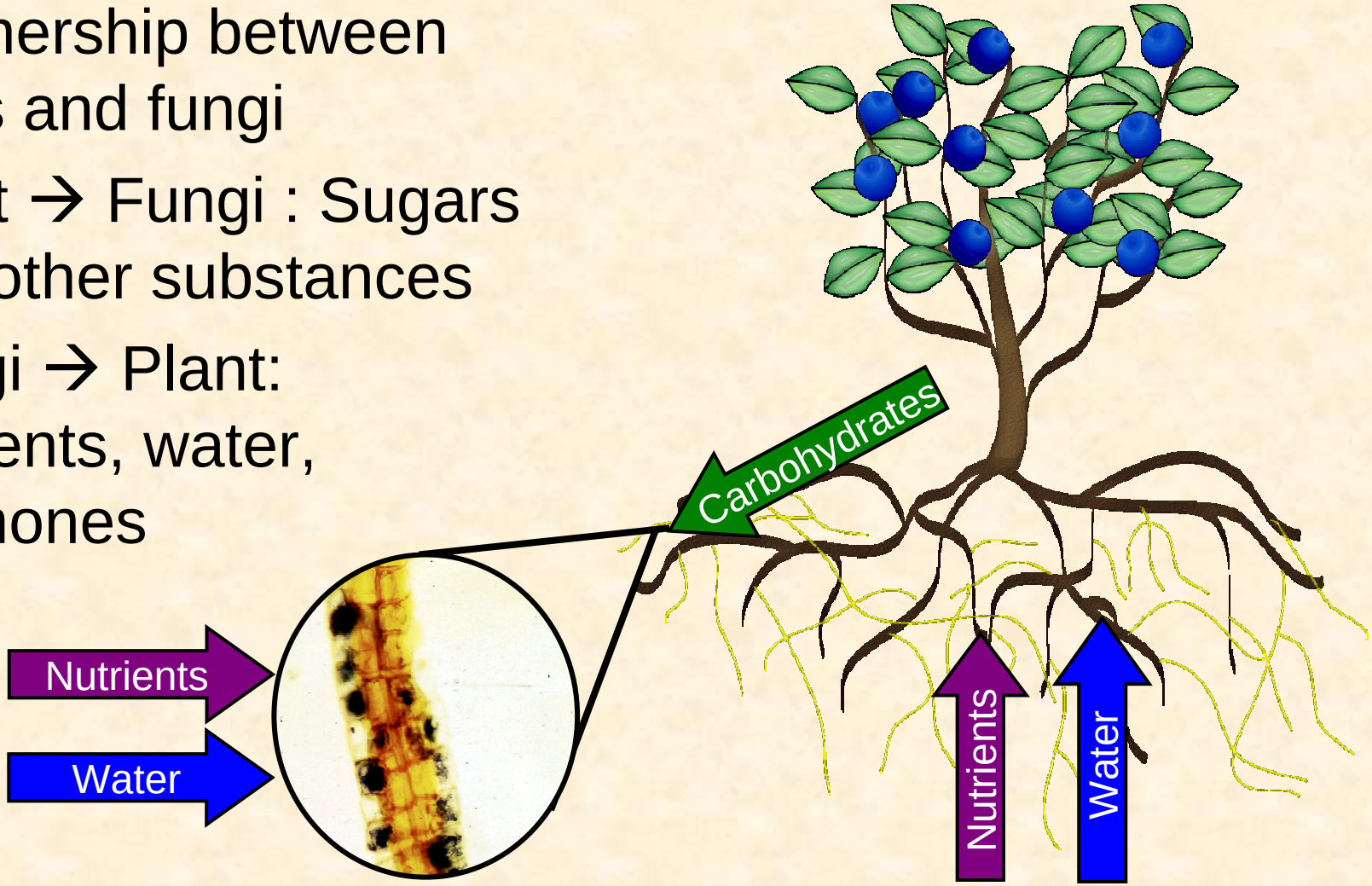
Mycorrhizal Fungi in Nursery Production: Facts & Fiction

Carolyn Scagel
USDA-ARS-Horticultural Crops Research Laboratory
Corvallis, OR

What Are Mycorrhizae?

- Partnership between roots and fungi
- Plant → Fungi : Sugars and other substances
- Fungi → Plant: nutrients, water, hormones



What Are Mycorrhizae?

- **Fiction:**
  All plants need mycorrhizae

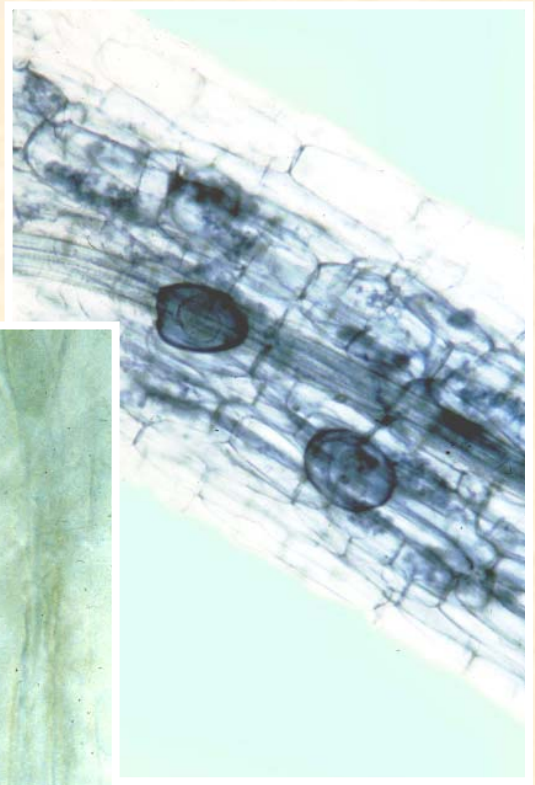
- **Facts:**
  1. Almost all plants are capable of forming mycorrhizae.
  2. Some plants do not naturally form mycorrhizae.
  3. Plants can potentially grow & survive without the fungus.
  4. The fungus is often completely dependent on the plant .

What Do Mycorrhizae Look Like?

- Several types of mycorrhizal associations:
  - Arbuscular mycorrhizae (AM)
  - Ectomycorrhizae
  - Ericoid mycorrhizae
  - Arbutoid mycorrhizae
  - Orchid mycorrhizae
  - Monotropoid
  - Ectendomycorrhizae

Arbuscular Mycorrhizae (AM)

- Growth **within** root cortical cells
- Vesicles, arbuscules
- External hyphae
- Most angiosperms, some gymnosperms (*Taxus*, *Sequoia*, *Thuja*, *Chamaecypris*), mosses, ferns



Ectomycorrhizae

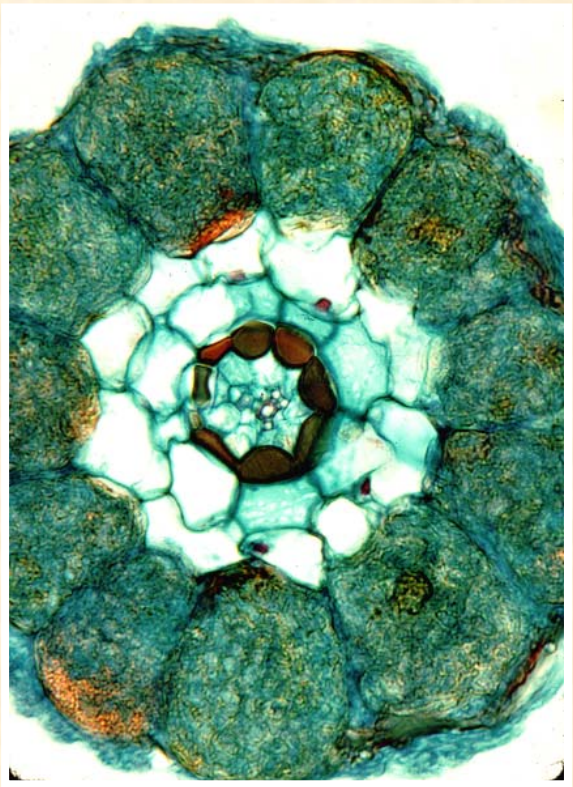
- Growth **between** root cortex cells – Hartig Net
- Sheath on root surface
- External hyphae
- Betulaceae, Fagaceae, Pinaceae, Salicaceae, Myrtaceae

Ericoid Mycorrhizae

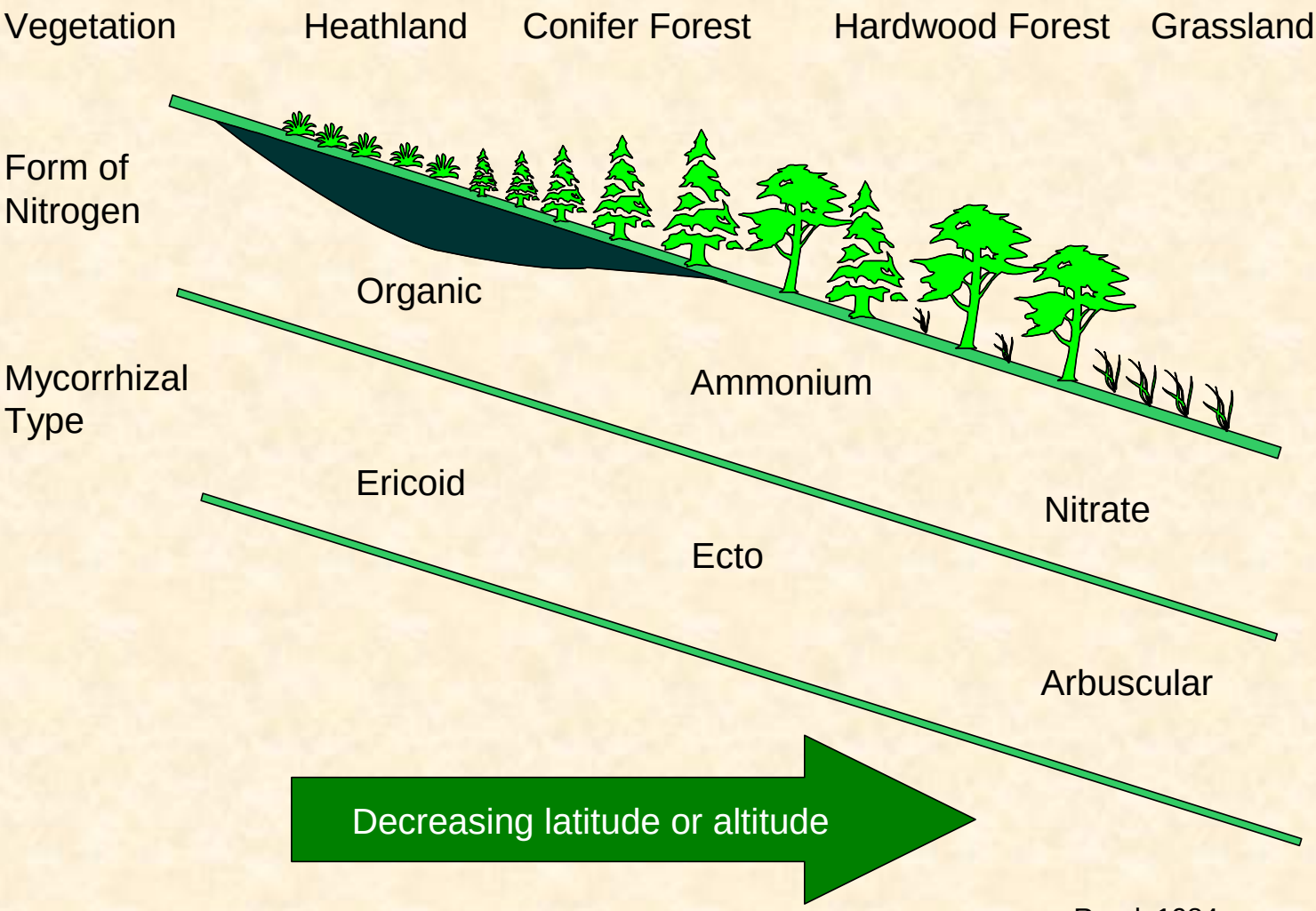
- Growth **within** root cortical cells
- Hyphal coils
- External hyphae
- Ericaceae, Emptetraceae, Epacridaceae.

Arbutoid Mycorrhizae

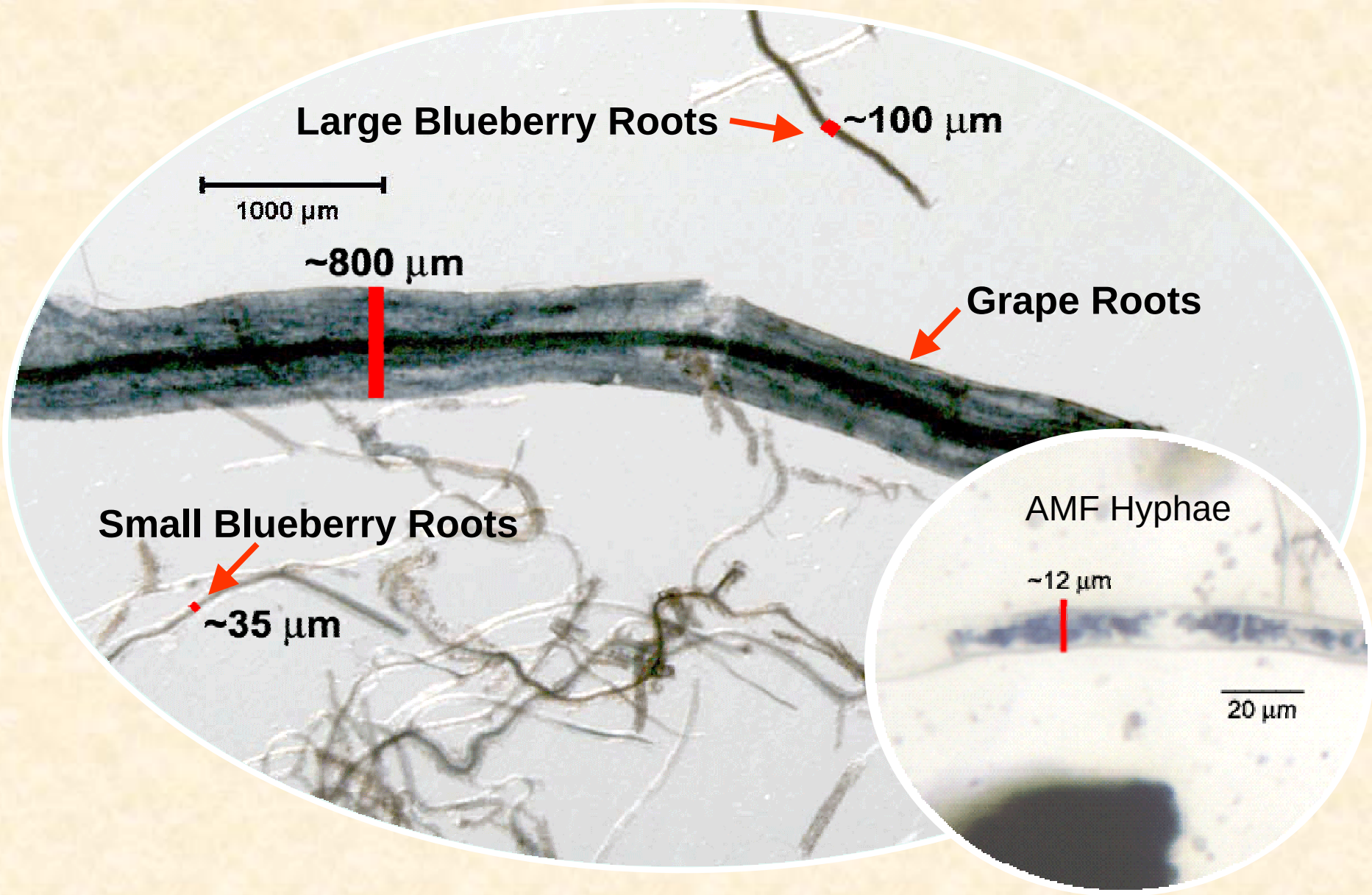
- Growth **within** and **between** root cells
- Sheath on root surface
- External hyphae
- Ericales genera including *Arbutus*, *Pyrola*, *Arctostaphylos*



Ecological Perspective



Read, 1984


Large Blueberry Roots
~100 µm
1000 µm
~800 µm
Grape Roots
Small Blueberry Roots
~35 µm
AMF Hyphae
~12 µm
20 µm

1 cm = 10,000 µm

What Do Mycorrhizae Look Like?

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

- **Facts:**
  1. The only way to confirm whether a plant is colonized by AM or ericoid fungi is by a microscope or DNA analysis.

  2. Most ecto and arbutoid mycorrhizae can be seen on roots; however some do not produce a mantle that is visible without using microscope.

  3. If inoculation effects plant growth do not assume the plant is mycorrhizal; other organisms or components of the inoculum may cause a plant response without colonization.

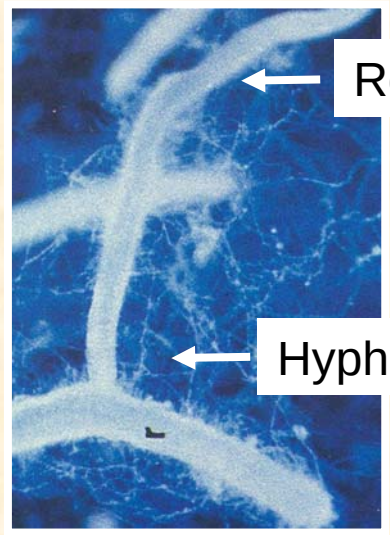
Why Are Mycorrhizae Important?

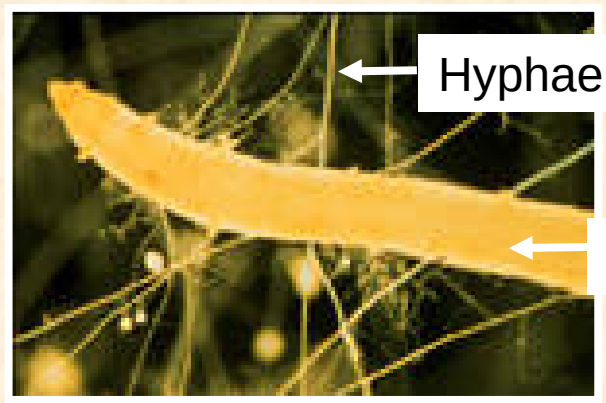
- **Nutrition**
  - Increase nutrient use efficiency
  - Decrease run off and leaching
  - Improved Water Quality
- **Disease**
  - Suppression of pathogens
  - Increase plant health
  - Decrease pesticide use
- **Drought and Salinity**
  - Increase efficiency of water use
  - Decrease crop loss
  - Increase acreage of farm land
- **Soil Quality**
  - Improve soil structure & stability
  - Decrease erosion & topsoil loss
  - Enhance nutrient retention
- **Efficiency & Profitability**
  - Improve root growth & survival
  - Decrease production time
  - Enhance marketability
- **Product Quality**
  - Alter phytochemical attributes
  - Increase flowering
  - Enhance nutritional value

Nutrient & Water Uptake

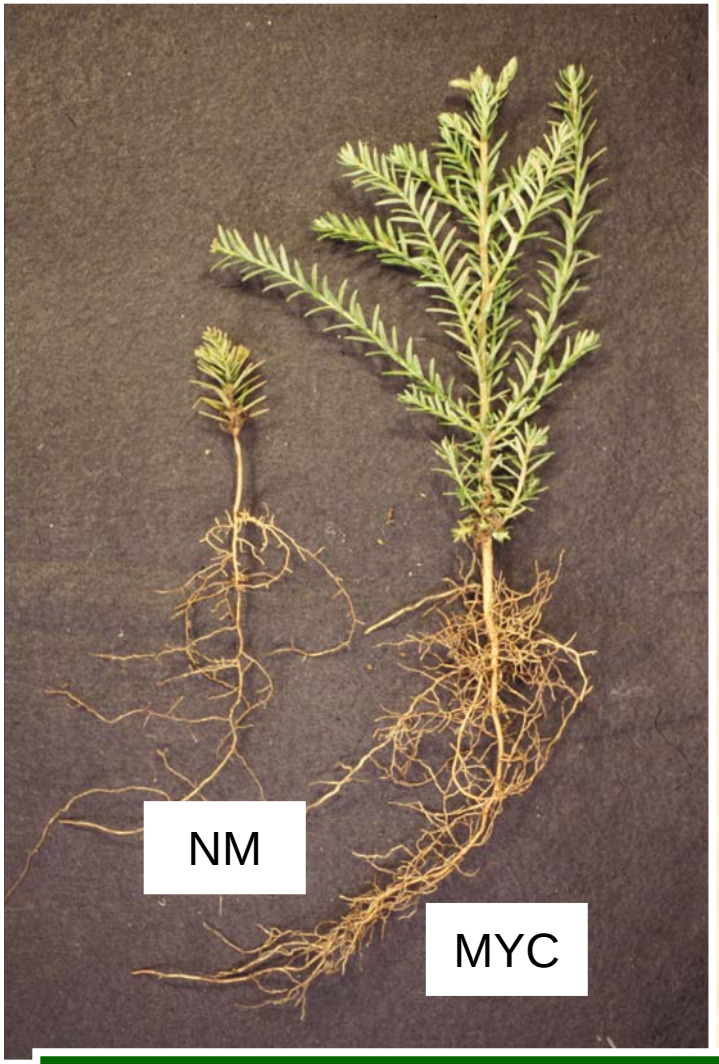
- Hyphae extend out from roots into soil

- 50 to 100 times more reserves available to a mycorrhizal plant than a non-mycorrhizal plant





Growth: Big Plant vs Little Plant



Little plants may not be representative of normal production practices

Growth & Culture

None Inoculated
Low P

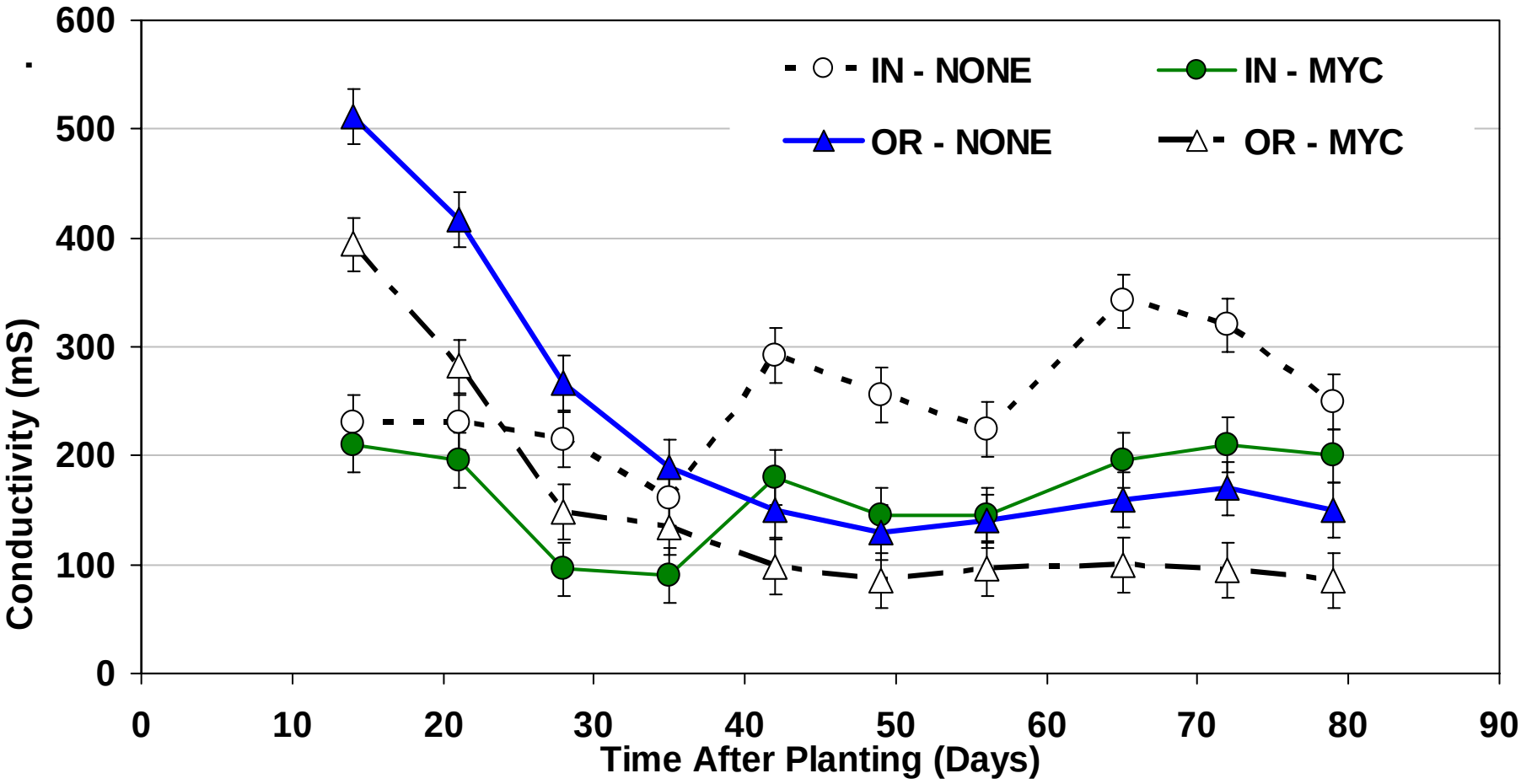
None Inoculated
High P

Benefits sometimes are masked by cultural conditions

Growth: Hidden

Benefits sometimes are only seen belowground

Fertilizer Uptake & Run-off



Response can depend fertility and type of fertilizer

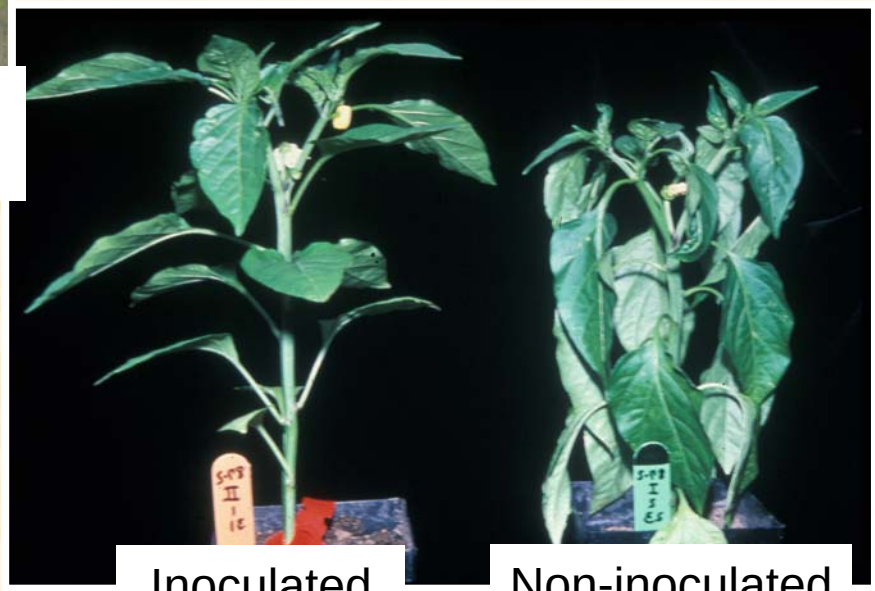
From Scagel, 2005

Drought & Salt Tolerance

Benefits sometimes only detectable plants are exposed to stress

Salt: Low High High Low

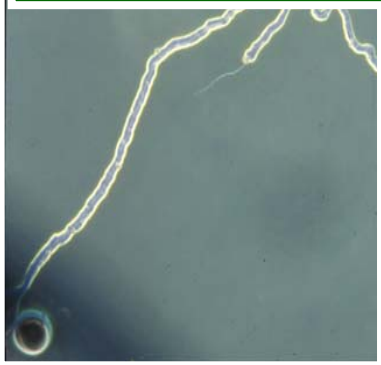
Non-inoculated Inoculated

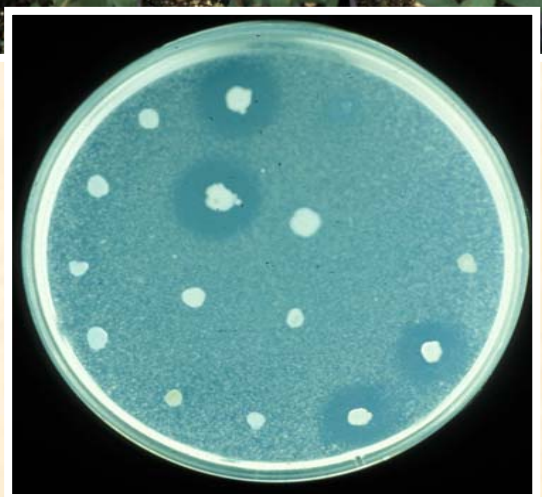


Inoculated Non-inoculated

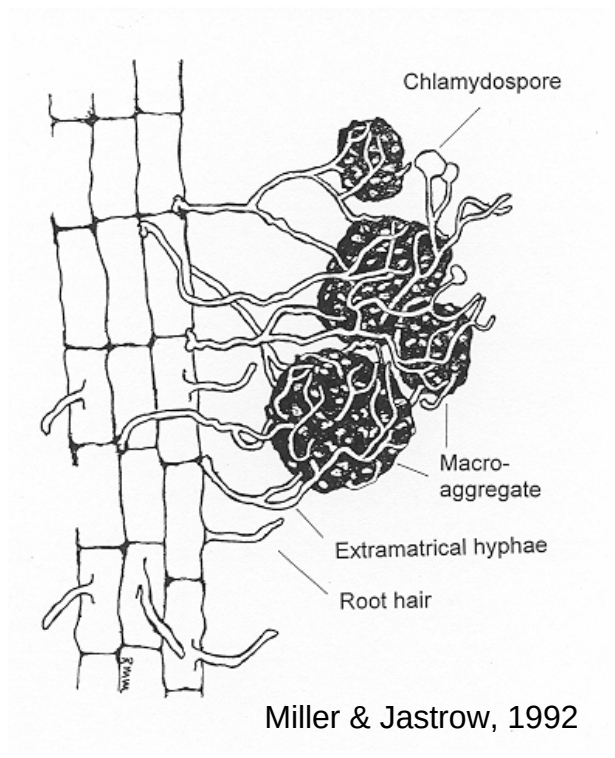
Root Disease & Pests

Benefits may be indirectly due to other organisms enhanced in soil around the roots of a mycorrhizal plant

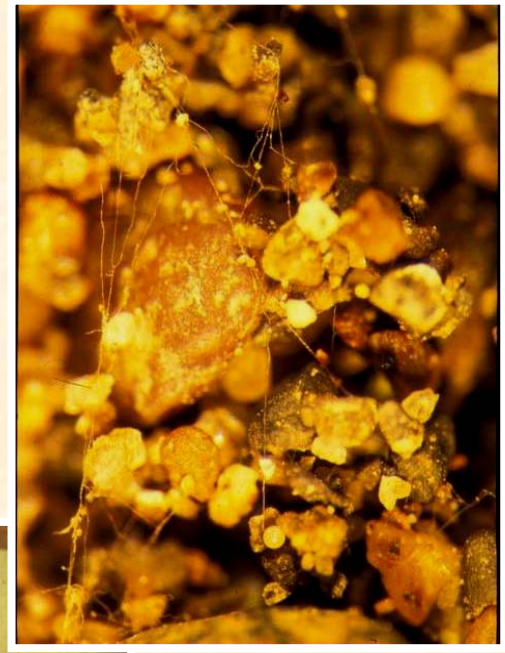


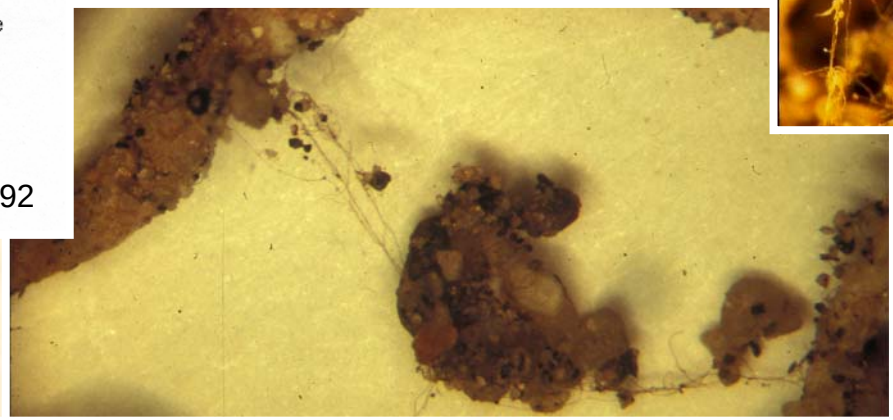


Soil Aggregation



Miller & Jastrow, 1992

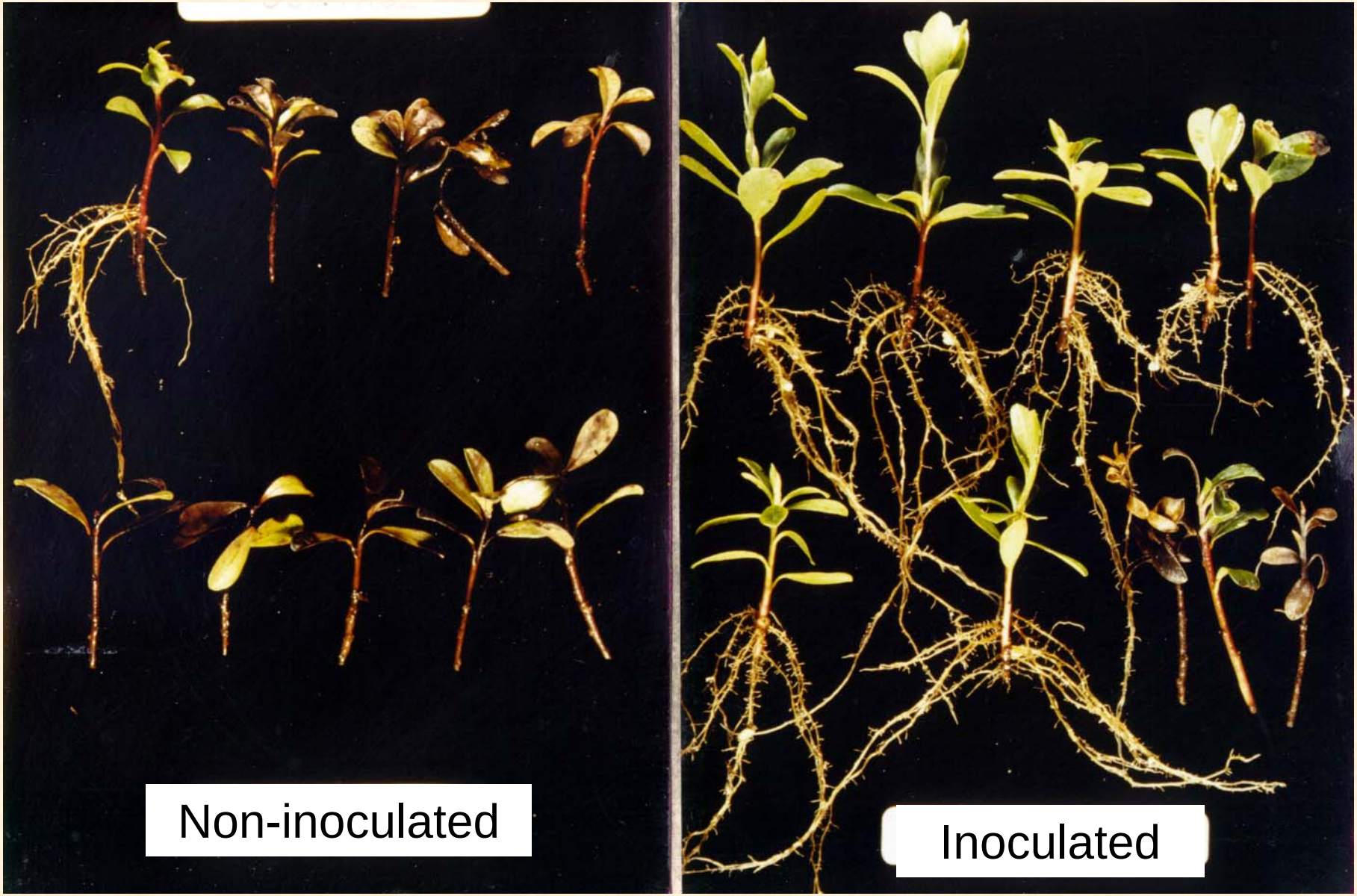




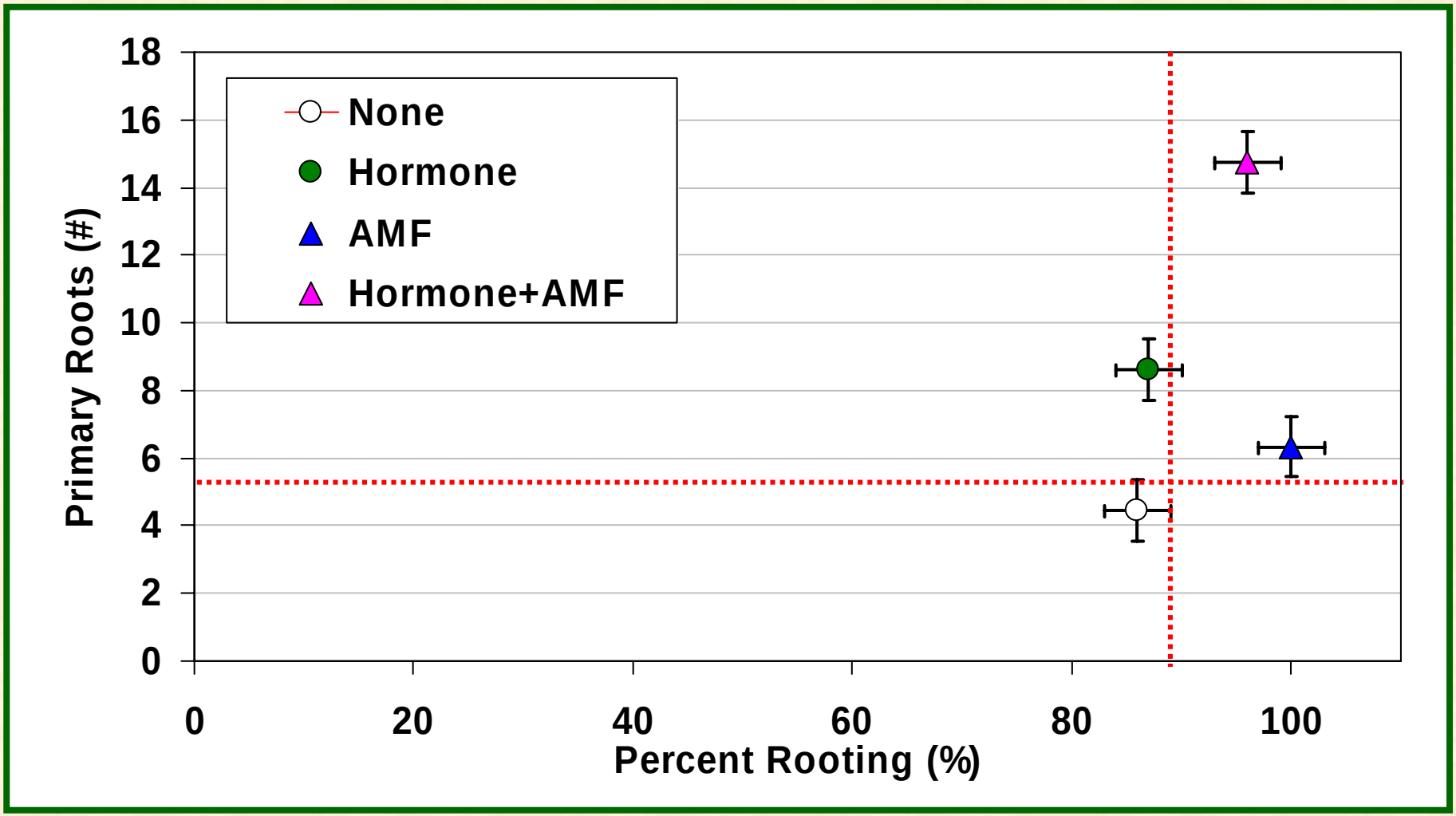
Importance during in-field production and landscape however difficult to measure

Root Growth

- Rate limiting step in production of cuttings and tissue culture plants
- Correlated with plant survival after transplanting
- Implications to production efficiency and costs

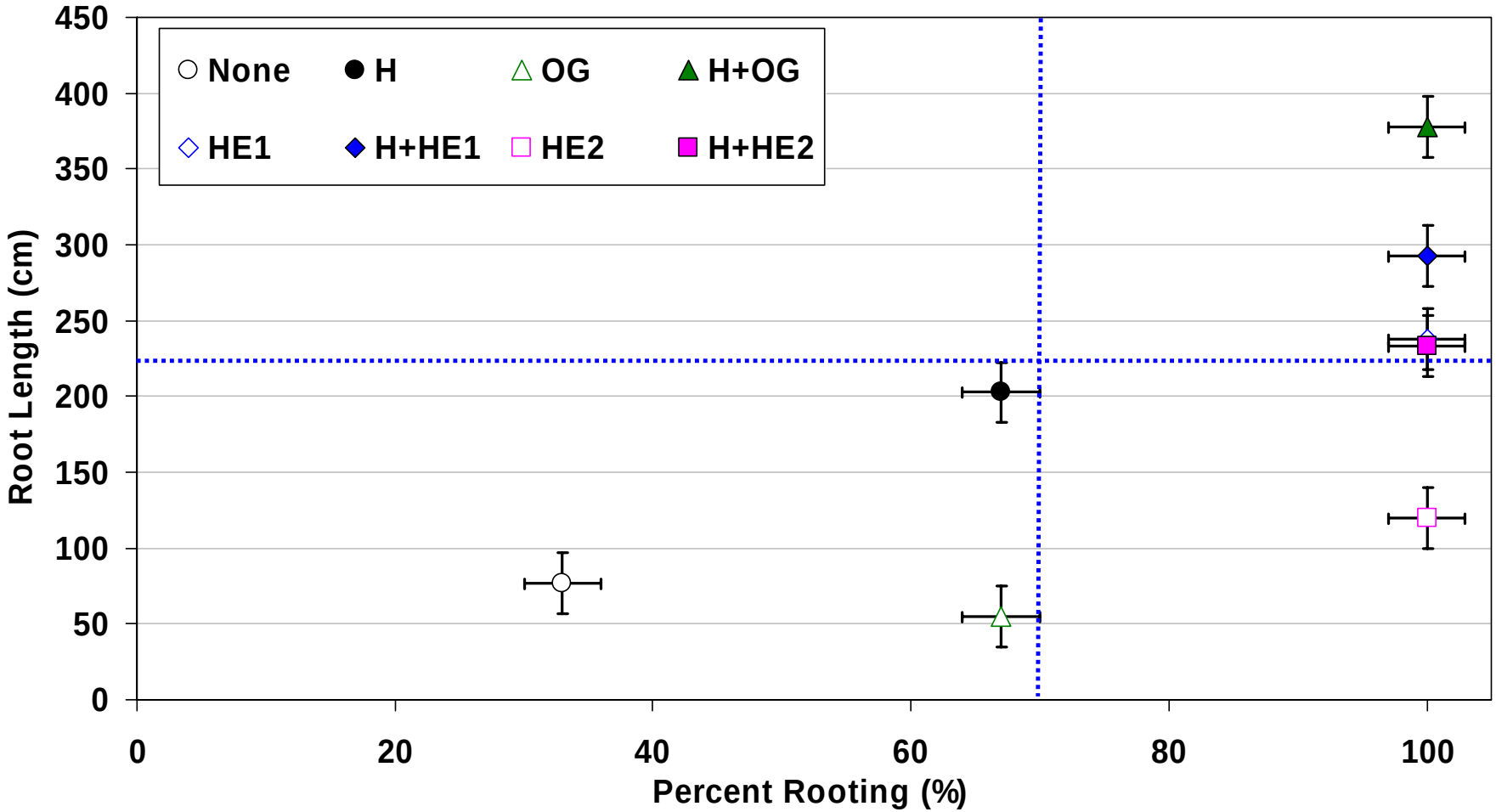

Non-inoculated
Inoculated

Benefit Depends on Goal



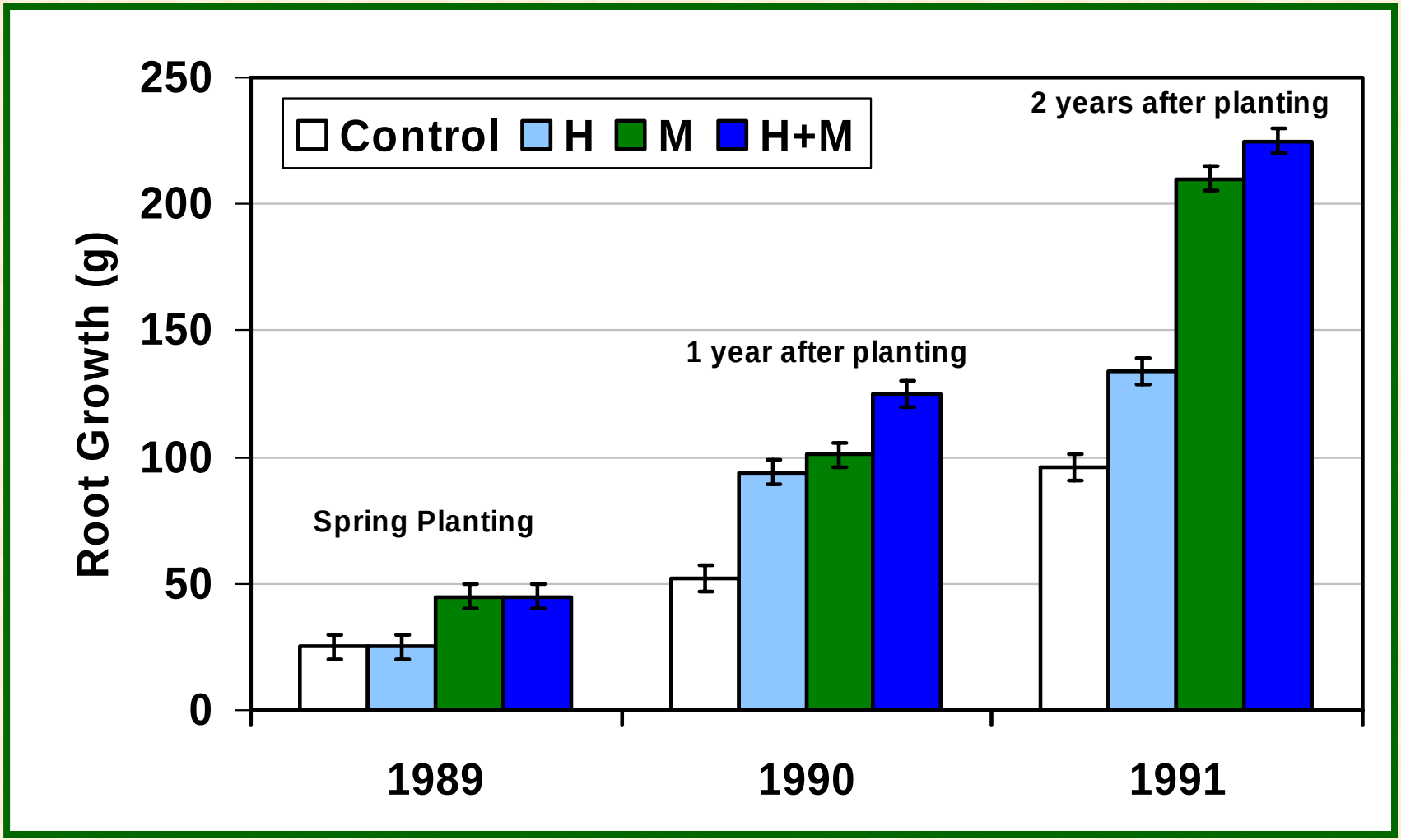
From Scagel, 2001

Benefit Depends on Fungus



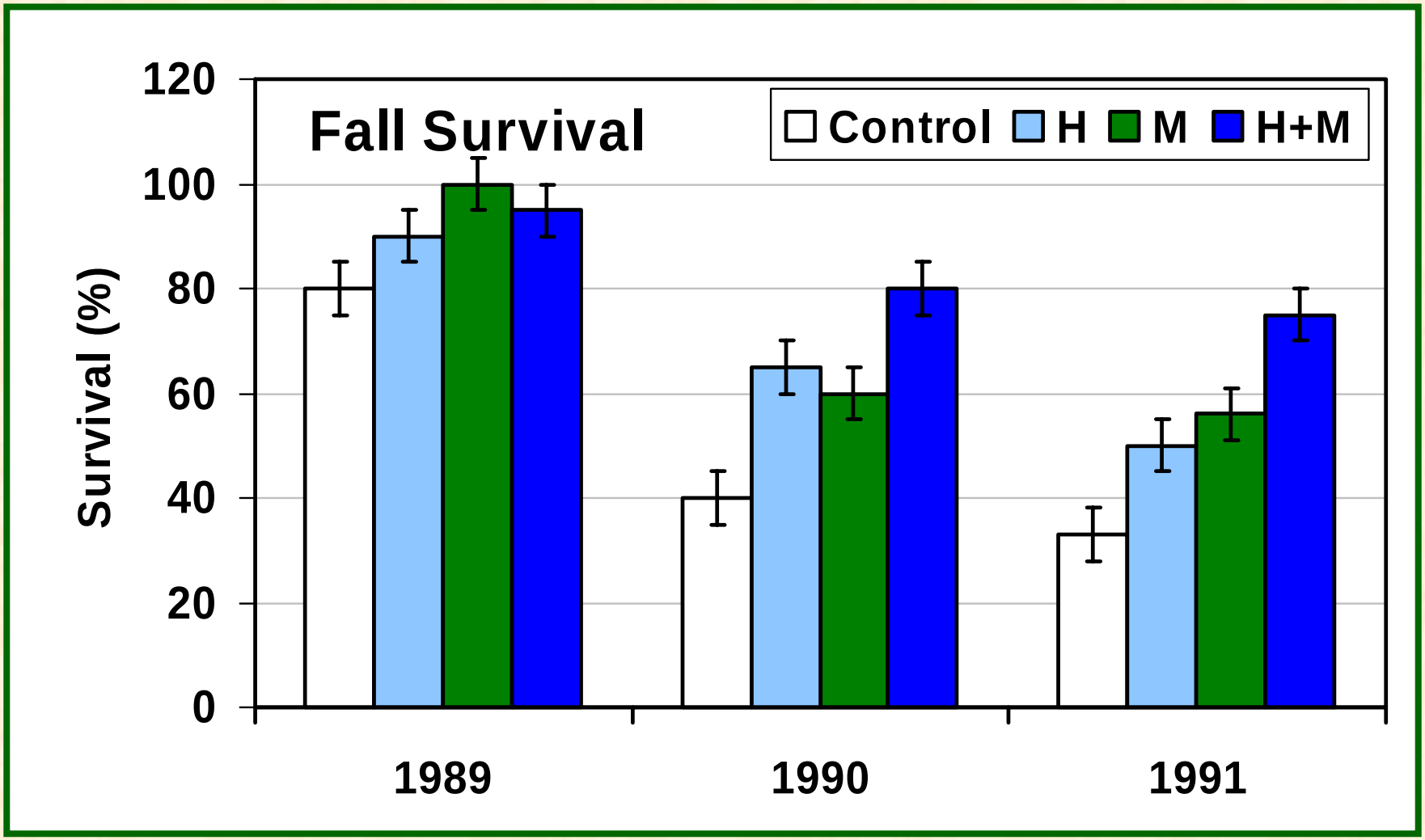
From Scagel, 2004

Benefit Changes with Time



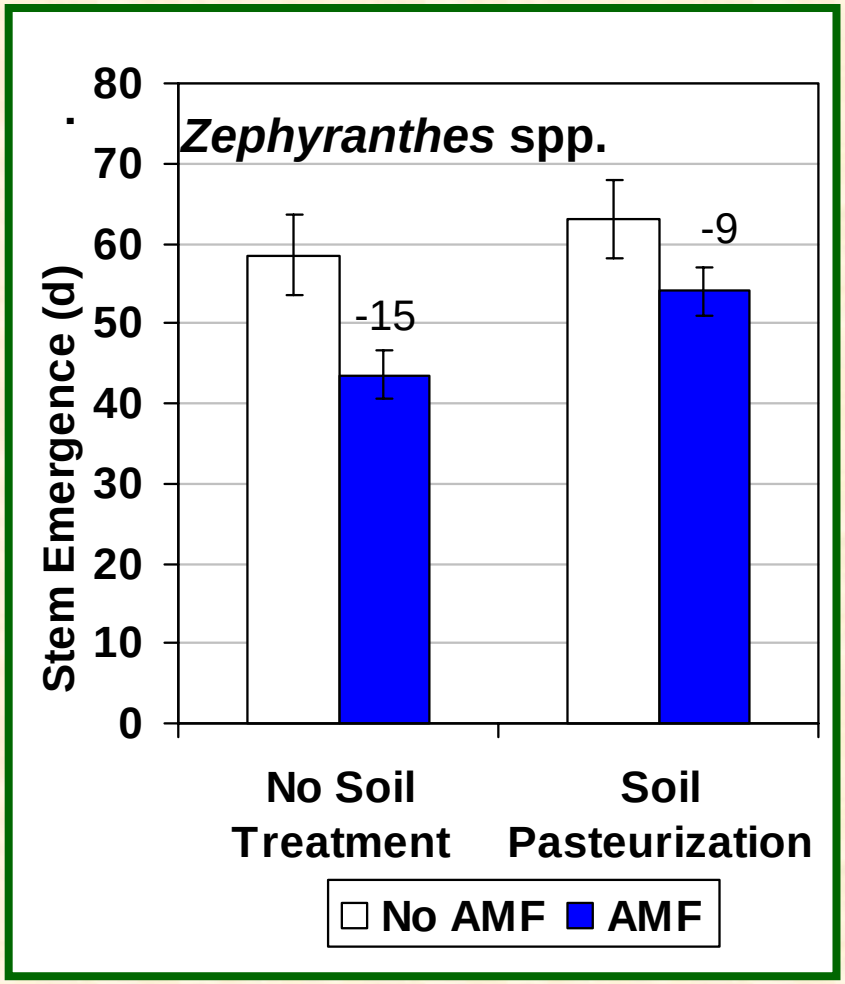
From Scagel, 1999

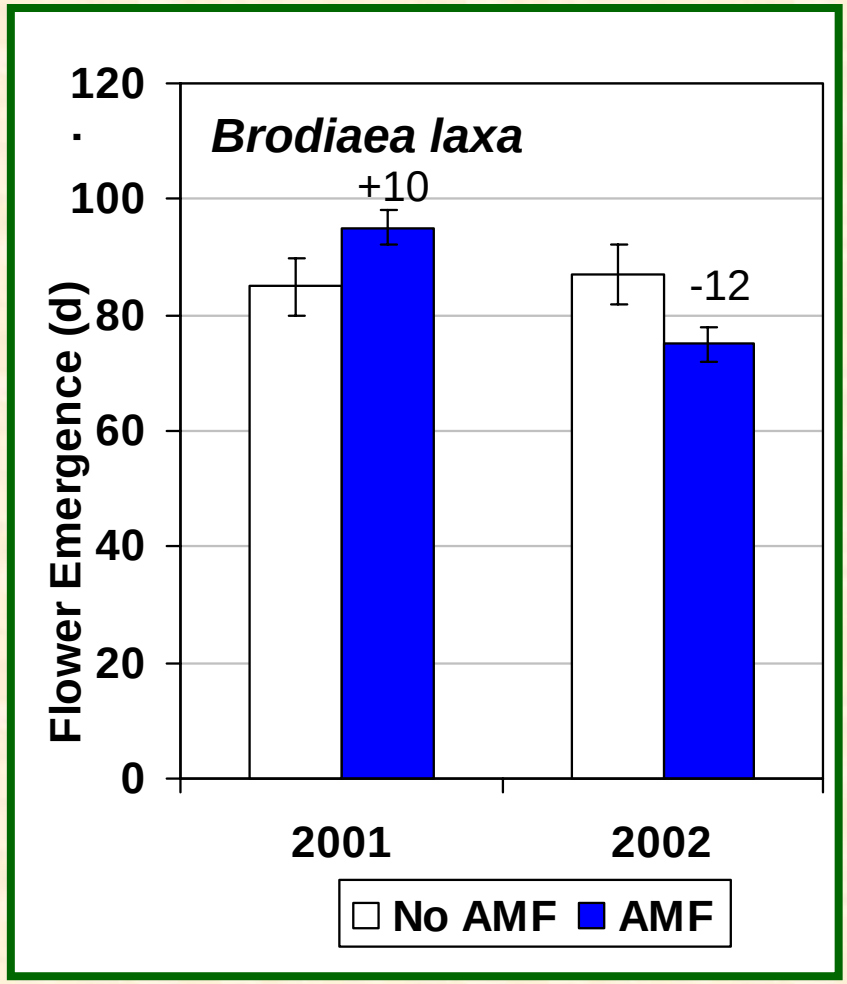
Benefit Changes with Time & Goal



From Scagel, 1999

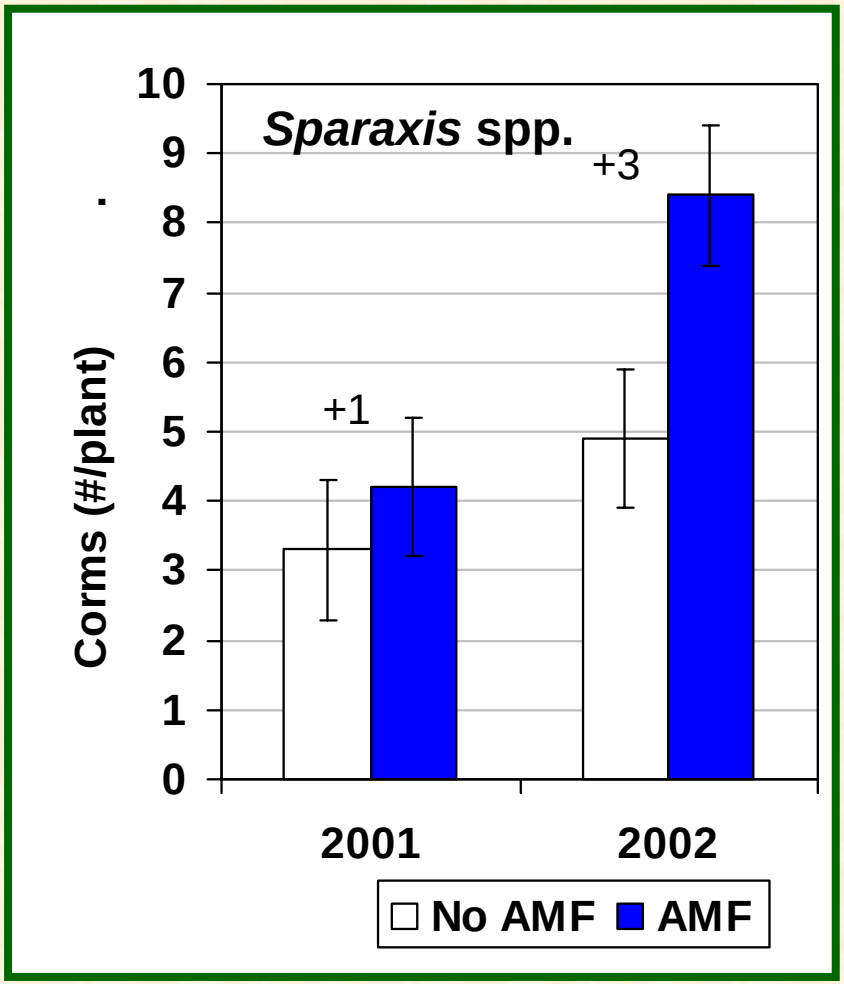
Benefit change with culture and plant development

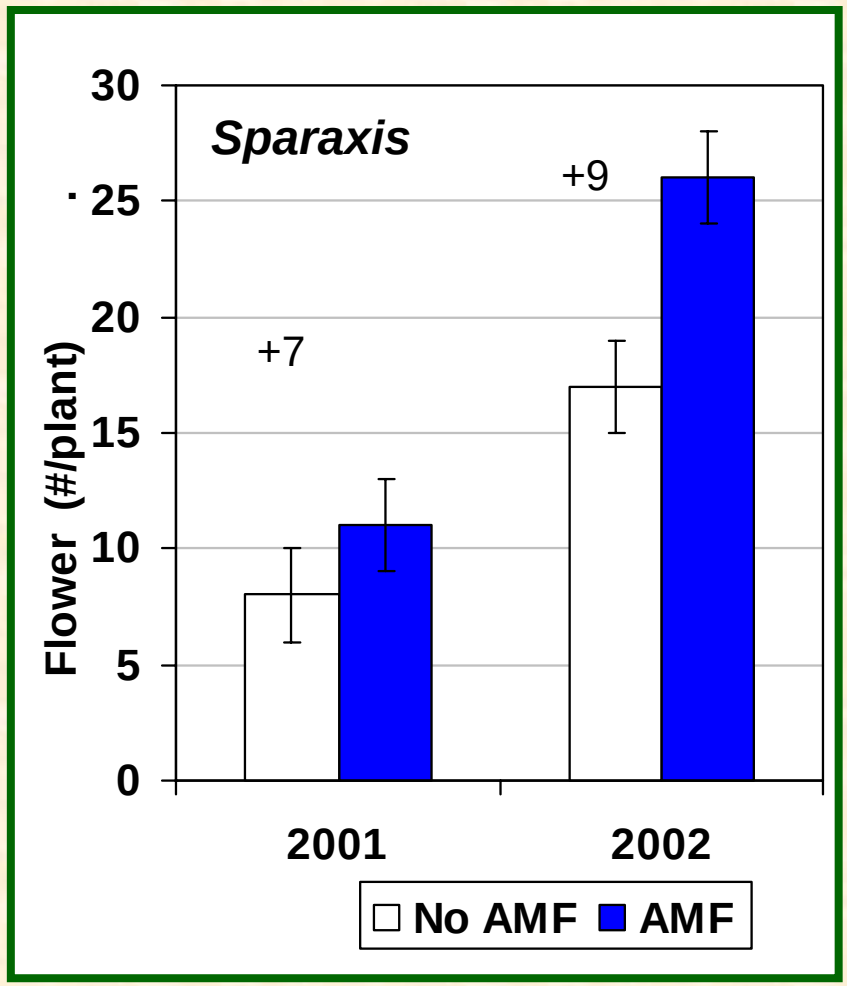




From Scagel, 2004

Benefit Expressed as Quality





From Scagel, 2004

Benefits?

- **If plants have mycorrhizae, benefits can vary with:**
  - the plant and fungal species in the association
  - the environmental and cultural factors present during production or in the landscape.
- **In many cases, the benefits of mycorrhizae are not recognizable unless:**
  - non-mycorrhizal plants are used for comparisons
  - comparisons are made based on product quality or performance of the product

Why Are Mycorrhizae Important?

- **Fiction:**
  Mycorrhizae will solve all my production problems

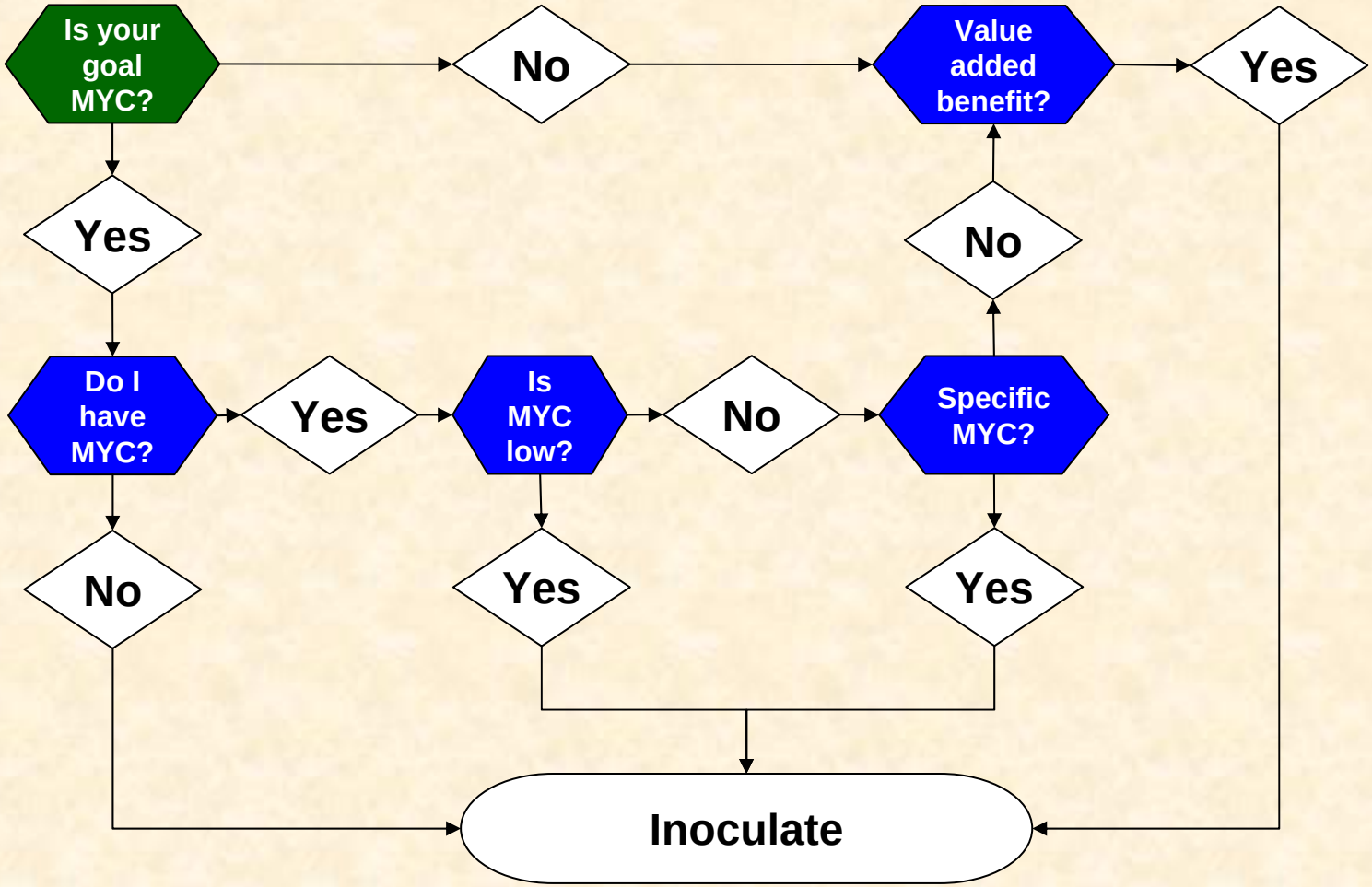
- **Facts:**

1. Proof of benefit by research does not necessarily translate in all production systems or landscape situations.

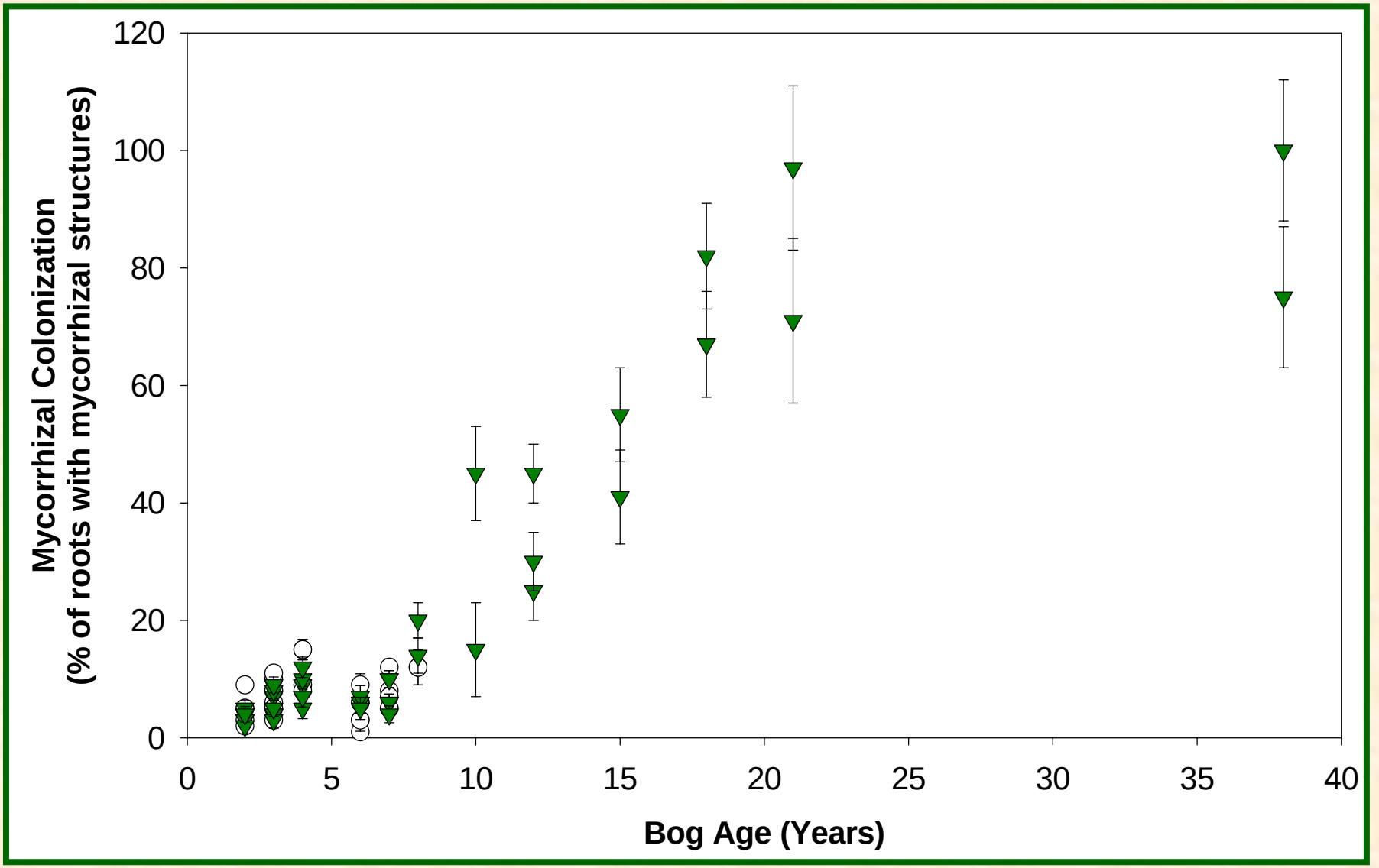
2. Benefits derived from mycorrhizae will depend on production goals or objectives.

3. 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.

Do I Need To Inoculate?

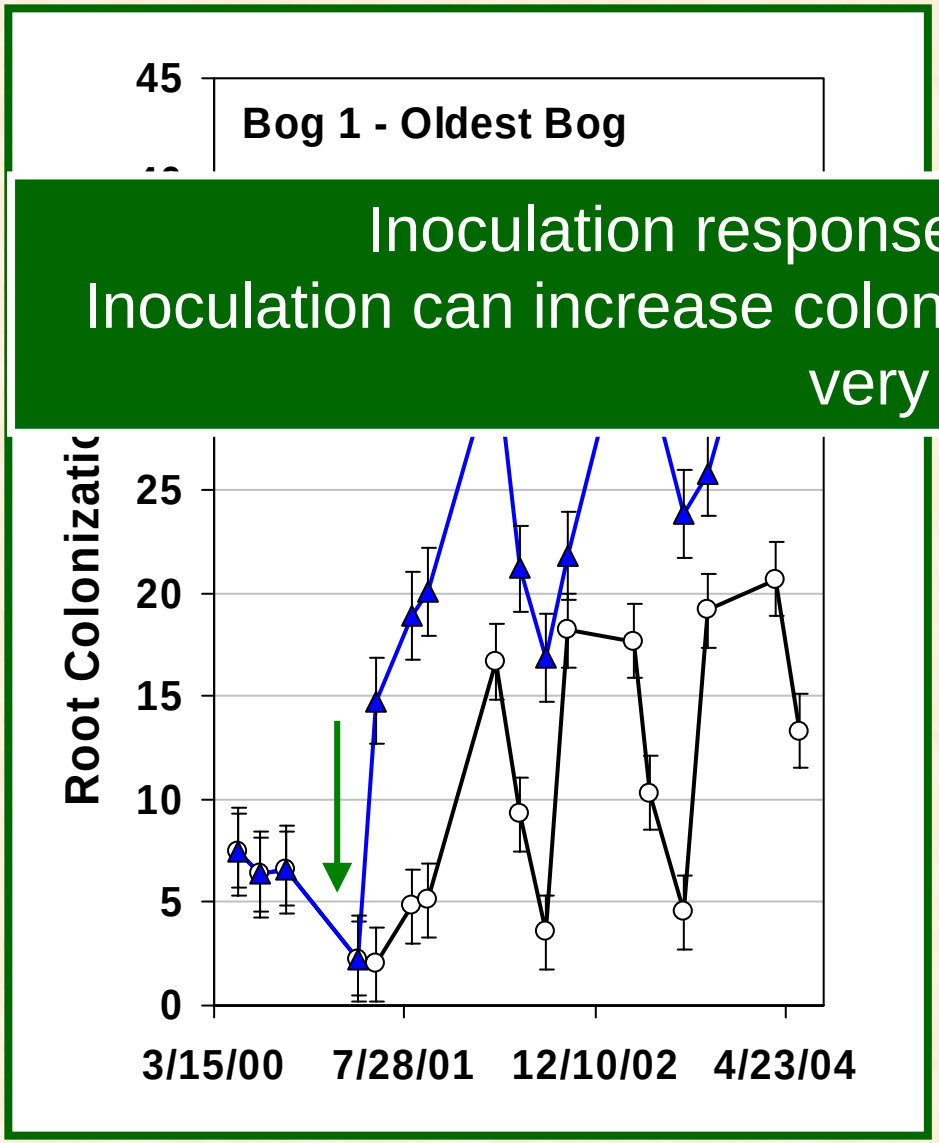


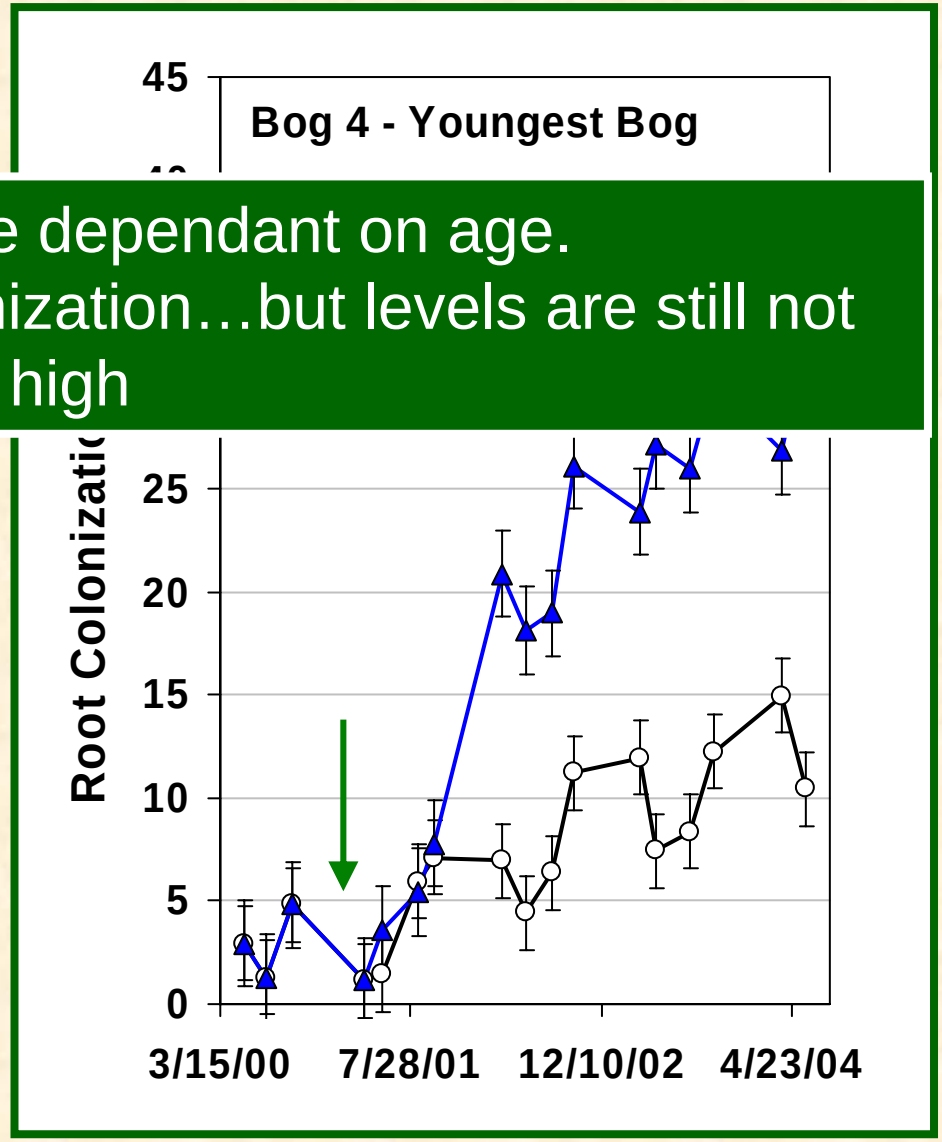
Do I Have Mycorrhizae?



Scagel 2002

Inoculation Trials

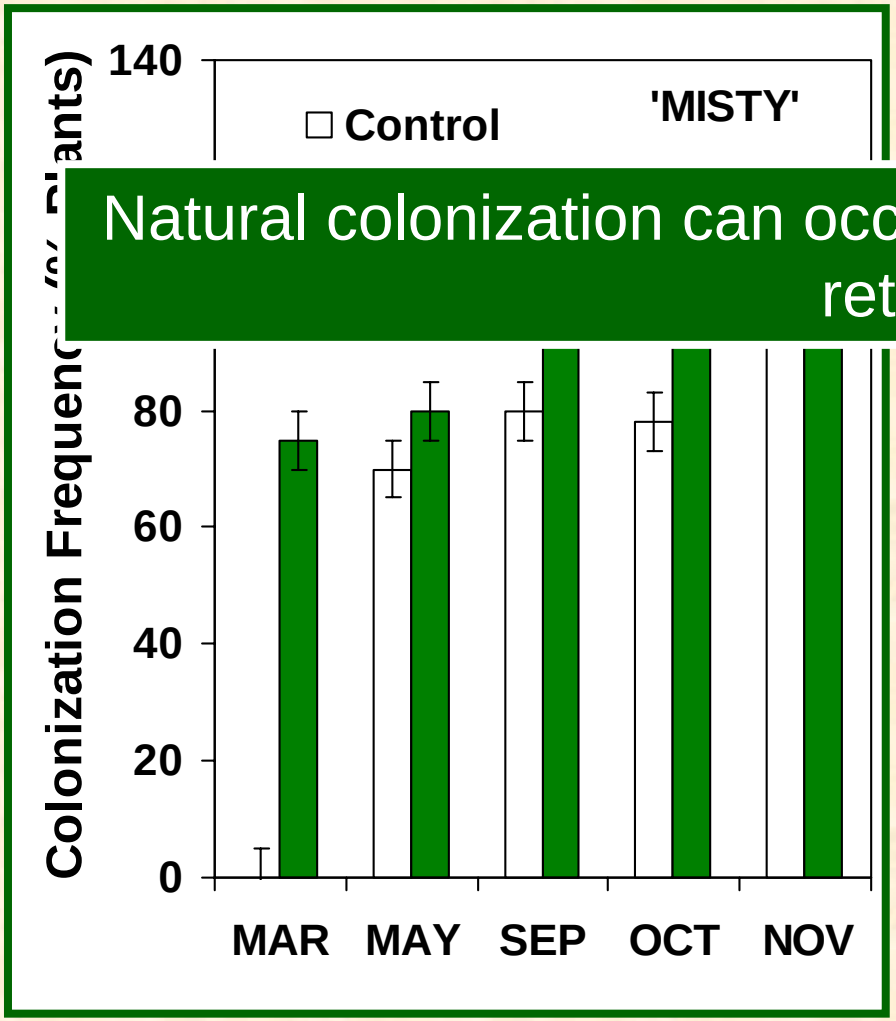


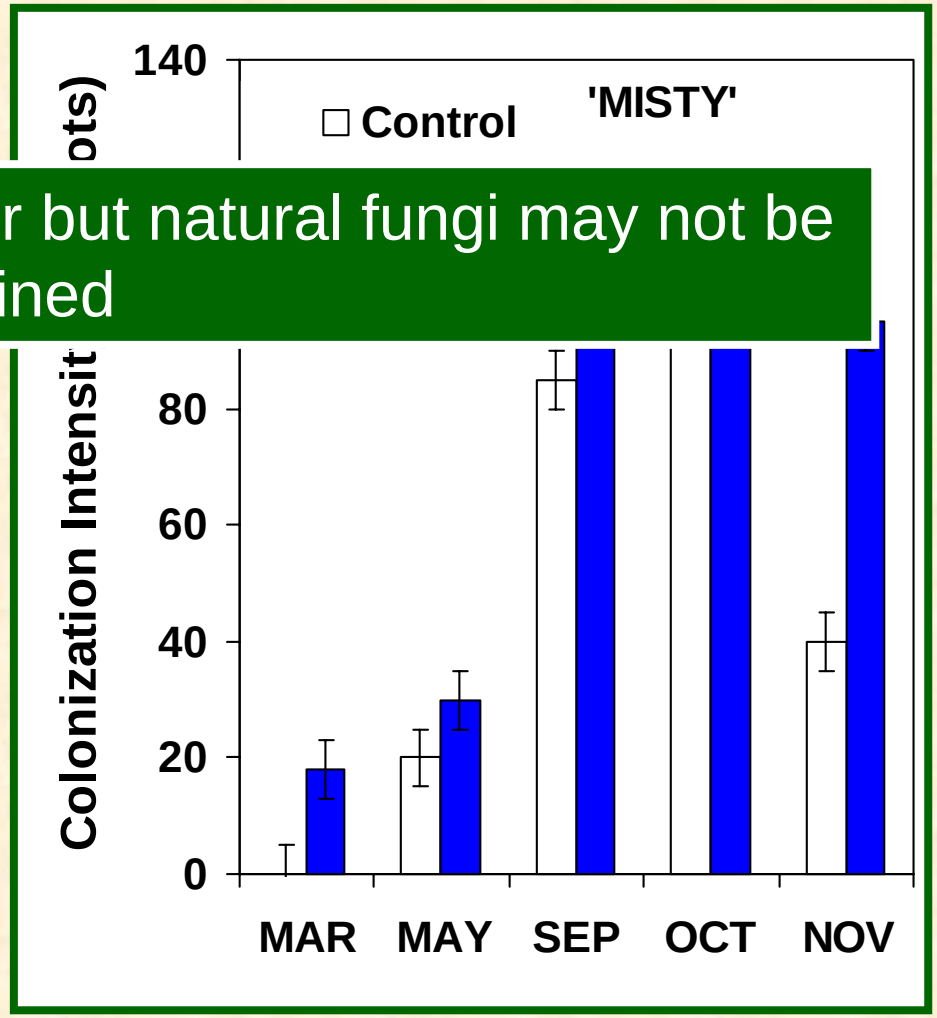


Inoculation response dependant on age.
Inoculation can increase colonization…but levels are still not very high

Scagel 2003

Is Colonization Low?

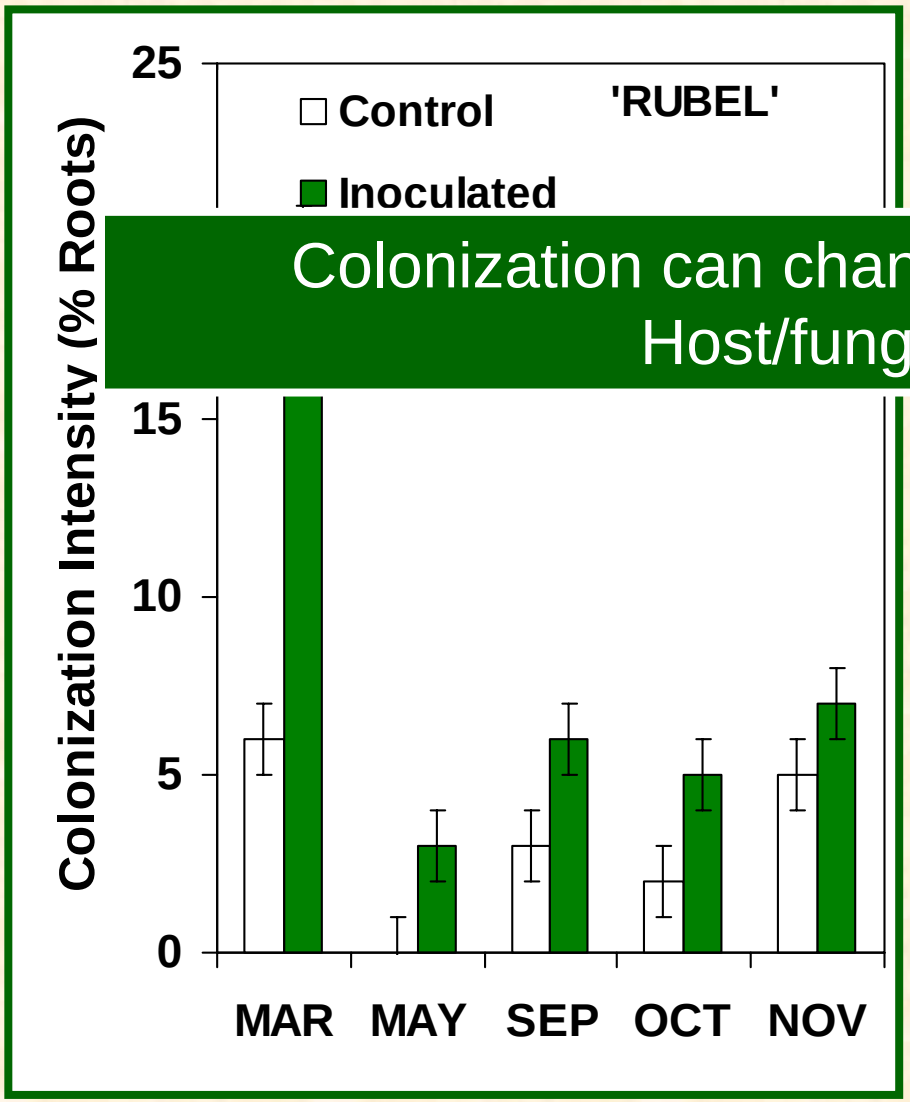


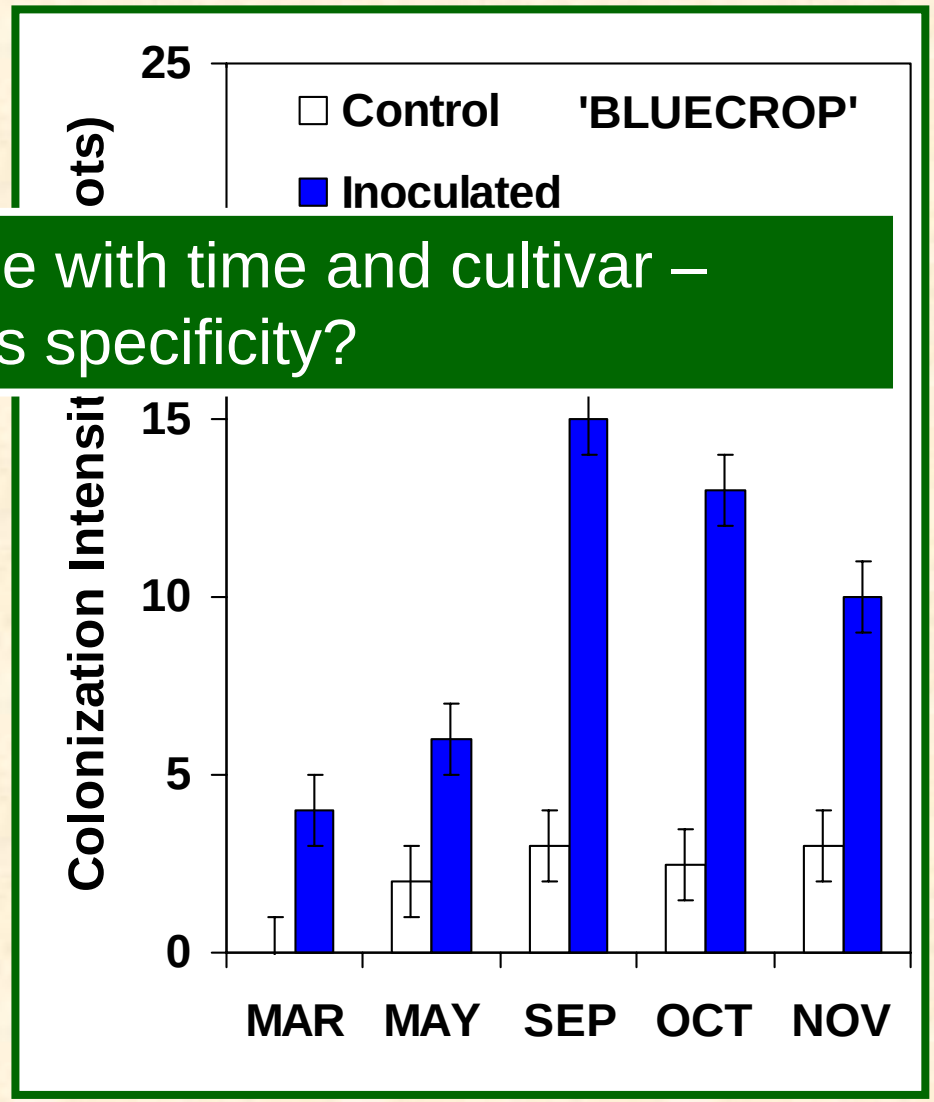


Natural colonization can occur but natural fungi may not be retained

From Scagel, Wagner, Winiarski, 2005

I Want Specific Fungi

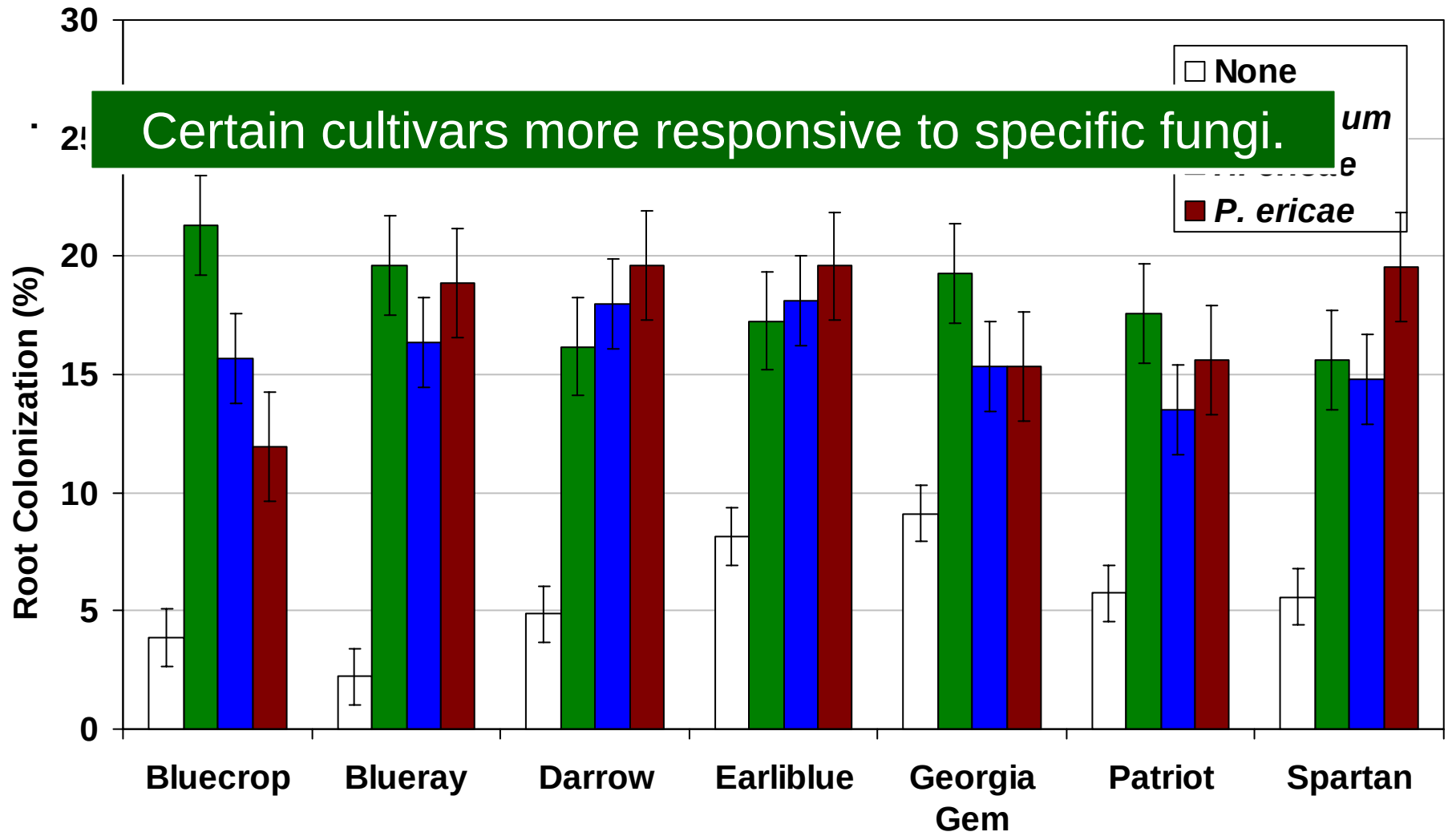




Colonization can change with time and cultivar – Host/fungus specificity?

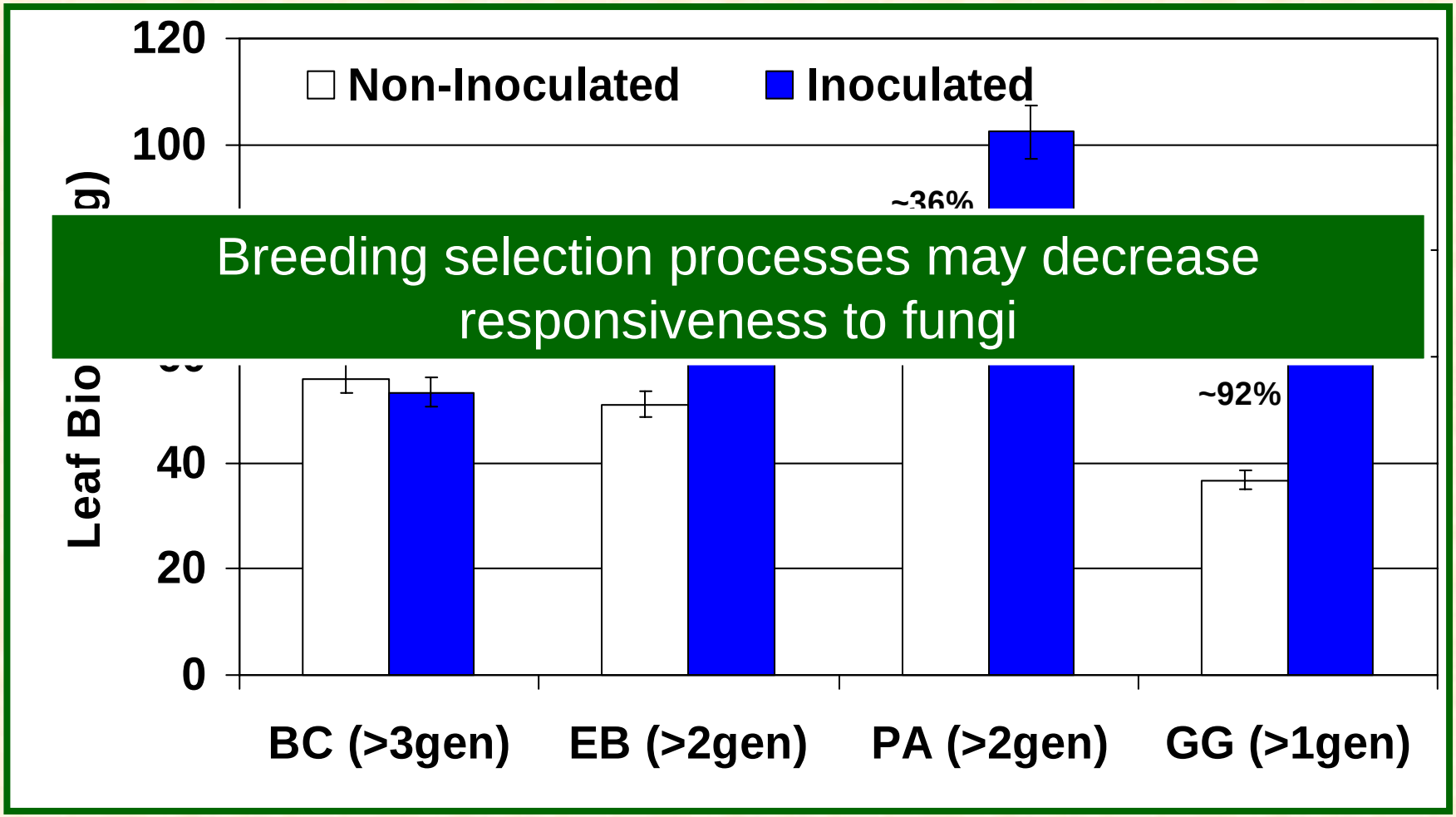
From Scagel, Wagner, Winiarski, 2005

Cultivar x Fungus Interaction



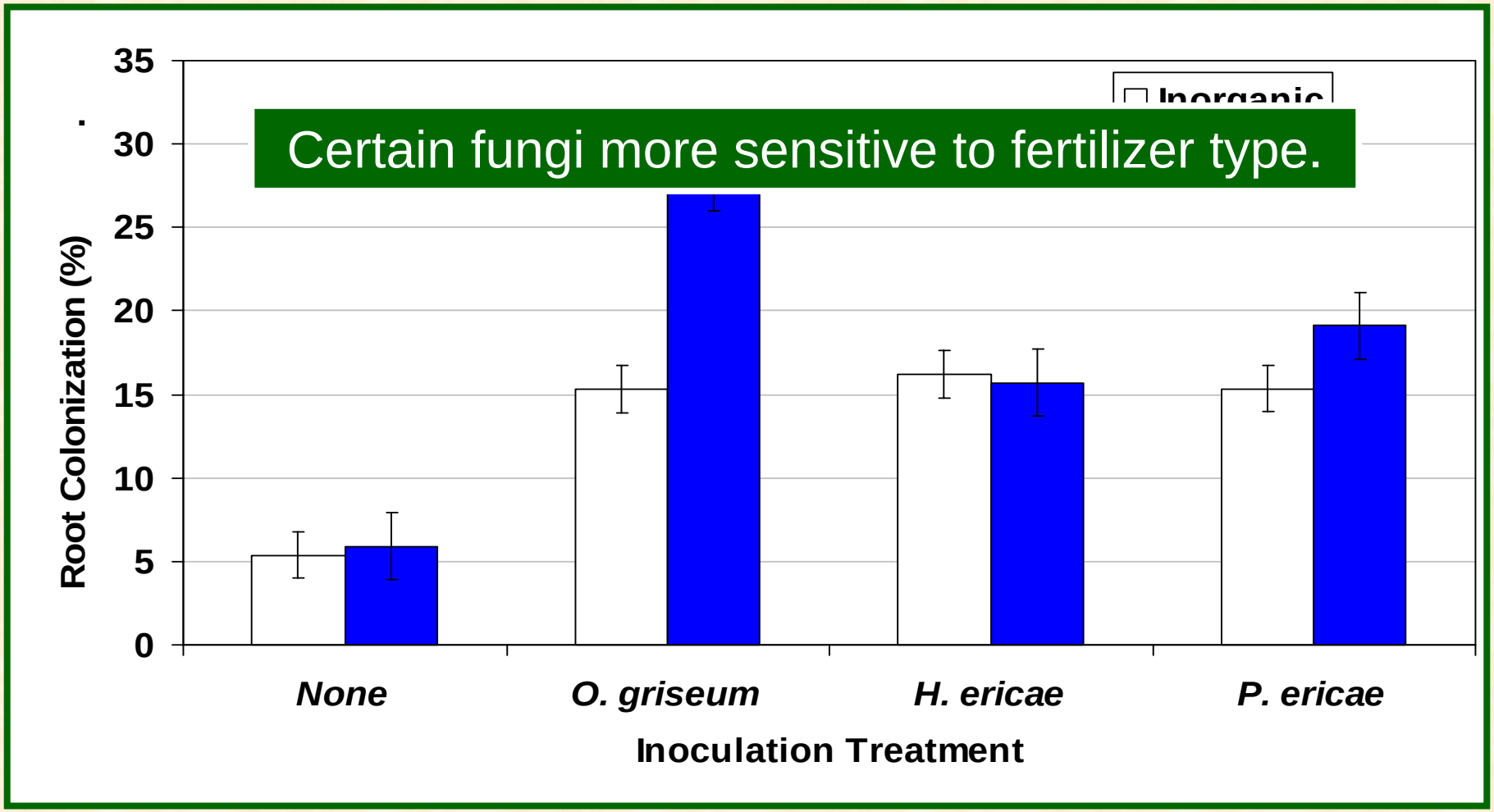
Scagel, 2005

Cultivar x Fungus Interaction



From Scagel, 2005

Culture x Fungus Interaction



Scagel, 2005

Inoculation?

To become mycorrhizal plants require:

- Viable inoculum available to roots
- Inoculum compatible with host type
- Environmental and cultural conditions suitable for colonization

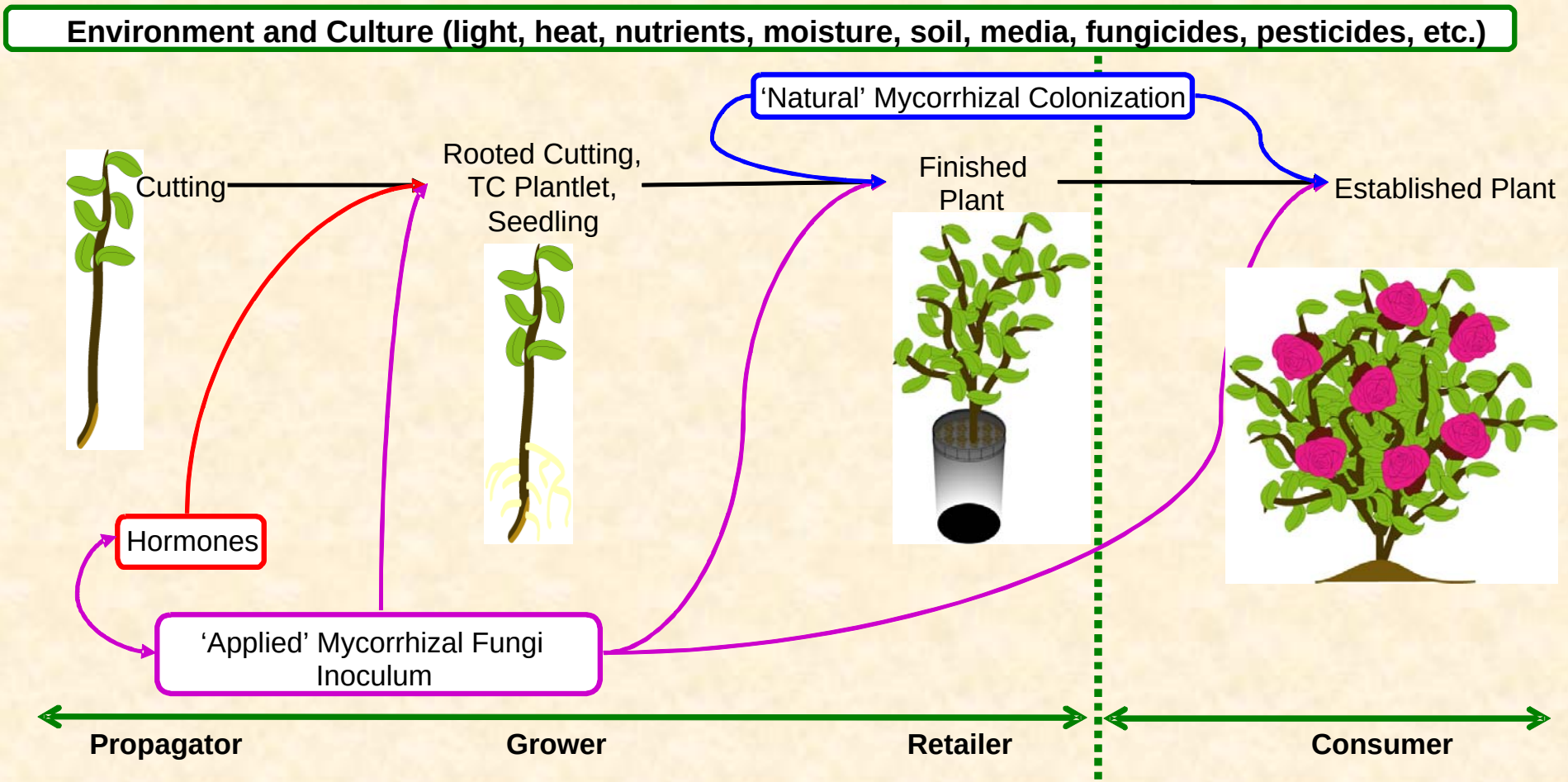
Do I Need To Inoculate?

- **Fiction:**
  Plants are mycorrhizal if they have been inoculated and are ‘naturally’ mycorrhizal if they have been grown in soil.

- **Facts:**
  1. Application of inoculum or growing plants in soil does not guarantee mycorrhizae formation.

  2. If mycorrhizae formation is a production goal, then process and quality control measures need to be in place to evaluate the success of practices used to achieve colonization.

When Do I Manipulate Mycorrhizae?



When Do I Manipulate Mycorrhizae?

- There are several opportunities during different stages of production. Timing depends on goal and culture.
- Benefits of having mycorrhizae are cumulative and may not be visible during production.
- Early mycorrhizae formation improves ability to capture benefits of the association.

When Do I Manipulate Mycorrhizae?

- **Fiction:**
  Once plants have mycorrhizae they retain them and the benefits from mycorrhizae that occur in the nursery will occur in the landscape

- **Facts:**
  1. Changes in the environment and culture that occur during different stages of production can alter mycorrhizal status of the plant.

  2. Mycorrhizal fungi that perform well during early states of production may not be the best fungi during later stages of production or in the landscape.

How Do I Use Mycorrhizal Fungi?

STAGE I

- Determine the specific goals or objectives for using mycorrhizal fungi in your production system
- Evaluate current mycorrhizal status of crop under current production conditions
- Work with commercial suppliers, extension personnel, or other people familiar with mycorrhizal fungi to determine whether cultural manipulation can improve mycorrhizal status or whether inoculation is needed.

How Do I Use Mycorrhizal Fungi?

STAGE II

- If inoculation is needed, assess different products and determine host plant/fungus types required.
- Aspects of inoculum products include:
  - Purpose of product and how to use it
  - Content with species names, etc.
  - Guarantee of pathogen free content
  - Mycorrhizal effectiveness in a standard test
  - Maximum dilution of content
  - How to store inoculum
  - Recommended date of use

How Do I Use Mycorrhizal Fungi?

STAGE III

- Test inoculum products on a small scale using non-inoculated plants for comparison.
- Verify whether inoculation causes an increase in mycorrhizal colonization.

How Do I Use Mycorrhizal Fungi?

- **Fiction:**
  Inoculation with mycorrhizal fungi does not effect plants

- **Facts:**

1. Inoculation does not guarantee colonization. If you inoculate always verify colonization success.

2. If inoculation results in colonization, plants are influenced by the association; however
   - **the effect may not meet specific goals of inoculation; or**
   - **other production practices may mask potential benefit**

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

MYCORRHIZAE = FUNGUS + ROOT