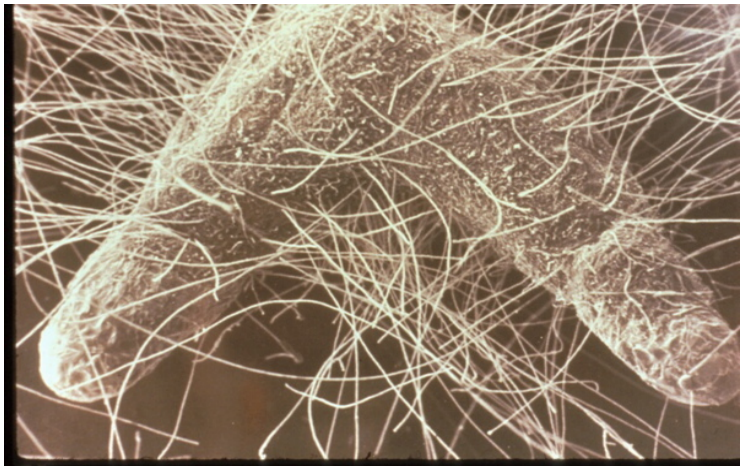
# WHY BOTHER?



- Soil organisms create soil structure
- They conserve and access soil nutrients
- A robust living soil prevents disease
- Soil organisms protect against stress events
- Soil organisms reduce input costs-$$$$$ and increase plant performance
- Make your products better

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# SOME OF THE PRIMARY PLANT BENEFITS DERIVED FROM MYCORRHIZAL FUNGI:

- Improved establishment, growth & survival
- Increased nutrient uptake
- Improved water uptake and drought tolerance
- Improved root development
- Parasitic nematode control
- Weed suppression
- Improves soil structure

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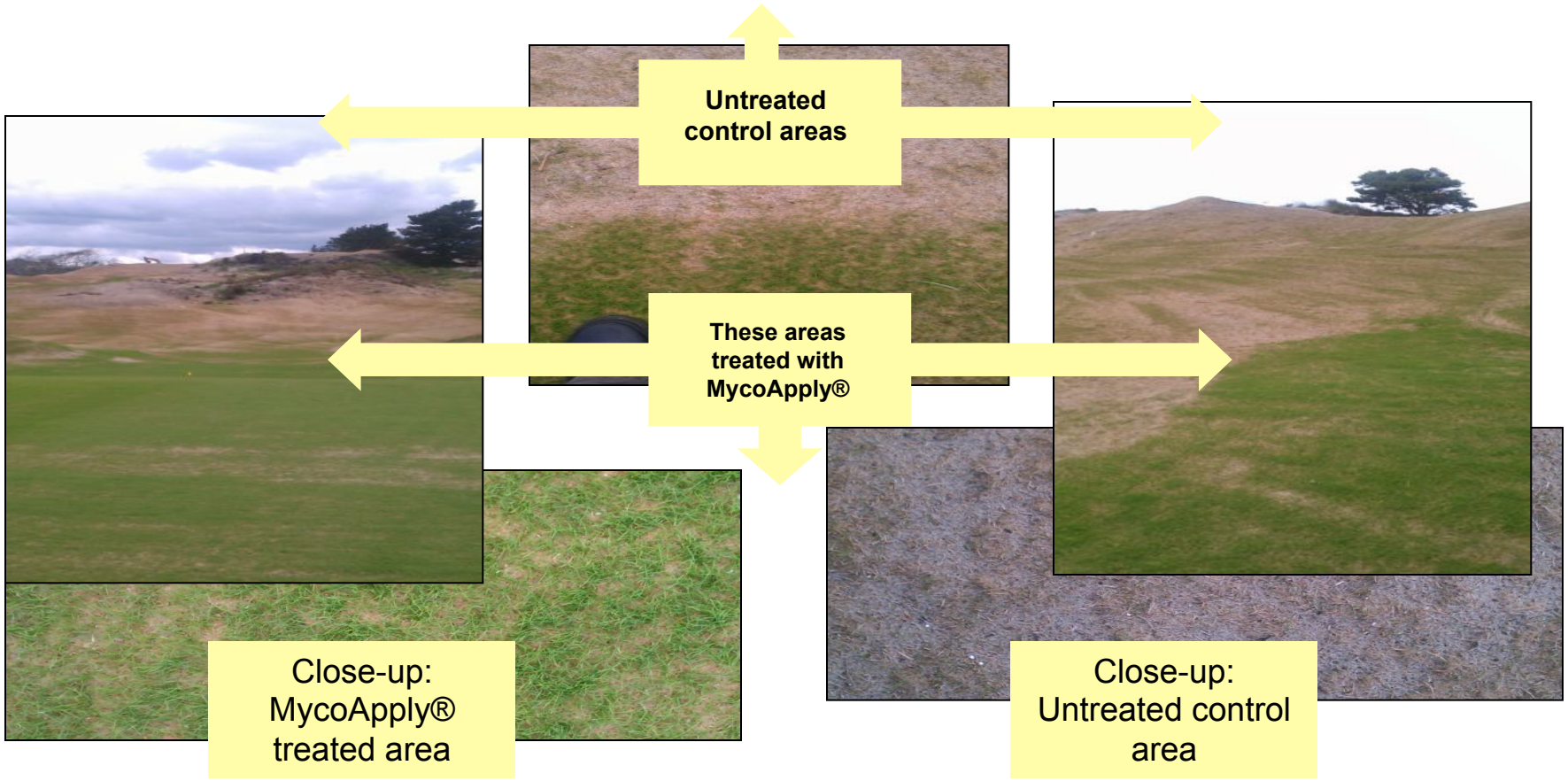
# SOME OF THE PRIMARY PLANT BENEFITS DERIVED FROM MYCORRHIZAL FUNGI:

- Improved establishment, growth & survival

# 2011 Turf Seeding Trial with mycorrhizal Inoculum at a Coastal Pacific Northwest Golf Course Project




- **Seed application method:** Hydro-seeding.
- **Mycorrhizal inoculant tested:** Ultrafine Endo (powder) mixed in tank.
- **Seed:** Fine Fescue blend
- **Seed Rate:** 8 lbs/1000 sq. ft.
- **Fertilizer pre-applied to site:** 6-18-18 @ 41.66 lbs / 1000 sq ft. (N=2.5 lbs urea treated with *NutriSphere* –N Stabilized Nitrogen / 1,000 sq ft)

- **Seeding Date:** May 20, 2011
- **Date of Photos:** June 2, 2011. ***13 days elapsed.***
- **Other inputs:** Entire trial areas received pre-application of gypsum and Dolopril (dolomite lime powder.) An 8-2-4 organic fertilizer and a micro-nutrient package was applied via the tank mix.

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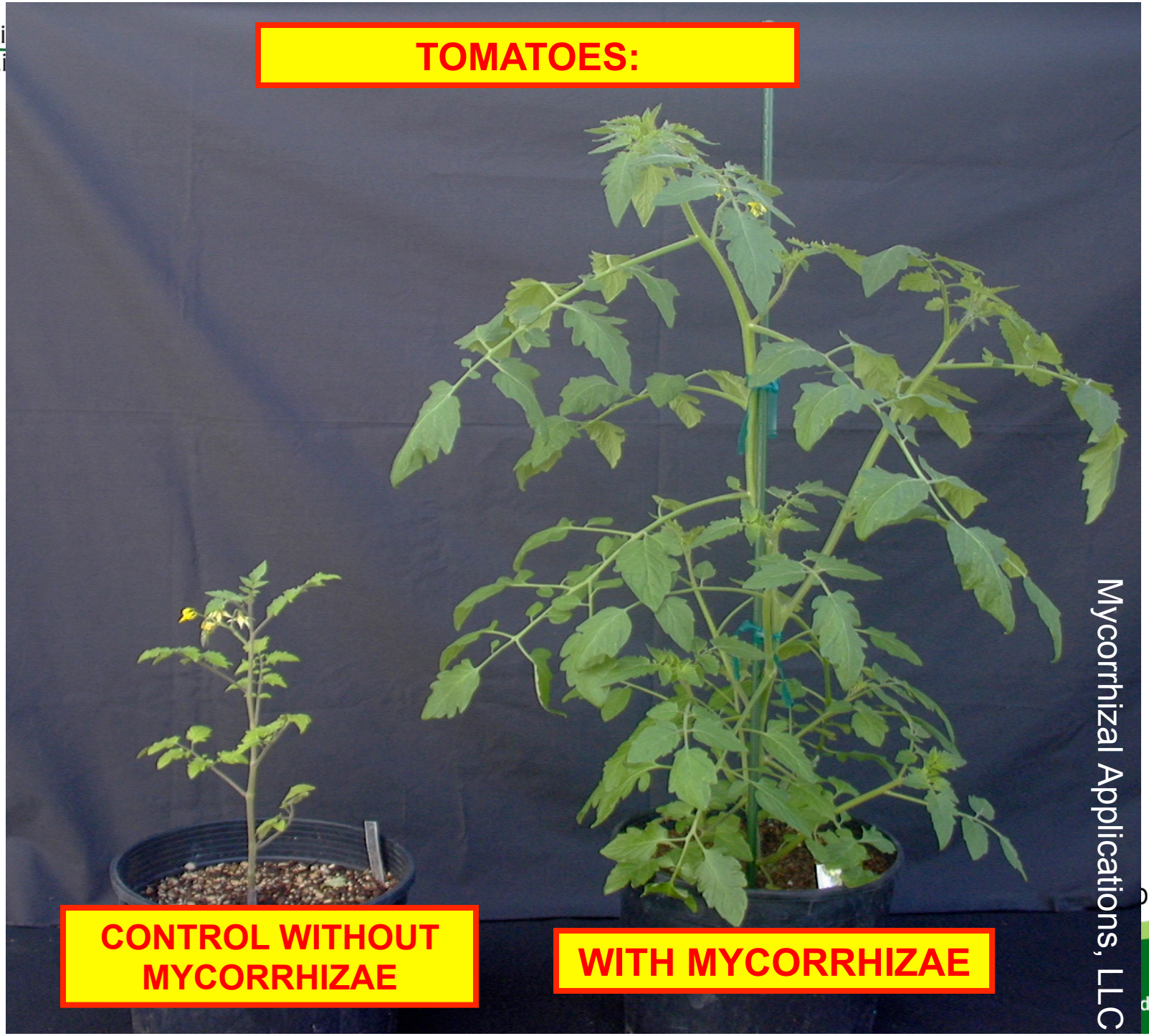
TOMATOES:
CONTROL WITHOUT MYCORRHIZAE
WITH MYCORRHIZAE
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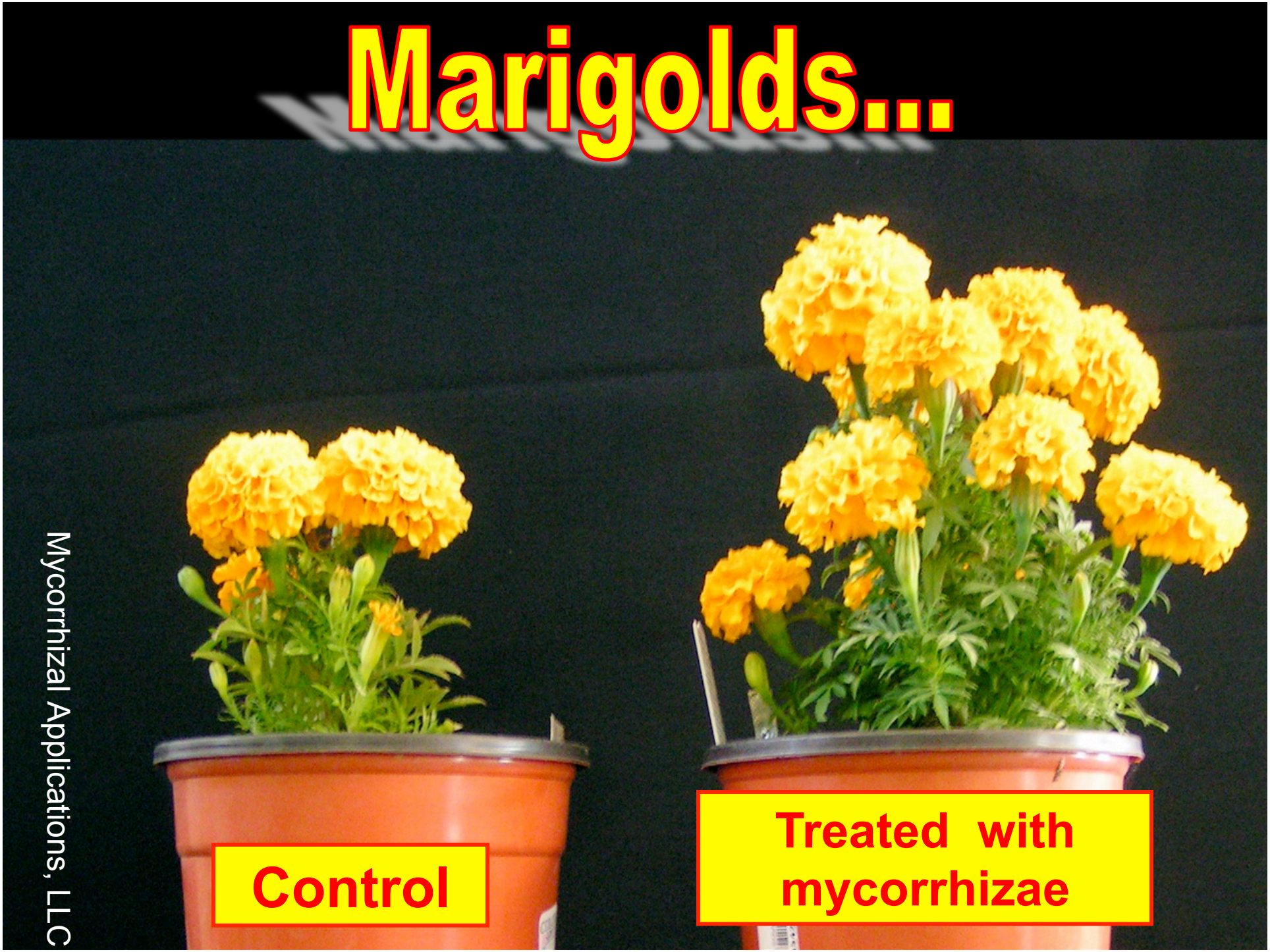
# Marigolds...

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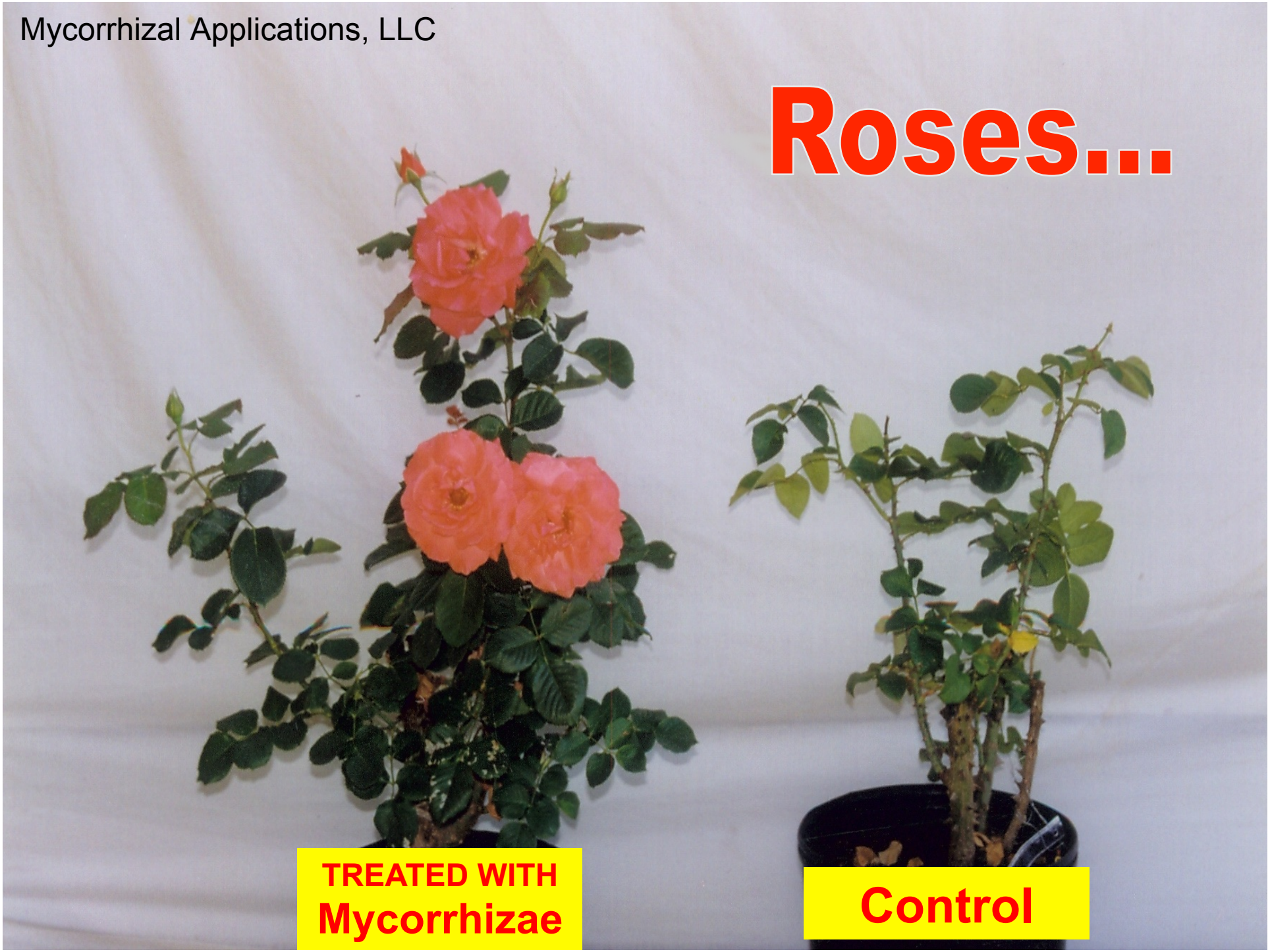
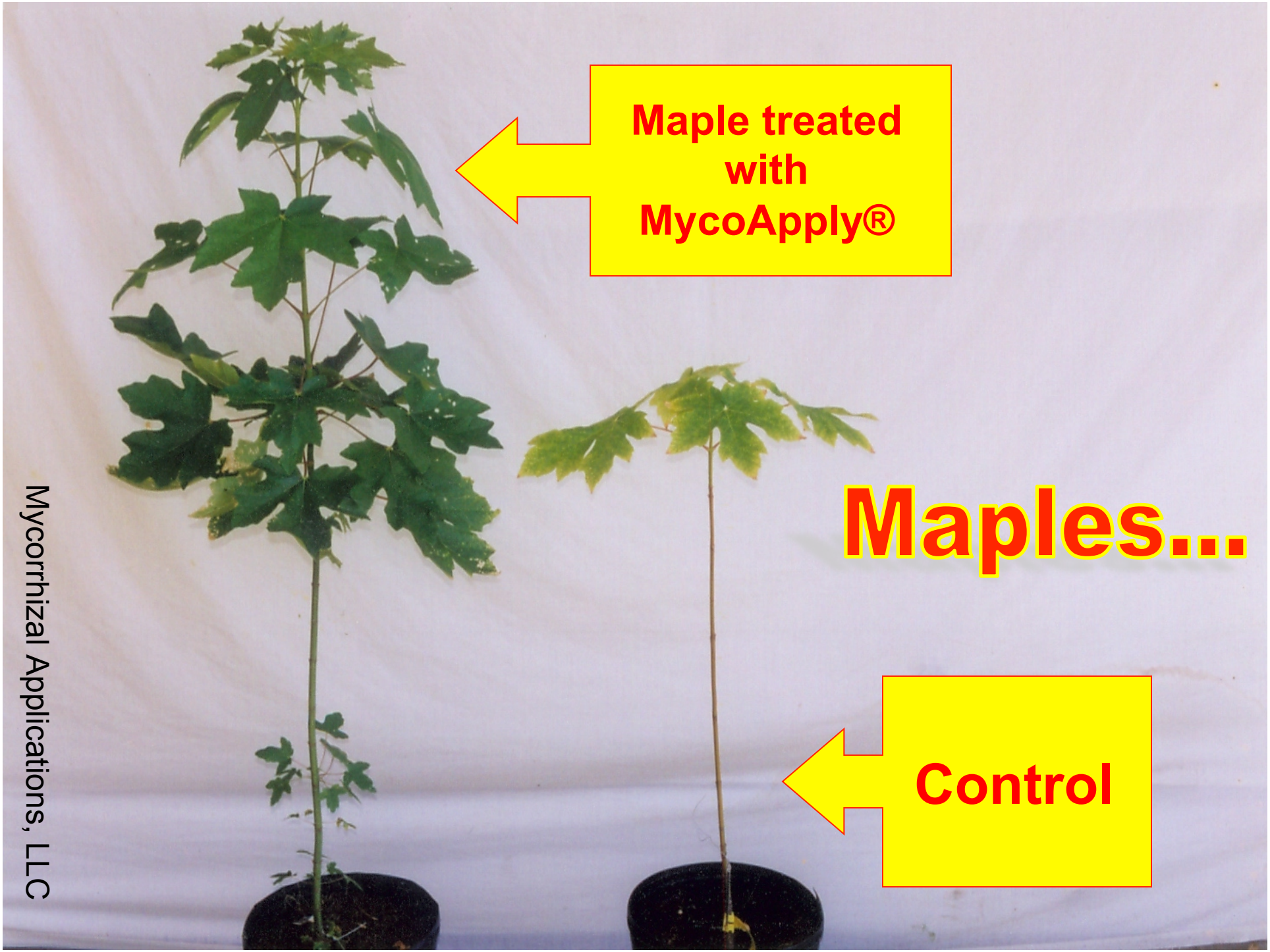
# Roses...



# SNAPDRAGONS: 14-DAY GROWTH TRIAL


Maple treated with MycoApply®
Maples...
Control
Mycorrhizal Applications, LLC

Mycorrhizal Applications, LLC

# PLANTING WITH MYCORRHIZAE...

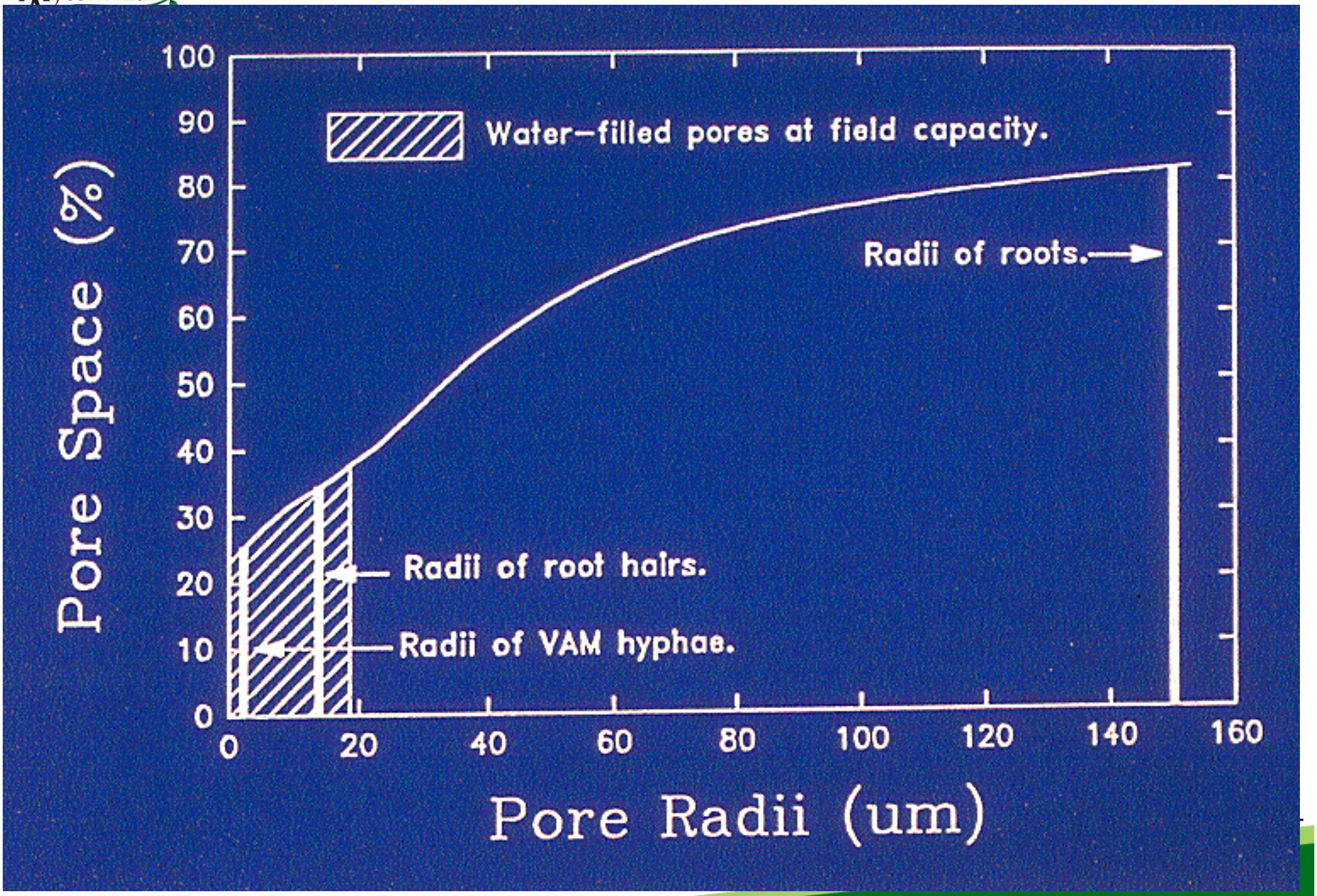
## BEFORE

## AFTER

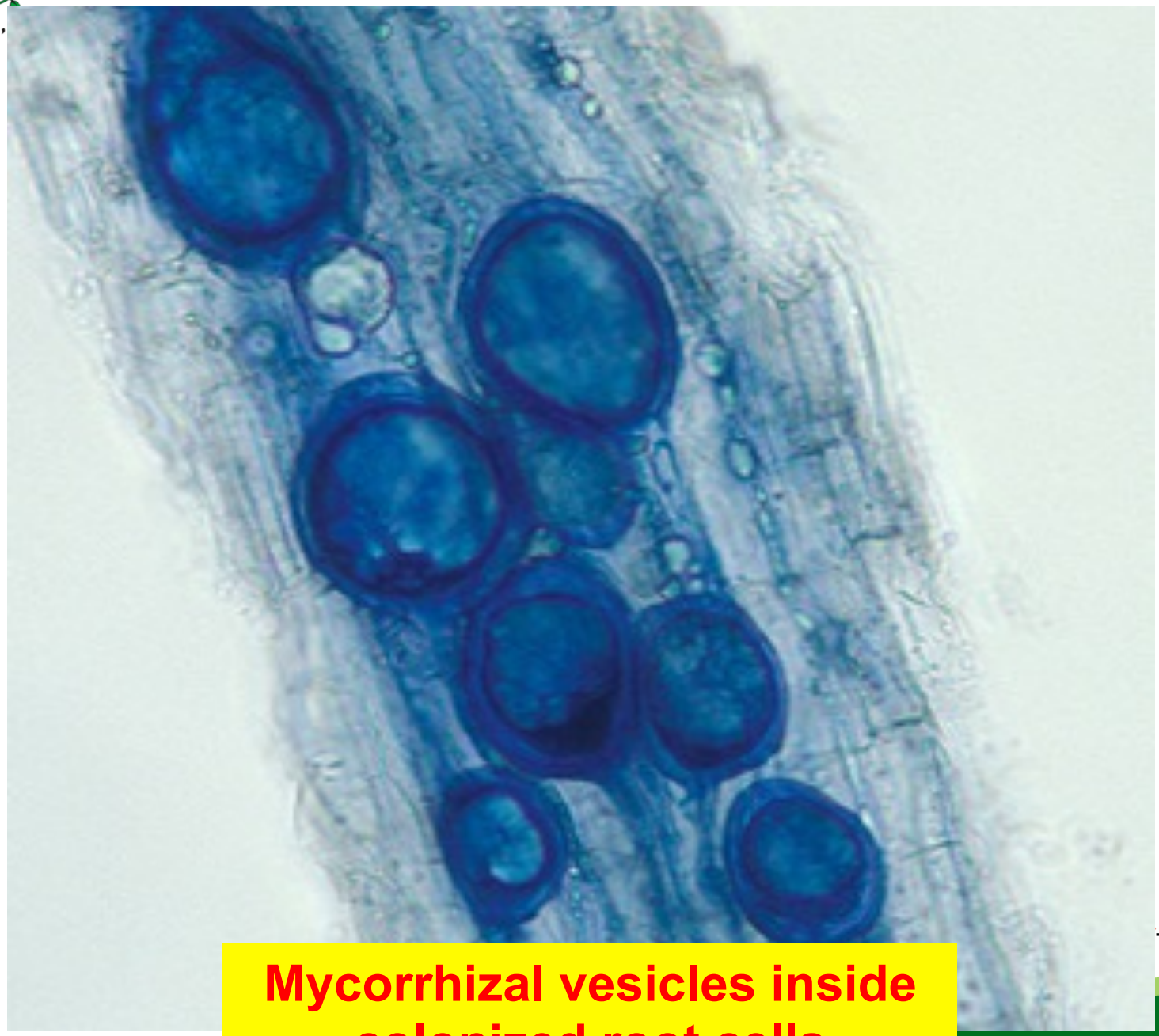
**(2 months later…)**

# SOME OF THE PRIMARY PLANT BENEFITS DERIVED FROM MYCORRHIZAL FUNGI:

- Improved water uptake and drought tolerance


Pore Space (%)
100
90
80
70
60
50
40
30
20
10
0
Water–filled pores at field capacity.
Radii of roots.
Radii of root hairs.
Radii of VAM hyphae.
0
20
40
60
80
100
120
140
160
Pore Radii (um)

Mycorrhizal Applications,



**Mycorrhizal vesicles inside colonized root cells**

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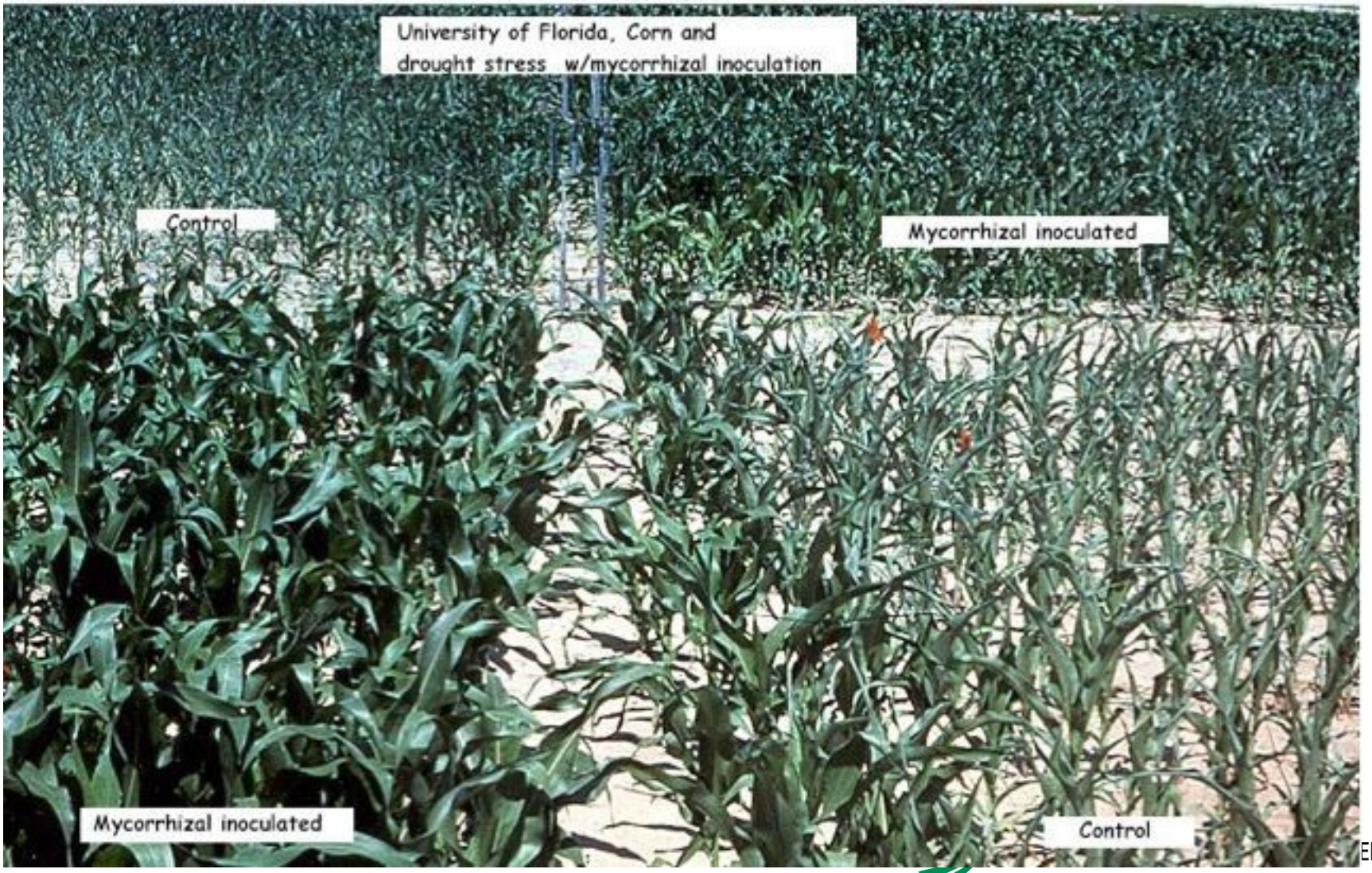


EMICAL

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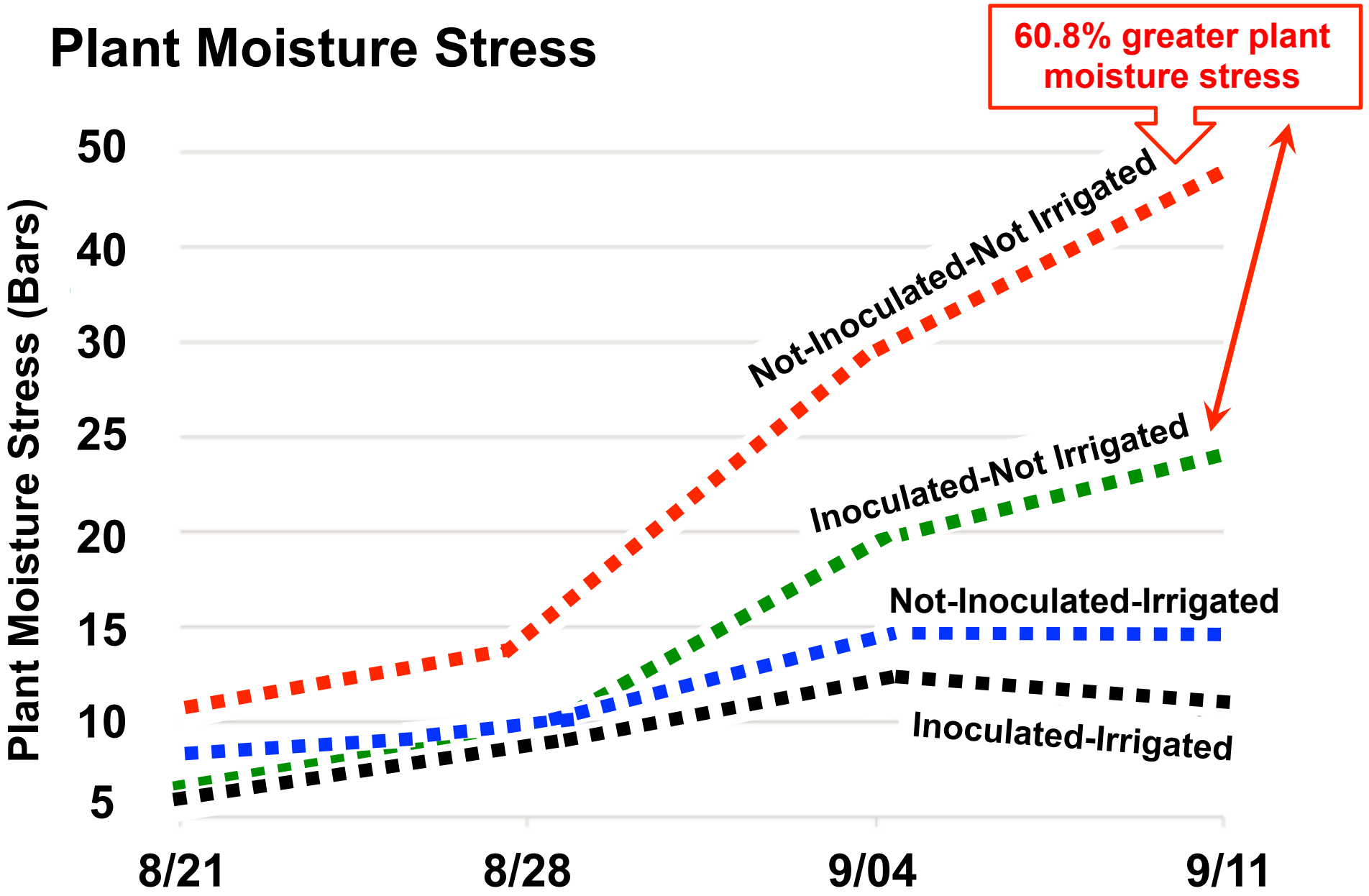
# Plant Moisture Stress




Treatments with different colors are significantly different (*P < = 0.1) as determined by one-way ANOVA.*

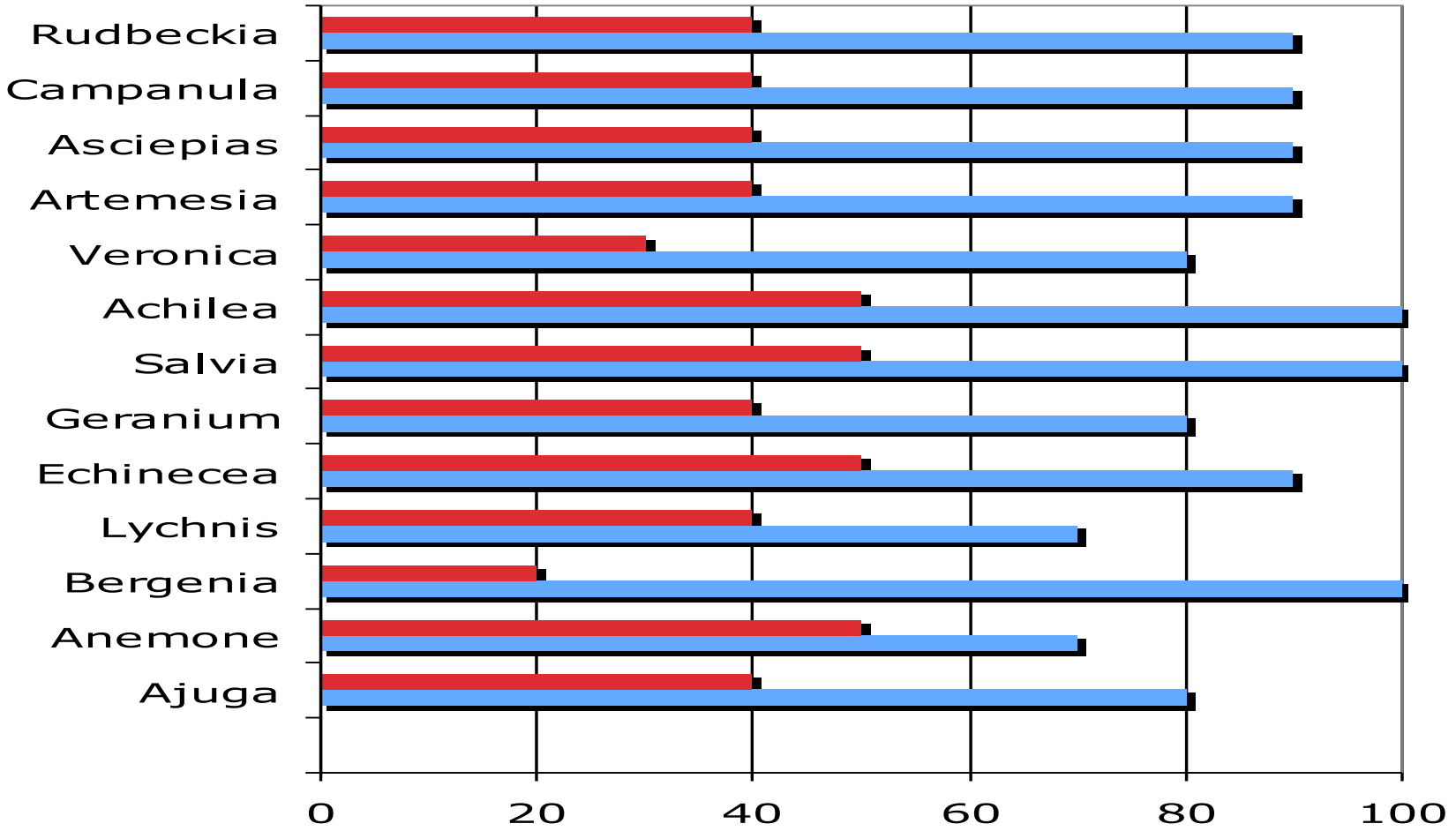
The effect of inoculation with the mycorrhizal fungus *Glomus intraradices* and extended drought on transplant survival of perennial herbaceous plants.

-Klironomos, et al 2008 University of Guelph, Ontario, Canada

**DROUGHT TOLERANCE!**

Survival without mycorrhizae **AVERAGE: 41%**

Survival with mycorrhizae **AVERAGE: 90%**



Mycorrhizal Applications, LLC

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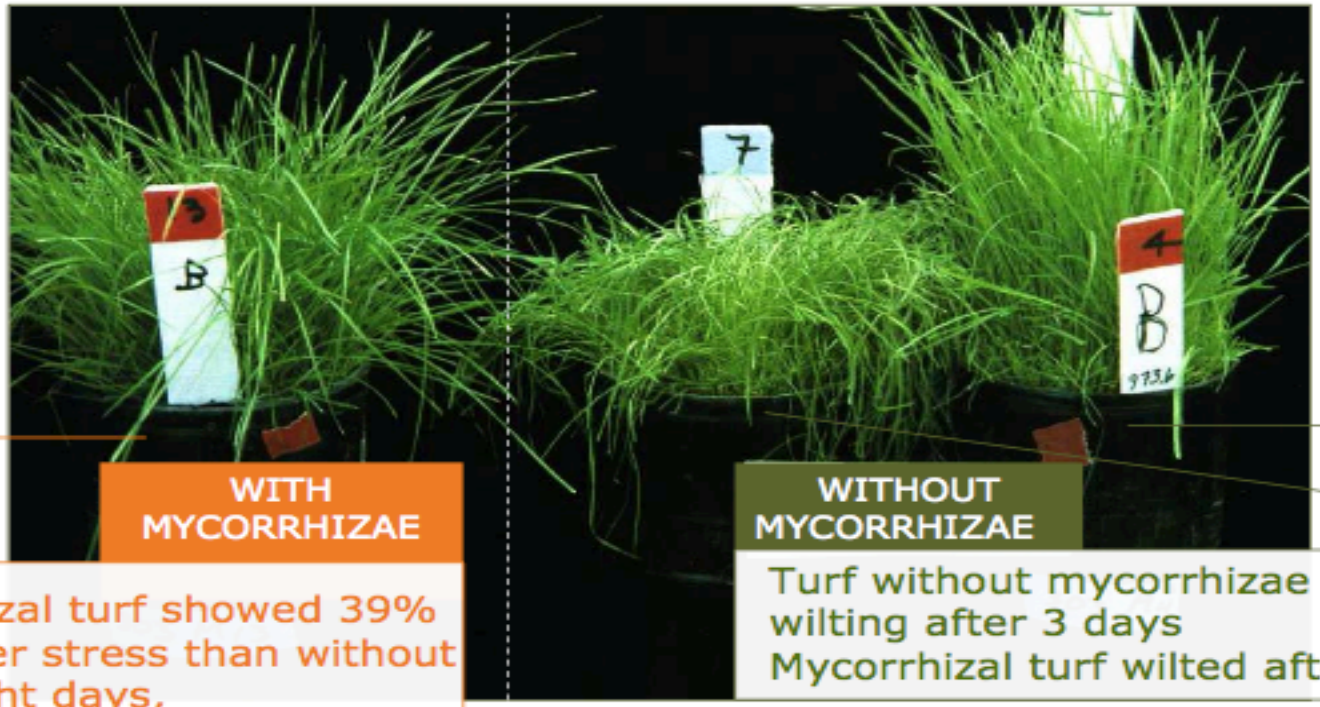
# RESULT: Water use

## Model tested: Penncross




Mycorrhizal turf showed 39% less water stress than without
After eight days, the difference was 60%

Turf without mycorrhizae began wilting after 3 days
Mycorrhizal turf wilted after 5 days

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# 2014 Almond Tree Drought Trial

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# Inoculated corn plants survived 28% longer in drought

# The Effects of Mycorrhizal Inoculation o the Drought Stress Tolerance of Corn

Nathan Hankes and Bill Anderson Ph. D.

• University of Wisconsin-River Falls •

## Background

Mycorrhizal fungi alter plant-water relations in several ways, but the potential role of the fungal hyphae as regulators of plant water uptake remains a controversial issue. Many mycorrhizal inoculants have been introduced into the market that claim the ability to improve water uptake, thereby reducing drought stress. Since irrigation water is becoming increasingly scarce and global climate changes are creating weather pattern fluctuations, these products are receiving considerable attention; however, the effect of soil type, specific crop, and weather patterns on the ability of the mycorrhizae to affect plant-water relations is largely unknown.

## Objectives

• Determine the soil water content percentage at the time of plant death for both mycorrhizal inoculated and un-inoculated corn plants.

• Determine whether mycorrhizal inoculation is a viable agronomic tool for growers.

## Methods

Conventional corn was planted into 2-gallon pots and grown in a greenhouse setting. Two treatments were replicated ten times. The pots were filled with a 1:1 mix of pasteurized field soil and a peat moss/composted bark mix. One trial had two grams of MycoApply® Micronized Endo Powder incorporated in the soil at the time of seeding. The experimental design was completely randomized.

The plants were allowed to grow in a regulated climate of 21°C during the day and 18°C at night, with a sustained relative humidity of 60 percent. All plants were watered regularly for five weeks. On the 36th day a drought was initiated.

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## Methods continued

The plants were allowed to wilt and die. When the sixth foliar leaf wilted below a 45° angle in relation to the stalk or the stalk lodged, the plant was considered dead, and an approximately 300 g soil sample was collected. Soil was collected 5 cm below the soil surface near the root mass using a small spade.

The soil sample was added to a beaker, weighed, and placed in an oven at 105°C until its mass stabilized. The moisture content (MC) of the soil as a percentage was calculated using the following equation:

$$MC = \frac{B - C}{C - A} \text{x } 100$$

A – Mass of beaker
B – Weight of moist soil and beaker
C – Weight of dried soil and beaker

Figure 1: The corn plants 8 days into a drought.

## Results

A slight average MC difference appeared between inoculated and un-inoculated plants at the time of death. On average, inoculated corn plants died with 0.526% less water in the soil, but after running one-way ANOVA data analyses, it was determined that there was no statistical difference between treatments. Inoculated plants did, however, survive 5.6 days, or 28%, longer during a drought than un-inoculated plants, on average, at the 95% level of significance.

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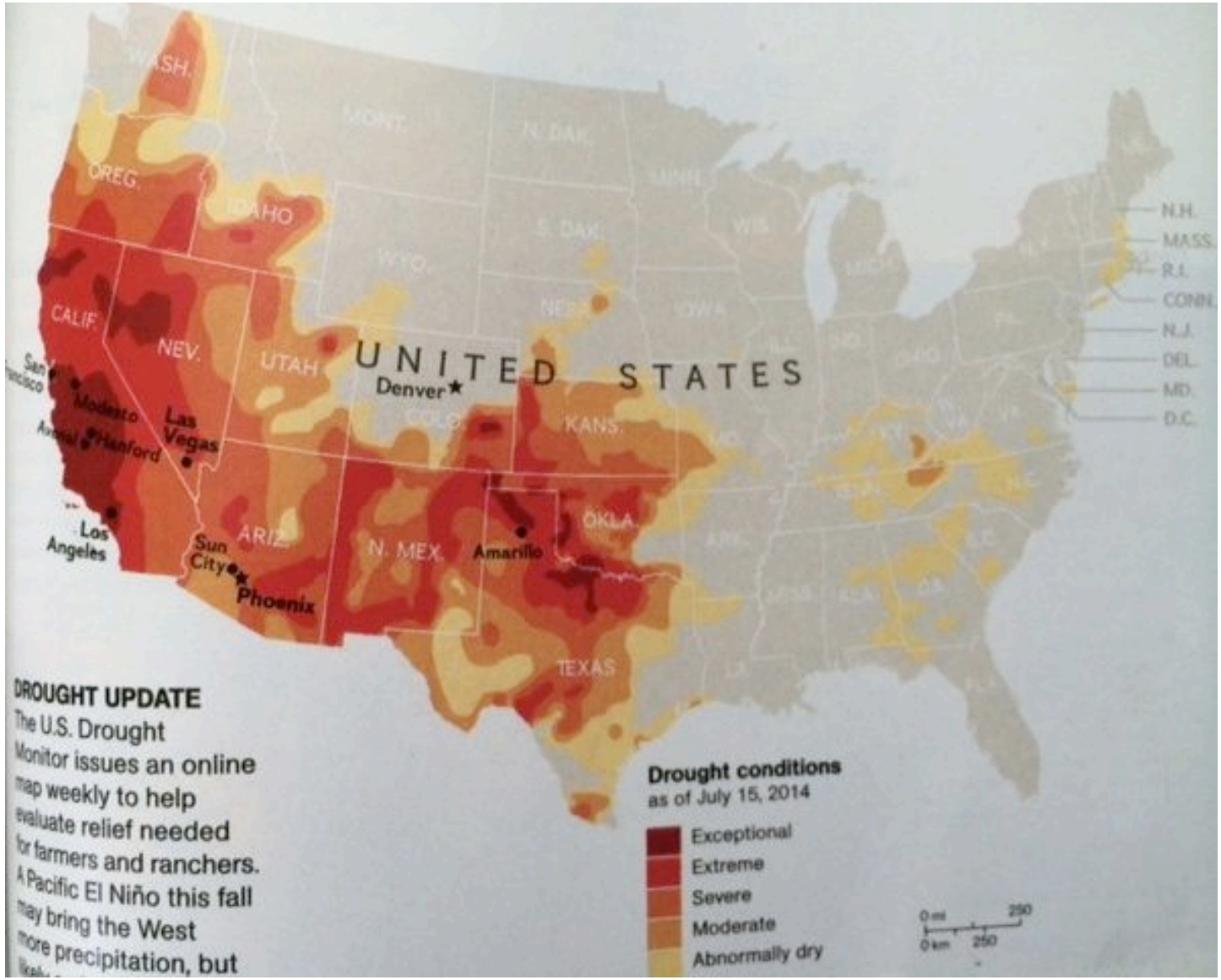


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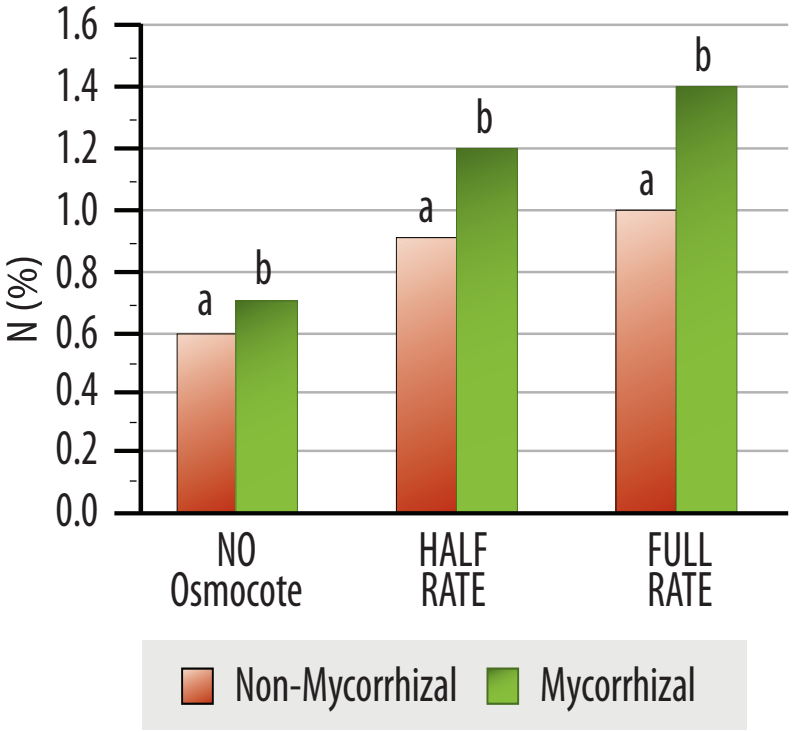
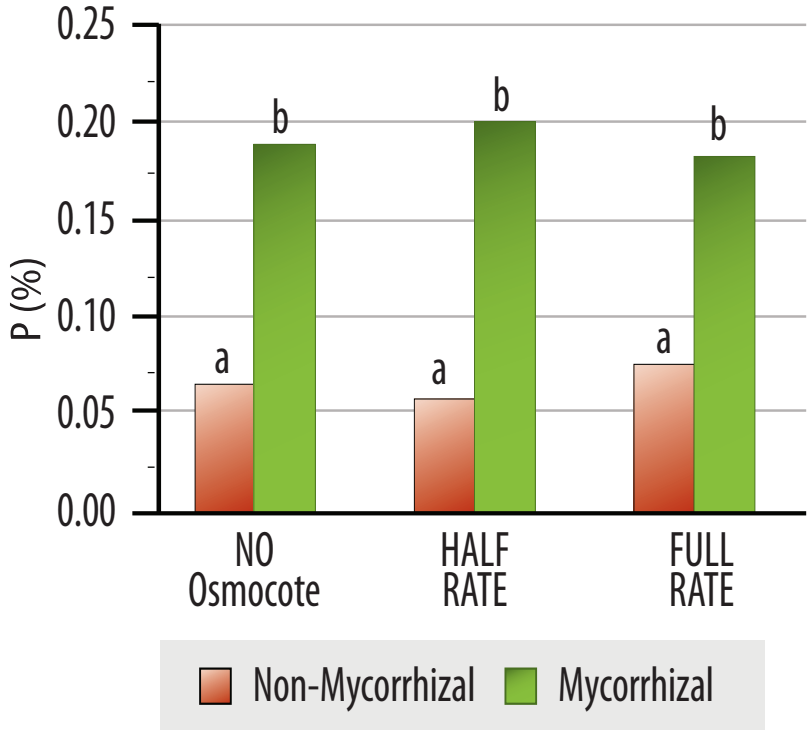
# Improved N and P nutrition

## Nitrogen and Phosphorus in Shoots




Corkidi et al. 2009 University of California Riverside · Rhus integrifolia grown for 8 weeks. Osmocote® 18N-6P-12K controlled release fertilizer.

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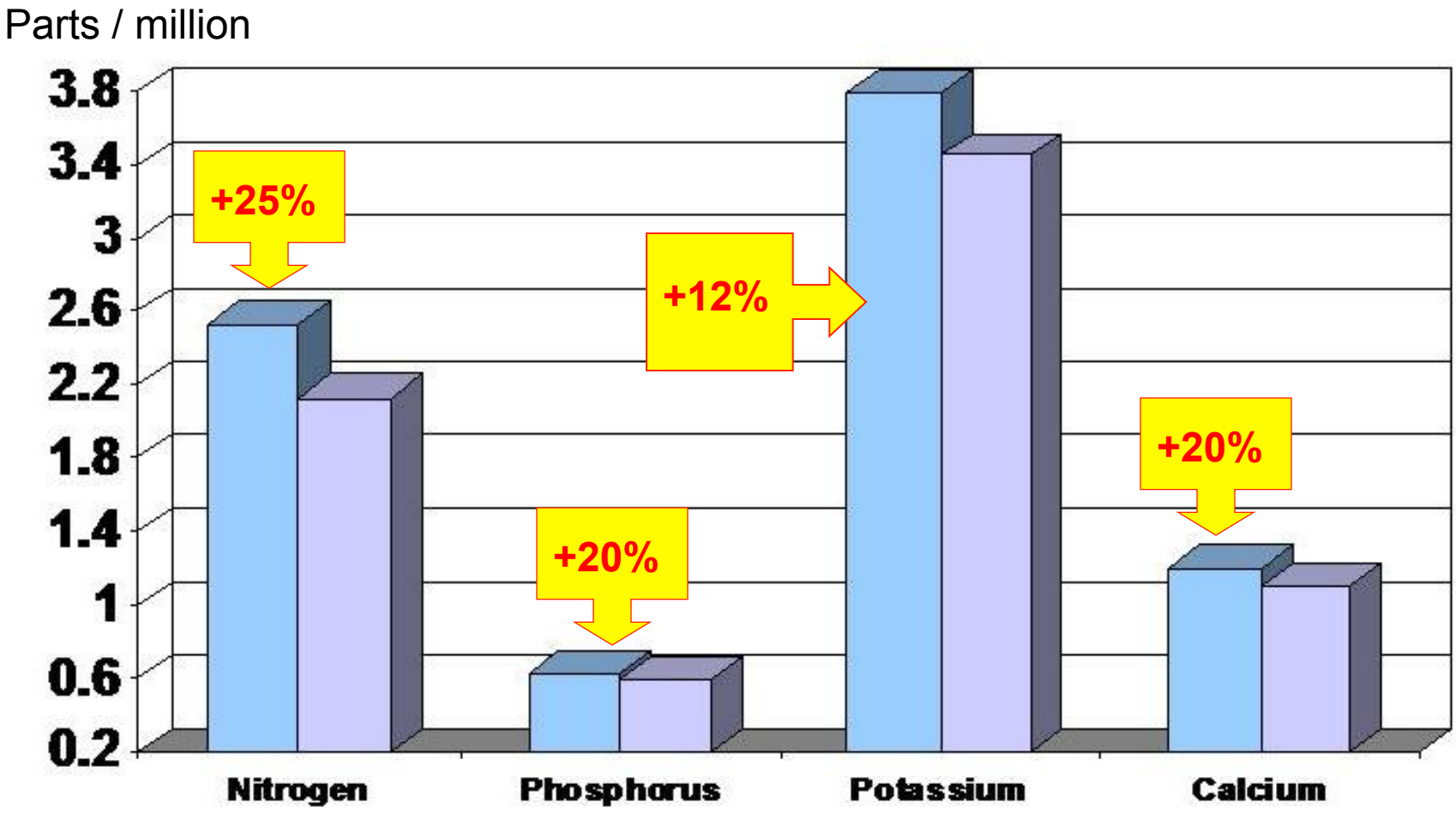
# Improved Nutrient Uptake Efficiency:

**Foliar nutrient levels of turf grass with and without treatment with mycorrhizal inoculant measured 50 days after germination**

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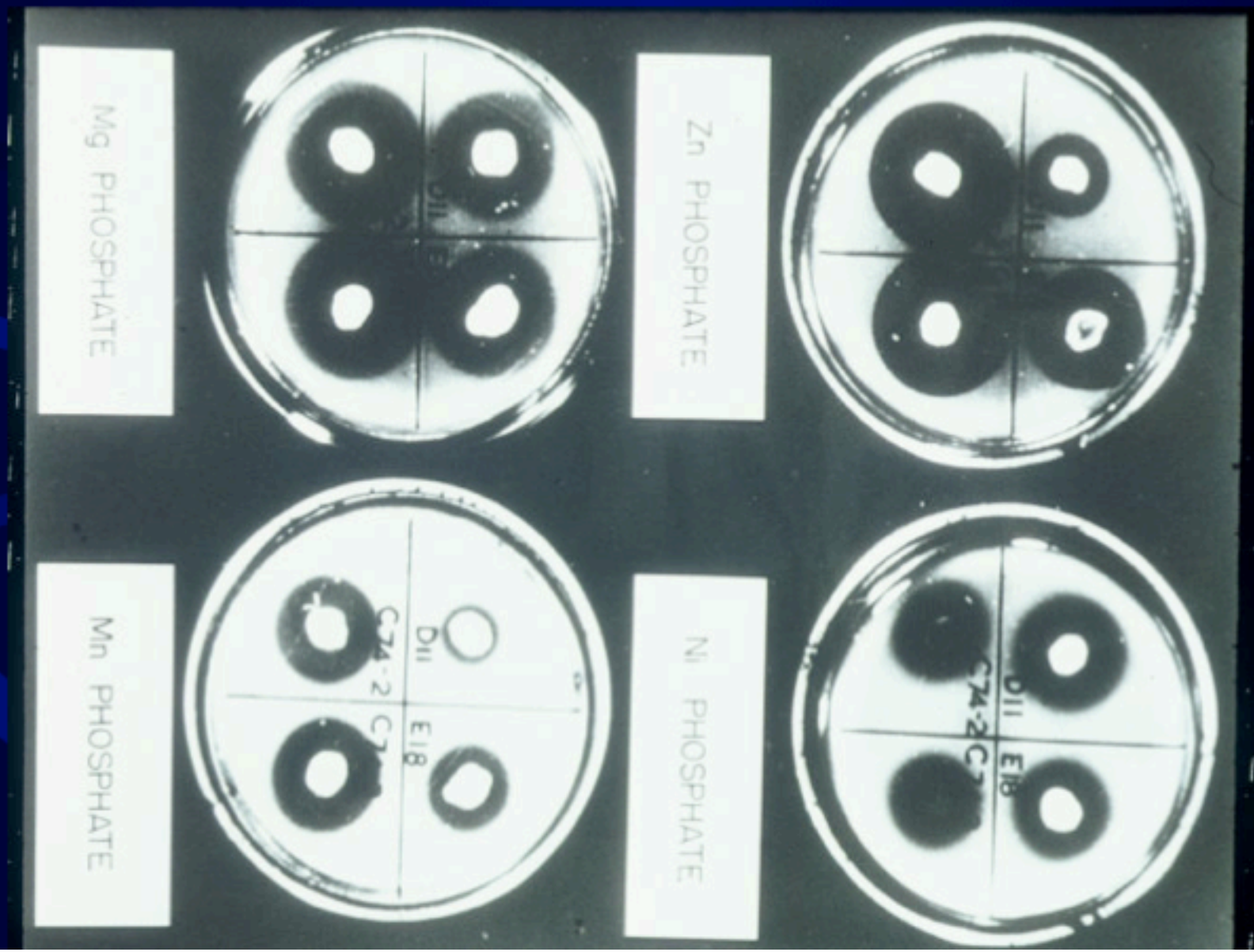
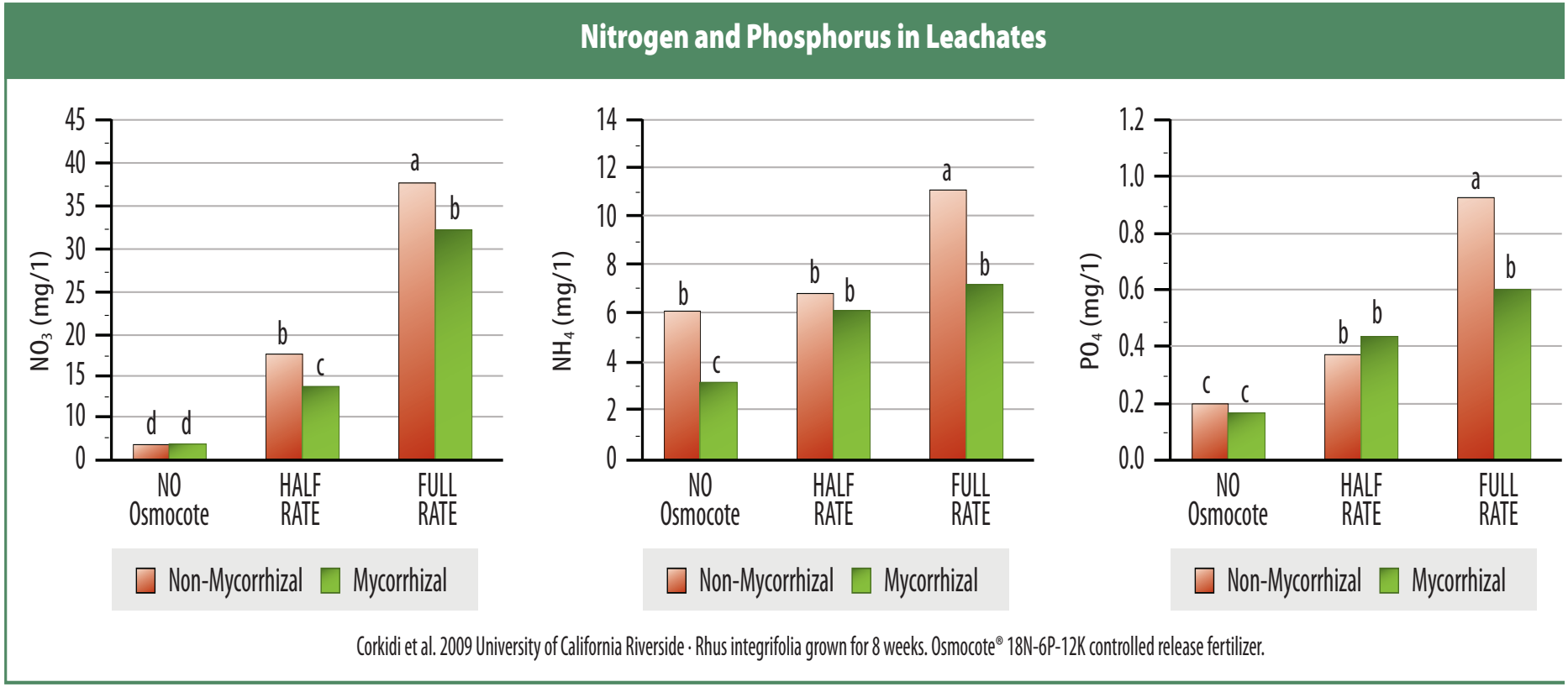
# ENZYME PRODUCTION



# Reduction in Nitrogen and Phosphorus Leachates




Corkidi et al. 2009 University of California Riverside · Rhus integrifolia grown for 8 weeks. Osmocote® 18N-6P-12K controlled release fertilizer.

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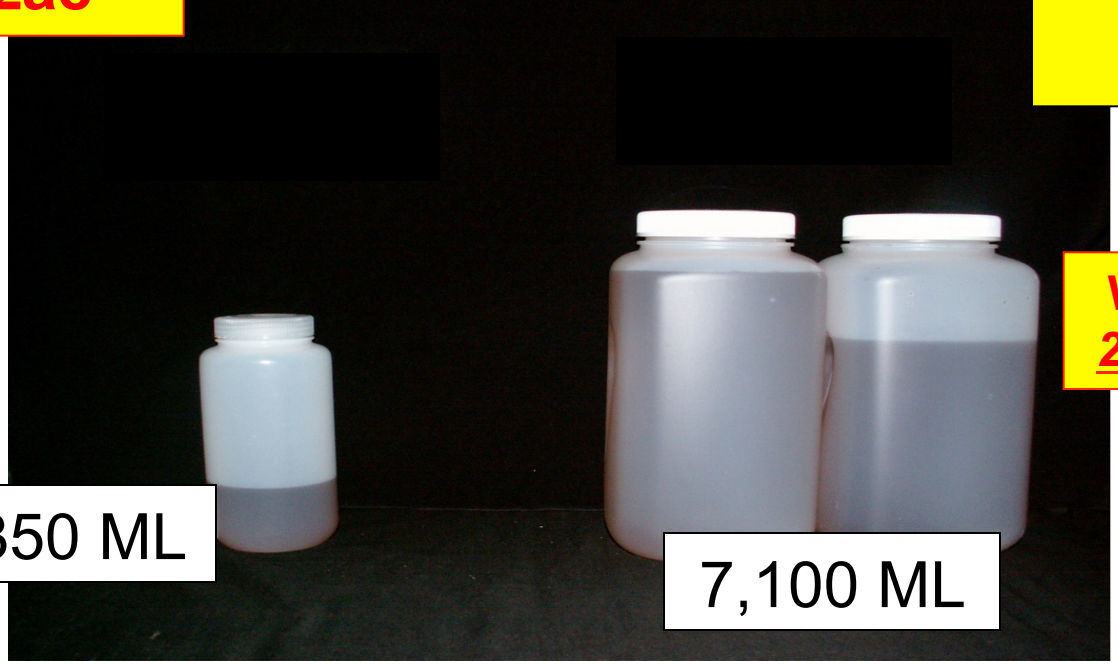
# WATER EFFICIENCY:

**fertilizer + mycorrhizae**

**fertilizer only**




**Water loss was *20 times* greater**

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A large Northern California grower conducted this growth trial with cotoneaster and star jasmine.

There were 50 replications of all the inoculated and non-treated plants.

This picture was taken at the start of the 2nd growing season.

Those on the far right side of the picture received 20% and 30% reductions in fertilizer respectively, yet they look as good or better than the controls.

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# IMPROVED FERTILIZER UTILIZATION

# MODERN AGRICULTURE DEPENDS UPON PHOSPHORUS

- 15% utilized by plants
- Roots utilize P in 1-2mm band
- Double food production 2050
- P is a non renewable resource
- US reserves used up by 2050

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# DO WE HAVE ENOUGH PHOSPHORUS TO FEED FUTURE GENERATIONS?

- World Production Peak -2035
- Known Reserves depleted by end of the century
- Morocco and Western Sahara 75% of the world's reserves
- USA 2% of world's reserves

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# MAJOR PROBLEMS LINKED TO PHOSPHORUS

- Blue Green Algae
- Hypoxia Zones
- Disruption of Food Chains
- Lake and River Pollution



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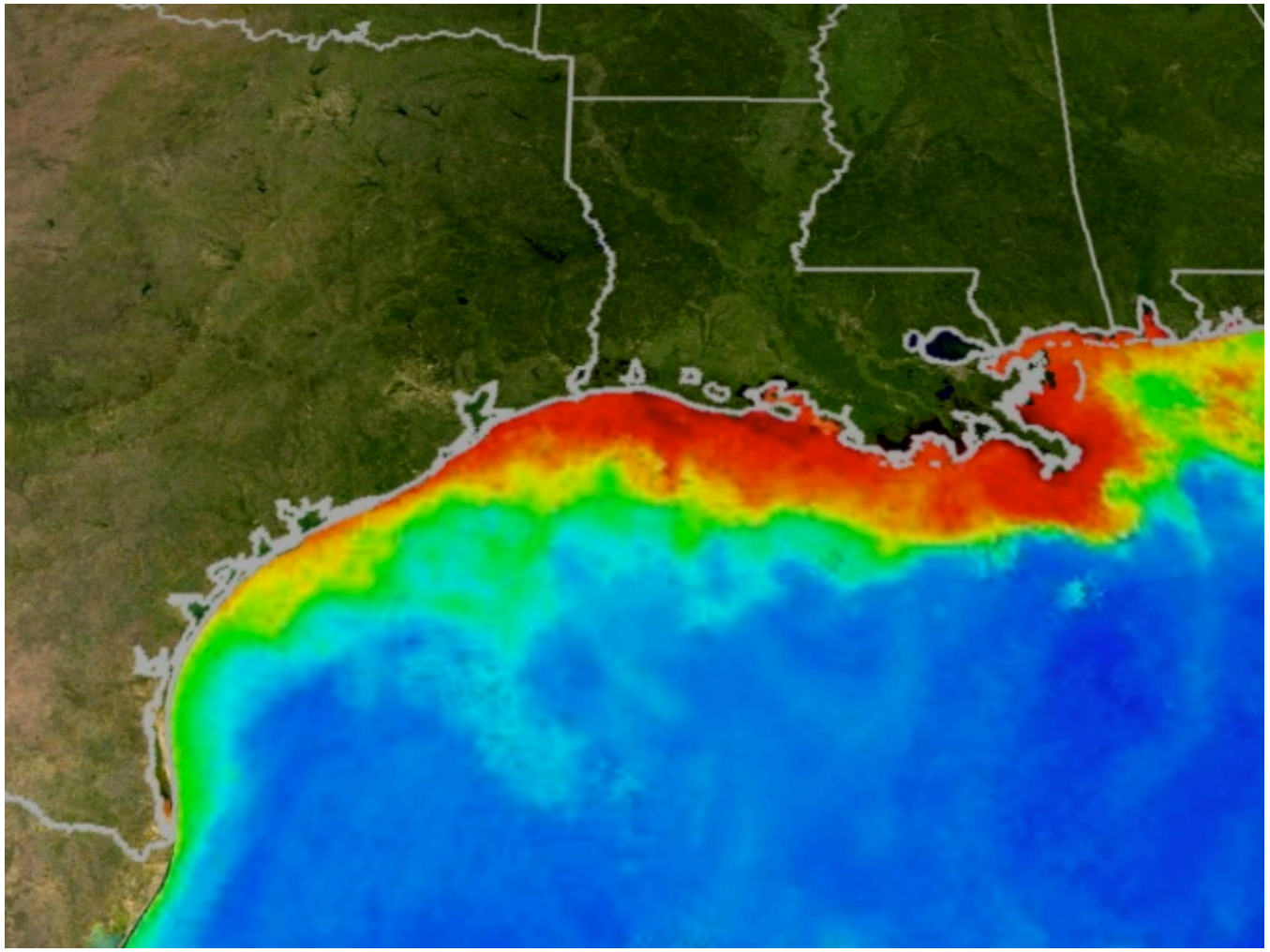

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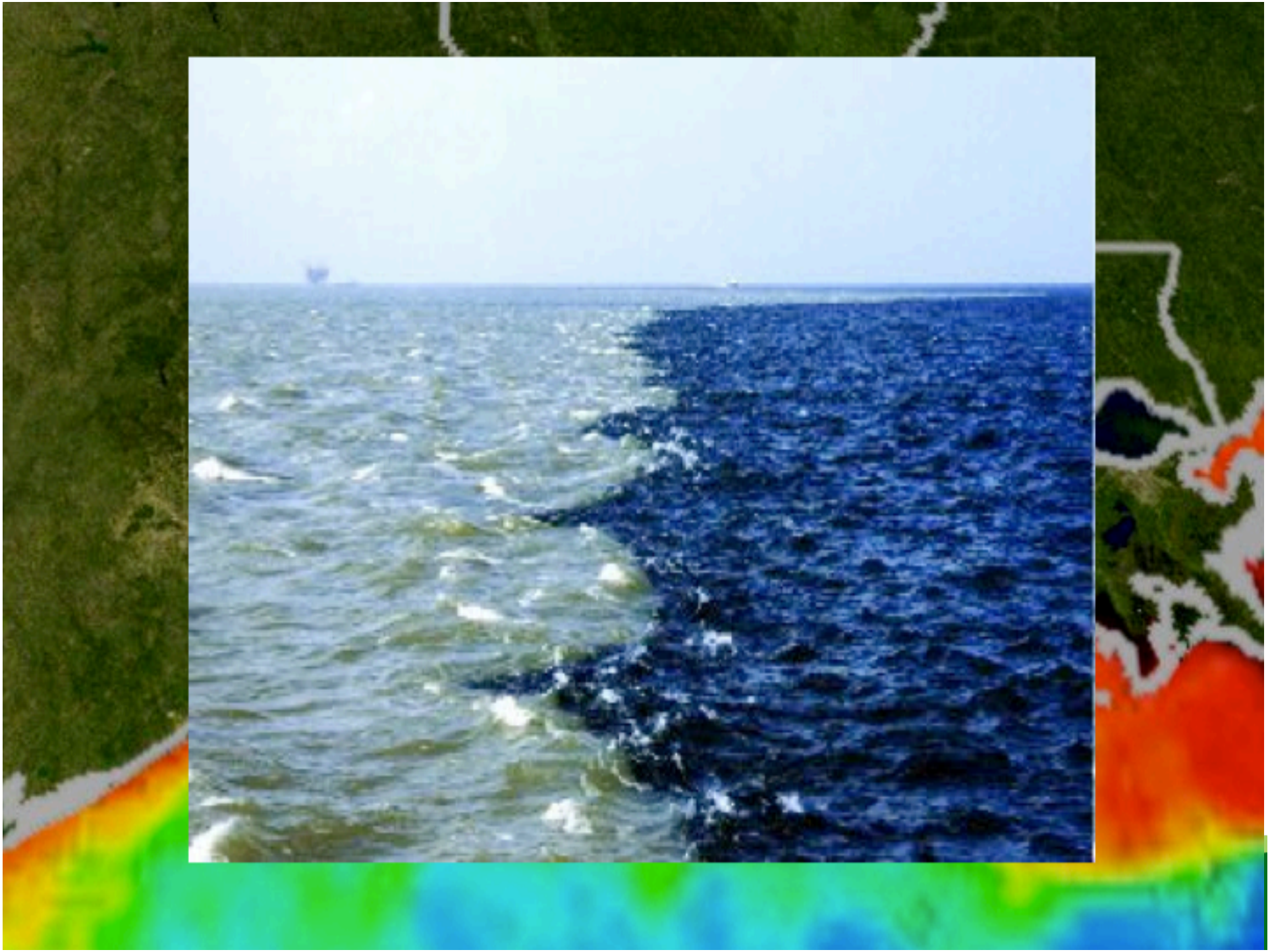

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## Environmental benefits of

## Mycorrhizal Inoculation

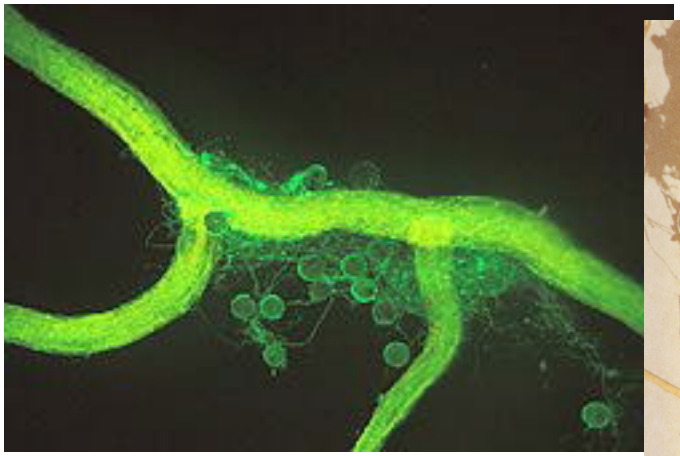
### in Landscape and Horticulture:

- Reduces groundwater contamination
- Reduces runoff contamination into lakes, streams and oceans
- Prevents wind and water erosion by improving soil stability
- Offsets global warming by sequestering atmospheric Carbon ($CO_2$) in the soil

# SOME OF THE PRIMARY PLANT BENEFITS DERIVED FROM MYCORRHIZAL FUNGI:

- Improves soil structure

# GLOMALIN-1/3 OF THE WORLD'S SOIL CARBON!



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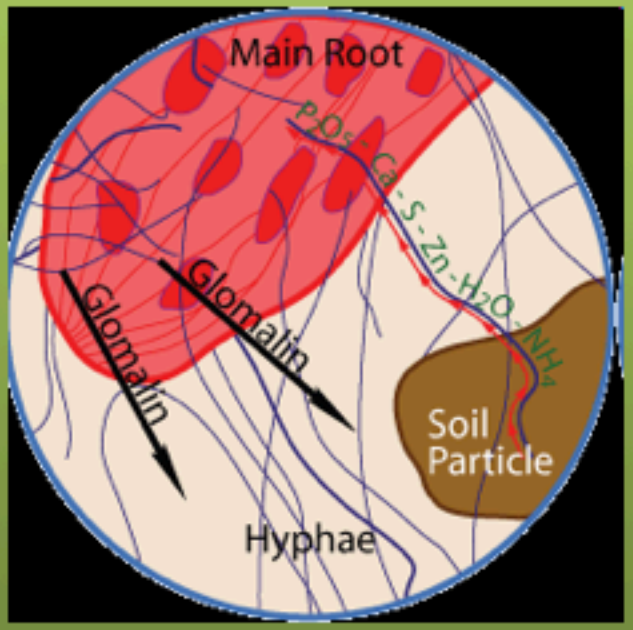
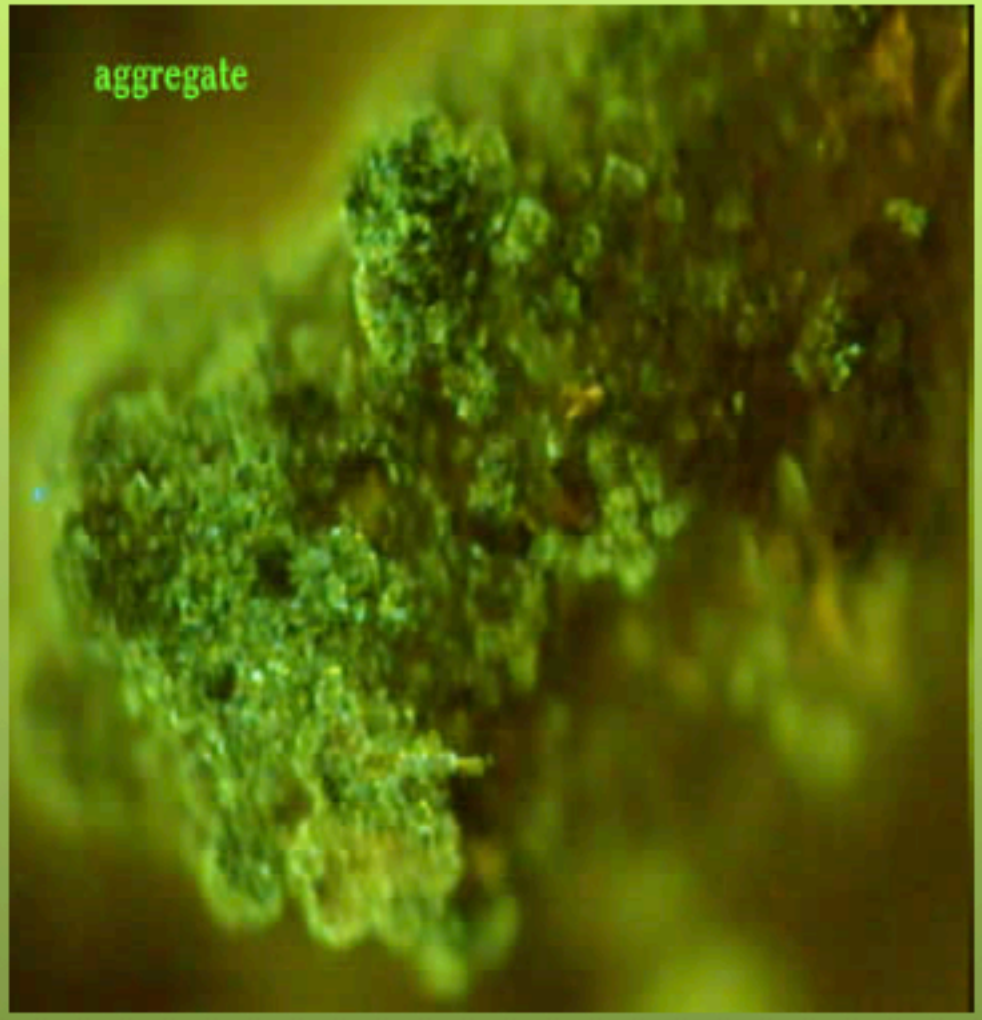
- Glomalin
  - Gives soils its tilth
  - Increases water and air infiltration
  - 30% of the carbon in the soil



# Aggregated Soil Structure

Glomalin contributes to the dark black color and “crumbly” texture we generally recognize in healthy soils. The black color is due to the Carbon content itself.

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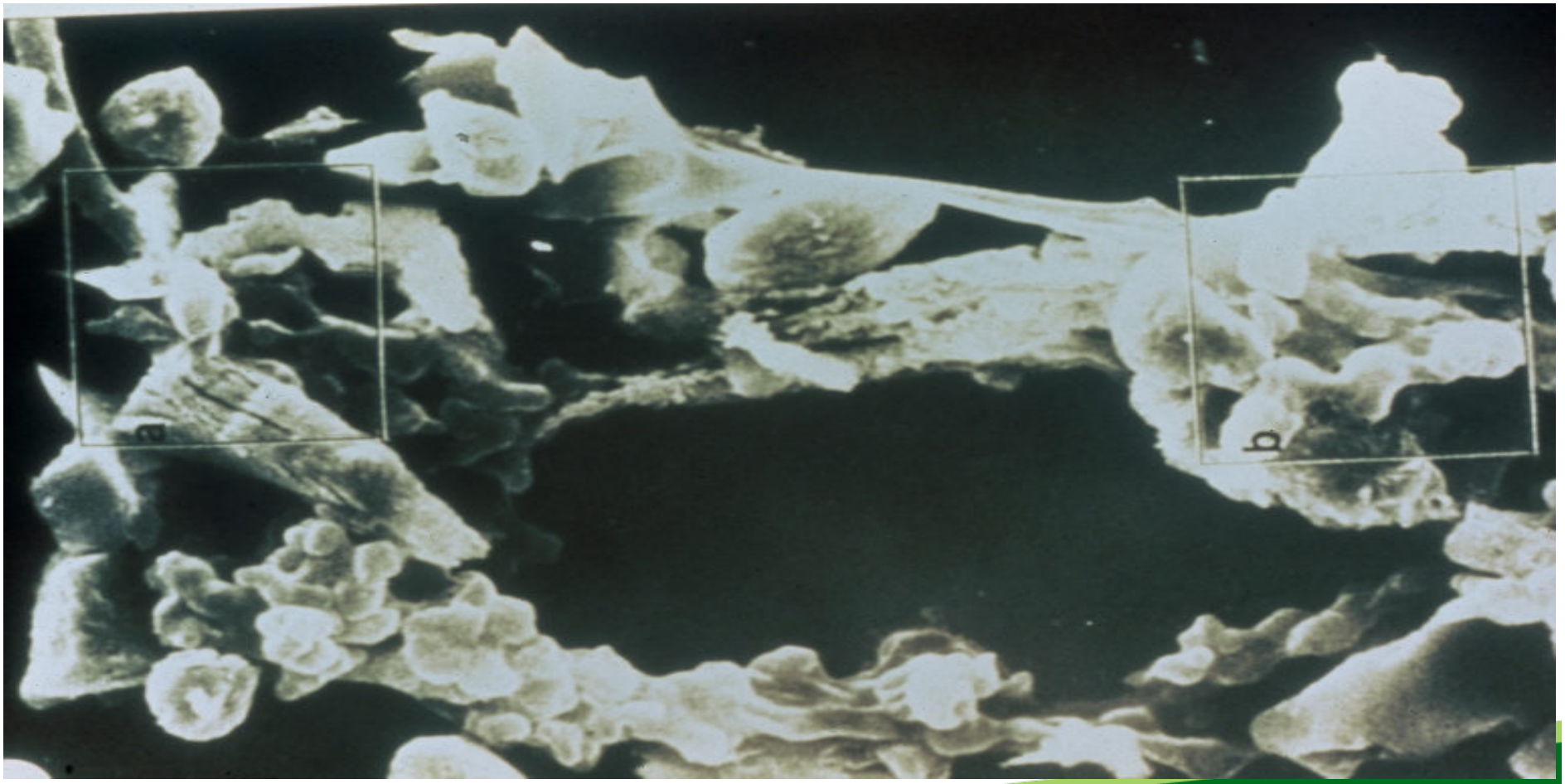
# SOIL STRUCTURE

***Glomalin is the "glue" that holds mineral and organic particles together to form soil aggregates.***



# Less soil erosion

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## *Performance Driven …*

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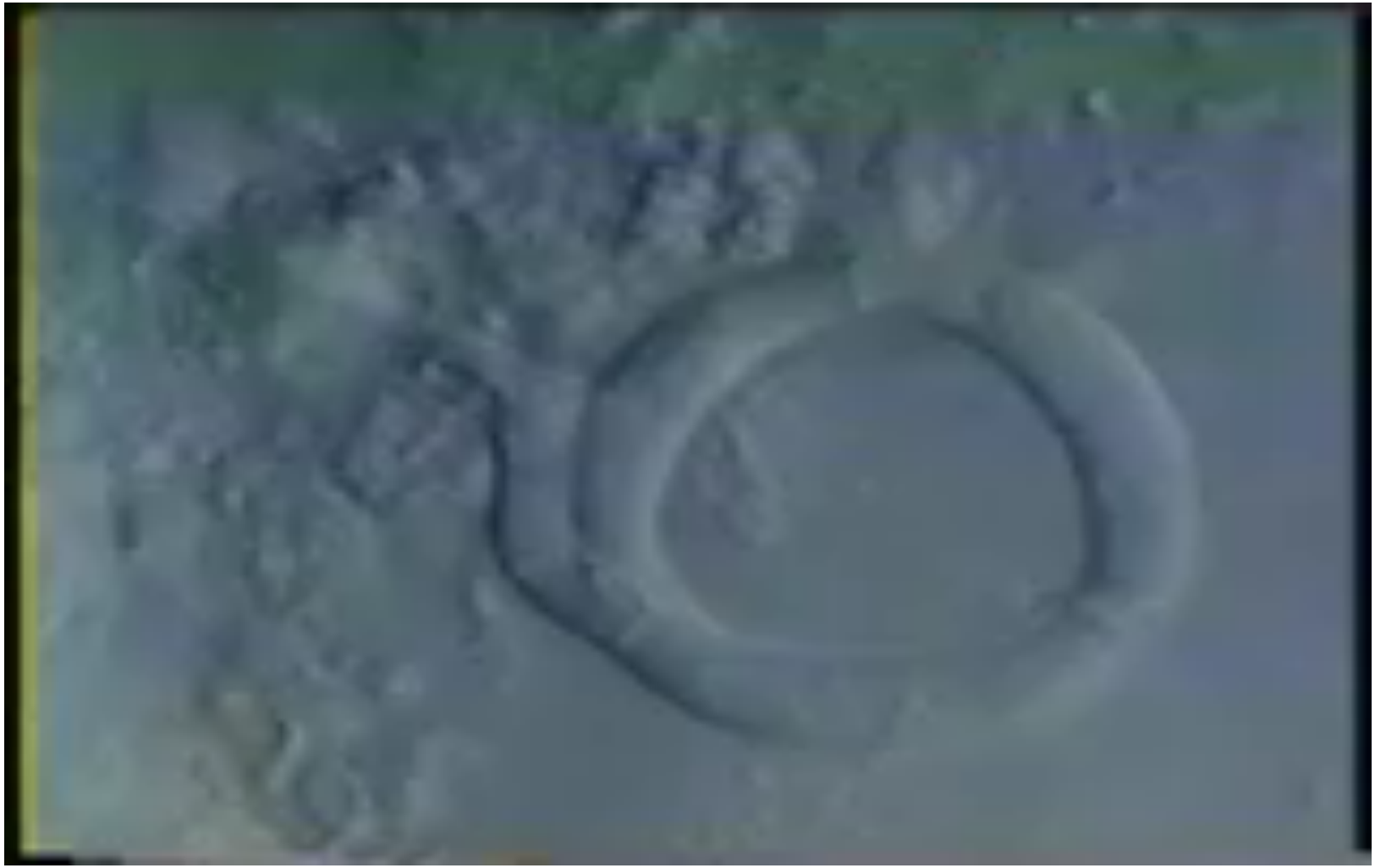
# SOME OF THE PRIMARY PLANT BENEFITS DERIVED FROM MYCORRHIZAL FUNGI:

- Parasitic nematode control

# “Soils” are alive!



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# Cross-section of a root cell colonized by ecto mycorrhizae

**Fungal Sheath**

**Hyphae**

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# Diversity matters! *If possible, look for mycorrhizal inoculants containing multiple species*

# 4 SPECIE MYCOAPPLY® FUNCTIONS

| Groups | Benefits | Glomus mosseae | Glomus aggregatum | Glomus intraradices | Glomus etunicatum |
|---|---|---|---|---|---|
| **Yield Increase** | Increases crop yield | x | x | X | x |
| **Nutrient Uptake** | Increases Nitrogen (N) and phosphorus (P) uptake | X | x | X | X |
| | Enzyme activity increases access micro nutrient uptake | X | | | X |
| | Tolerant of high fertility levels | | X | | |
| **Root Improvement** | Increases root and soil enyzme activity | | | | X |
| | Promotes root health | X | | | X |
| | Improves drought tolerance | | | X | X |
| **Plant Physiology** | Improves plant establishment | | | | X |
| | Increases flowering and fruiting | X | | | X |
| | Improves performance of palms and fruit trees | | X | | |
| | Improves performance in woody perennials | X | | | |
| **Plant Tolerance** | Improves plant performance in sandy soils | | X | | |
| | Improves plant salinity tolerance | | | X | |
| | Improves plant tolerance to a wide array of soil toxicities | | | X | |

# 4 SPECIES MYCOAPPLY® FUNCTIONS

Citations documented in published peer-reviewed research

| Groups | Benefits | Glomus mosseae | Glomus aggregatum | Glomus intraradices | Glomus etunicatum |
|---|---|---|---|---|---|
| **Yield Increase** | Increases crop yield | **5** | **3** | **10** | **11** |
| **Nutrient Uptake** | Increases Nitrogen (N) and phosphorus (P) uptake | **33** | **5** | **45** | **40** |
| | Enzyme activity increases access micro-nutrient uptake | **11** | | **6** | **15** |
| | Tolerant of high fertility levels | | **1** | | |
| **Root Improvement** | Increases root and soil enzyme activity | | | | **1** |
| | Increases root biomass | **3** | **2** | **10** | **13** |
| | Promotes root health, including root pathogen suppression | **23** | | **23** | **25** |
| **Plant Physiology** | Improves plant establishment, survival & growth | **33** | **7** | **46** | **50** |
| | Increases flowering and fruiting | **2** | | **5** | **1** |
| | Improves performance of palms, fruit and nut trees | **8** | **1** | **12** | |
| | Improves performance in woody perennials | **2** | | | |
| **Plant Tolerance** | Improves plant performance in sandy soils | **1** | **1** | | |
| | Improves plant salinity tolerance | **4** | | **3** | **2** |
| | Improves plant tolerance to insect pressure | **1** | | **1** | |
| | Improves plant tolerance to environmerntal stresses, e.g. temperature extremes | **1** | | | |
| | Improves plant drought tolerance | **33** | **2** | **45** | **11** |
| | Improves plant tolerance to a wide array of soil quality deficiencies, including toxicities e.g. heavy metals | **2** | **1** | **2** | **4** |
| **Soil Biology** | Enhances benefits contributed by collateral soil micro-organisms | **9** | **1** | **10** | **3** |

# SOME OF THE PRIMARY PLANT BENEFITS DERIVED FROM MYCORRHIZAL FUNGI:

- Weed suppression

## A partial list of common non-mycorrhizal weeds:

*Weeds on this list are among the approximately 5% of terrestrial plants worldwide that **do not** form a Mycorrhizal relationship on their roots. These weeds become starved for nutrients and soil moisture when competing in an environment against mycorrhizal colonized plants.*

- **Kochia** *(Kochia scoparia)*
- **Sedges and Nutsedges** *(Cyperus spp.)*
- **Wild buckwheat** *(Polygonum convolvulus)*
- **Pigweeds** *(Amaranthus spp.)*
- **Common lambsquarters** *(Chenopodium album)*
- **Wild radish** *(Raphanus raphanistrum)*
- **Red sorrel** *(Rumex acetosella)*
- **Curly dock** *(Rumex crispus)*
- **Common chickweed** *(Stellaria media)*
- **Shepherd's-purse** *(Capsella bursa-pastoris )*
- **Lesser Swinecress** *(Coronopus didymus)*

**Ricefield bulrush** *(Scirpus mucronatus)*

- **Fivehook bassia** *(Bassia hyssopifolia)*
- **Flixweed** *(Descurainia sophia)*
- **Nettleleaf goosefoot** *(Chenopodium murale)*
- **Common knotweed** *(Polygonum arenastrum)*
- **Ladysthumb** *(Polygonum persicaria)*
- **Mustards** *(Brassica spp.)*

# Some methods for using *granular* mycorrhizal inoculants in landscape projects:

- **For turf broadcast, hydro-seeding or re-seeding applications:** *Blend with grass seed or slurry*
- **For sod installation:** *Apply to soil surface prior laying sod.*
- **For container planting, greenhouse or nursery culture:** *Mix with growing medium.*
- **For transplanting:** *Apply in planting hole for maximum root contact.*


# Blend granular MycoApply® with nursery growing media


EMICAL

pple™


Myco
Apply
Ultrafine
Endo


Blend with dry fertilizers

# MYCORRHIZAL FUNGI VS BACTERIA/ TRICHODERMA

1. AMF must have plant supplied energy
2. MF propagules are dormant/Don't need food
3. Propagule populations stable in bags
4. MF have unique QC protocols

## CLAIMS & BENEFITS

**Optimizes crop yield by improving physiological plant functions.**

1. **Roots**: Mycorrhizae fungi rapidly establish an expanded vascular network by providing more surface area beyond the plant root system to sequester more resources from the soil for better plant health.

2. **Nutrients**: Mycorrhizae fungi access, absorb and transport soil nutrients directly to the root for essential plant nutrition by producing enzymes that release specific nutrients tightly bound within the soil, particularly Phosphorus, Organic Nitrogen & Essential Micronutrients.

3. **Water**: Mycorrhizal fungi filaments access, absorb, transport and store soil moisture that is widely dispersed within the soil to provide the plant with greater heat and drought tolerance.

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## COULD YOUR PRODUCTS BENEFIT FROM THESE?

- Conserve nutrients and water
- Limit offsite erosion and nutrient loss
- Control diseases
- Protection against environmental extremes

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# MYCORRHIZAL FUNGI
# 100,000 RESEARCH STUDIES

- 460 million years-old
- 90% of plants form
- 39 years experience
- Mycorrhizal Research
- Practical Solutions

# Journal Publications

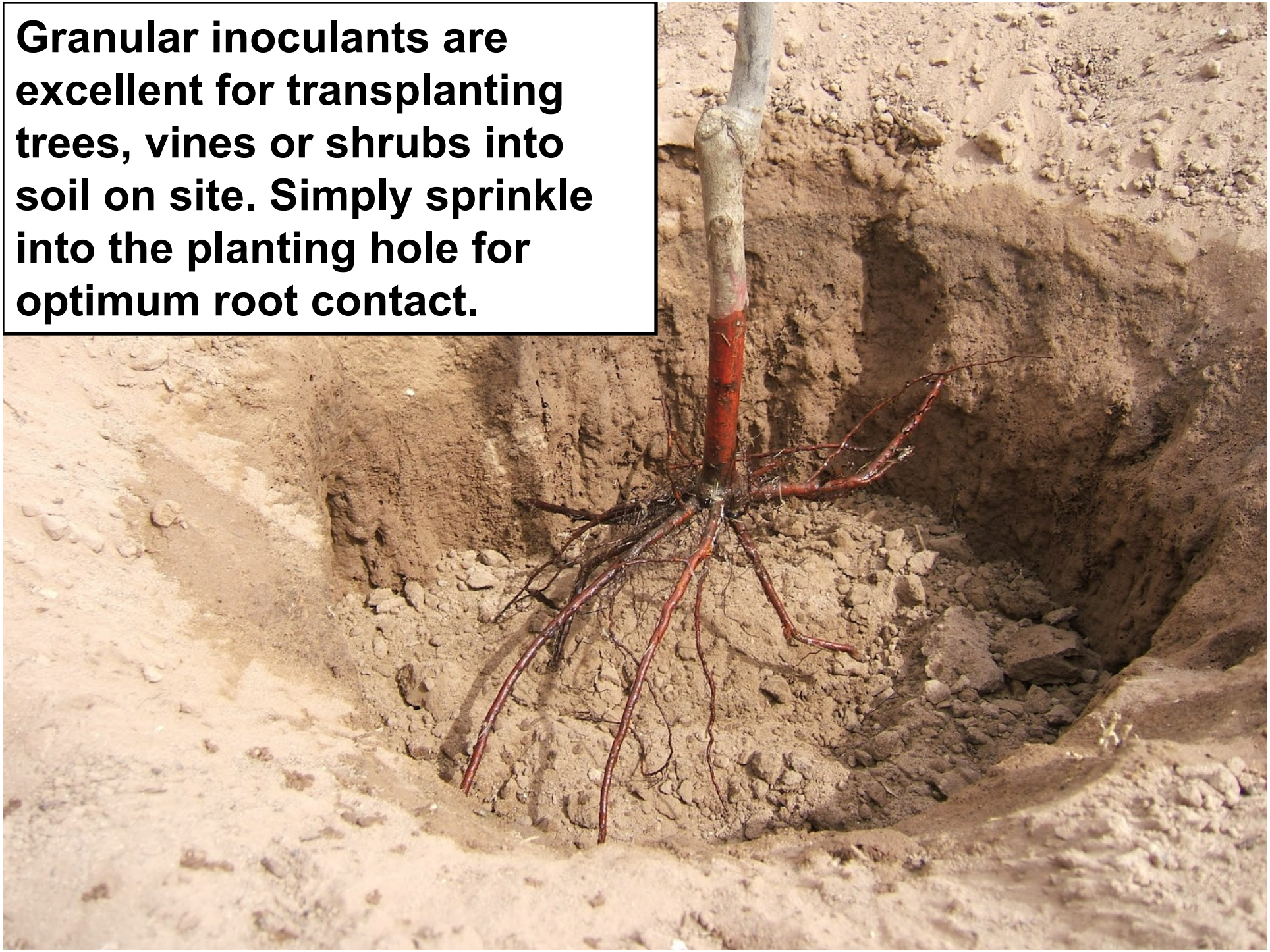
- Ecology
- Biological Sciences
- Turf grass Science
- Plant and Soil
- Native Plants
- Environmental Horticulture
- Sustainable Forestry
- Environmental Sciences

# 3rd Party Research

- University of Wisconsin
- University of California, Davis
- University of California, Berkeley
- University of California, Riverside
- North Dakota State University
- Purdue University
- University of Rhode Island
- University of Maine
- Montana State University
- University of Guelph

Broadcasting a granular inoculum prior to laying sod affords direct root contact, resulting in fast and effective turf colonization.

**Granular inoculants are excellent for transplanting trees, vines or shrubs into soil on site. Simply sprinkle into the planting hole for optimum root contact.**



# Liquids & Soluble Powders …

# Products 1996-2015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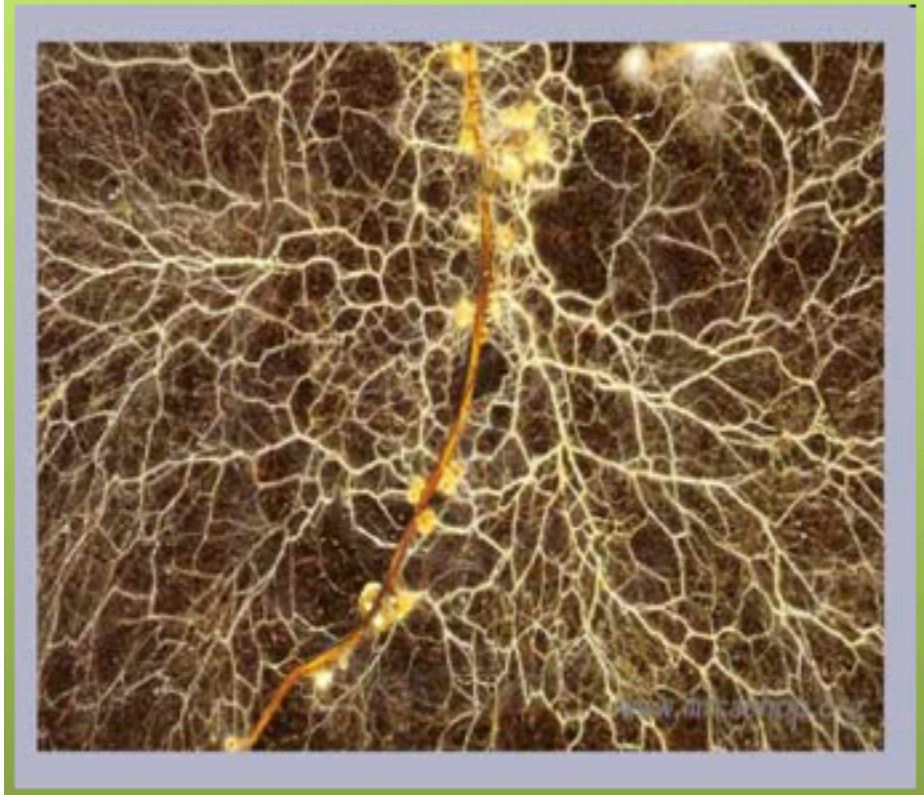

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# Exploring the power of Bio-Possibilities in manufactured soils