MYCORRHIZAL FUNGI: THE POWERHOUSE BEHIND SOIL HEALTH

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The Minnesota Office for Soil Health (MOSH) is a collaborative of the Minnesota Board of Water and Soil Resources and the University of Minnesota Water Resources Center.

CLEAN WATER LAND & LEGACY AMENDMENT

Soil health principles

- Keep the soil covered
- Minimize disturbance
- Increase crop diversity
- Keep living roots in the ground
- Integrate livestock

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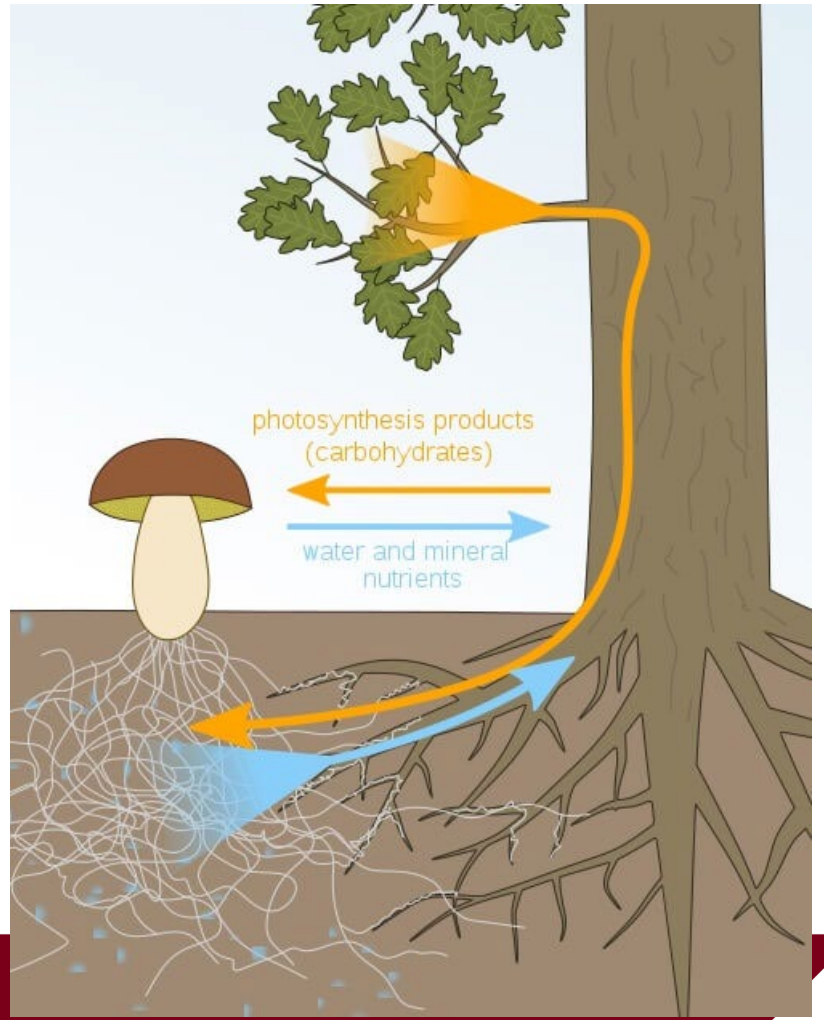
Saprotrophic fungi feed on dead organic material

Mycorrhizal fungi are in a relationship with plants



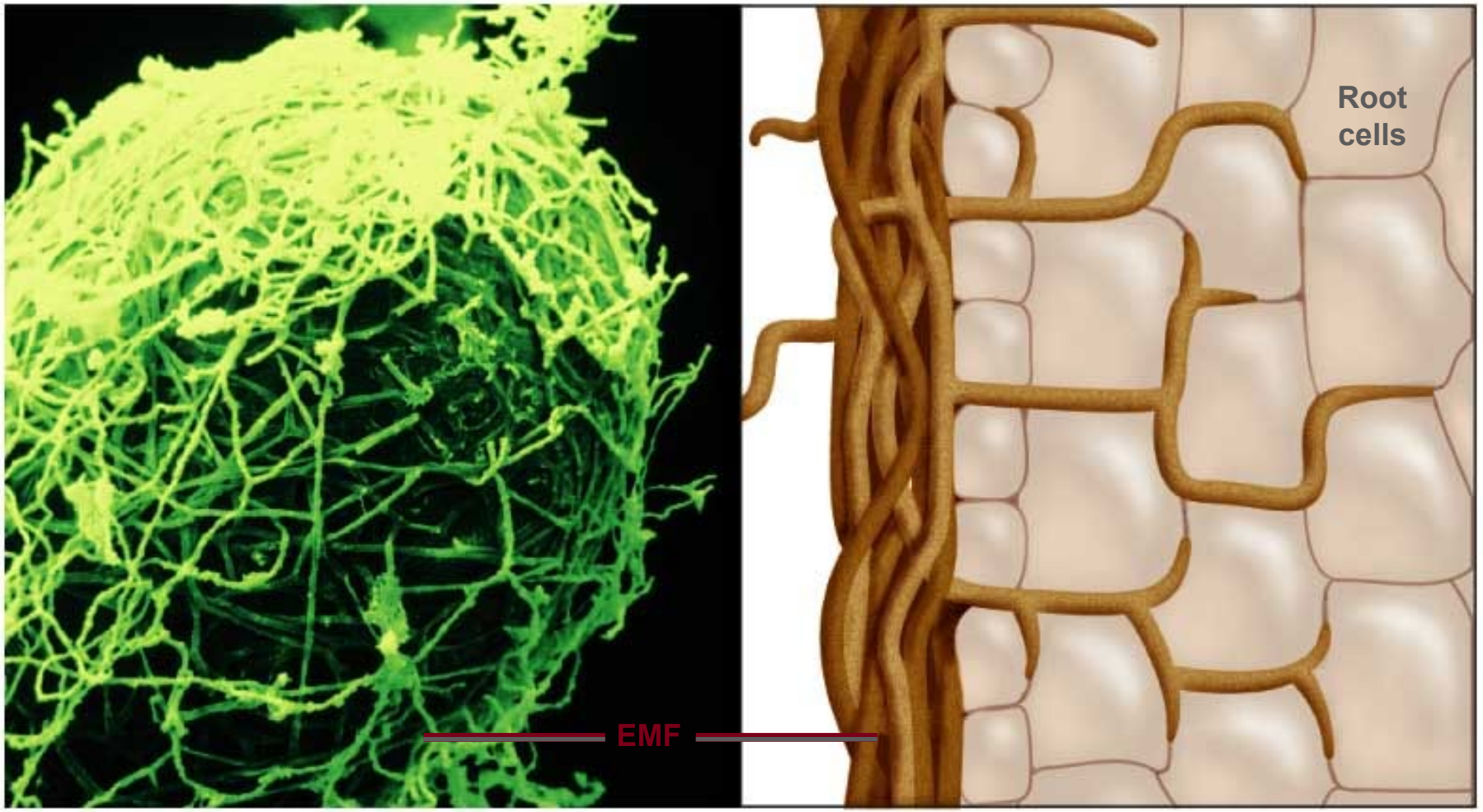
How widespread?

- 80% or more of all land plants have mycorrhizal relationships
- These relationships are varied, but having a microbial partner is usually an advantage
- Most horticulture and row crops are mycorrhizal
  - A notable exception being the *Brassicaceae*
  - Fertility and crop rotation play a large role on mycorrhizal associations in cropping systems

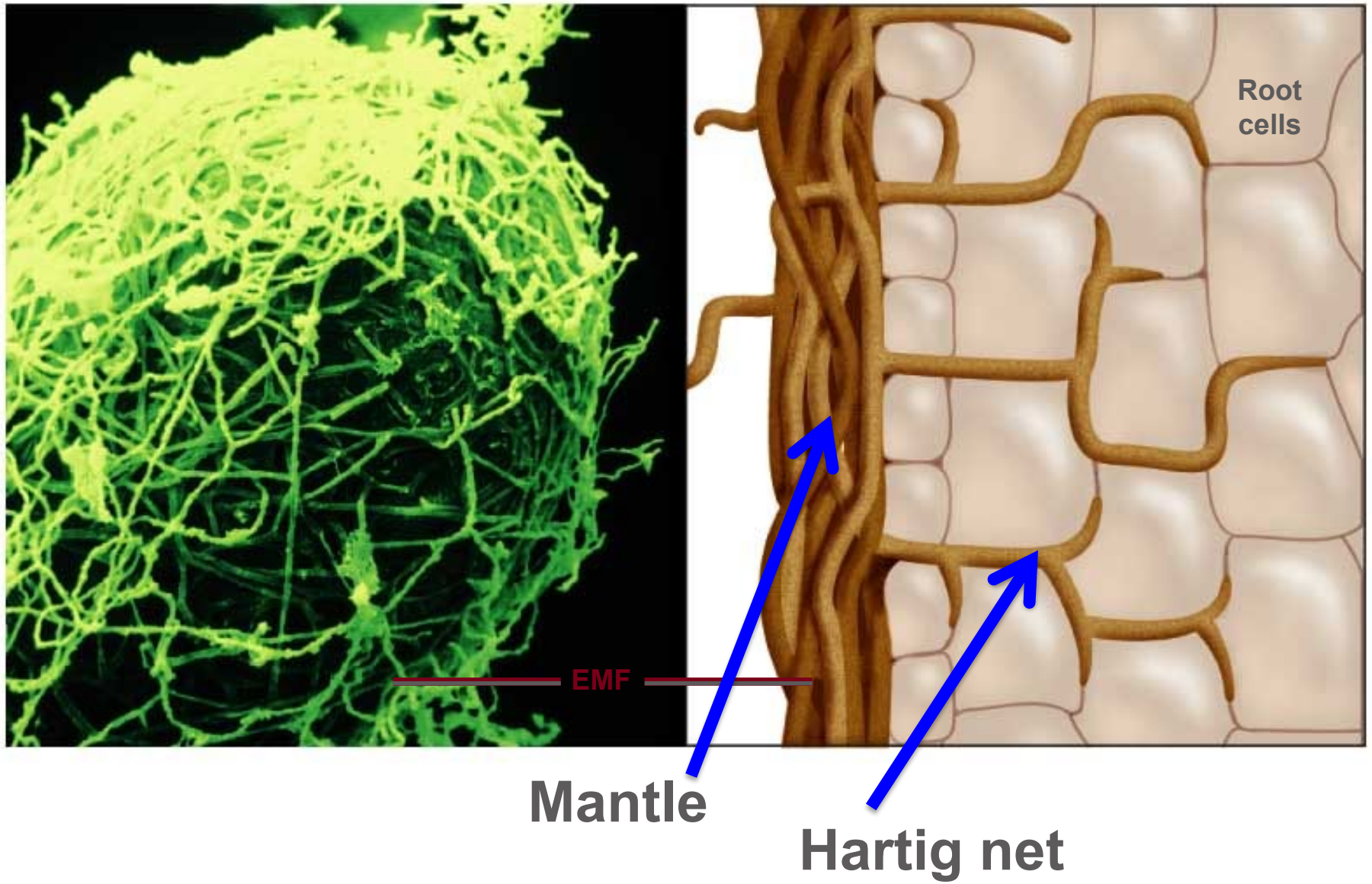
3 classes of mycorrhizal fungi

- Ectomycorrhizal fungi
- Endo, or Arbuscular, mycorrhizal fungi
- Ericoid mycorrhizal fungi

Ectomycorrhizal fungi (EMF)



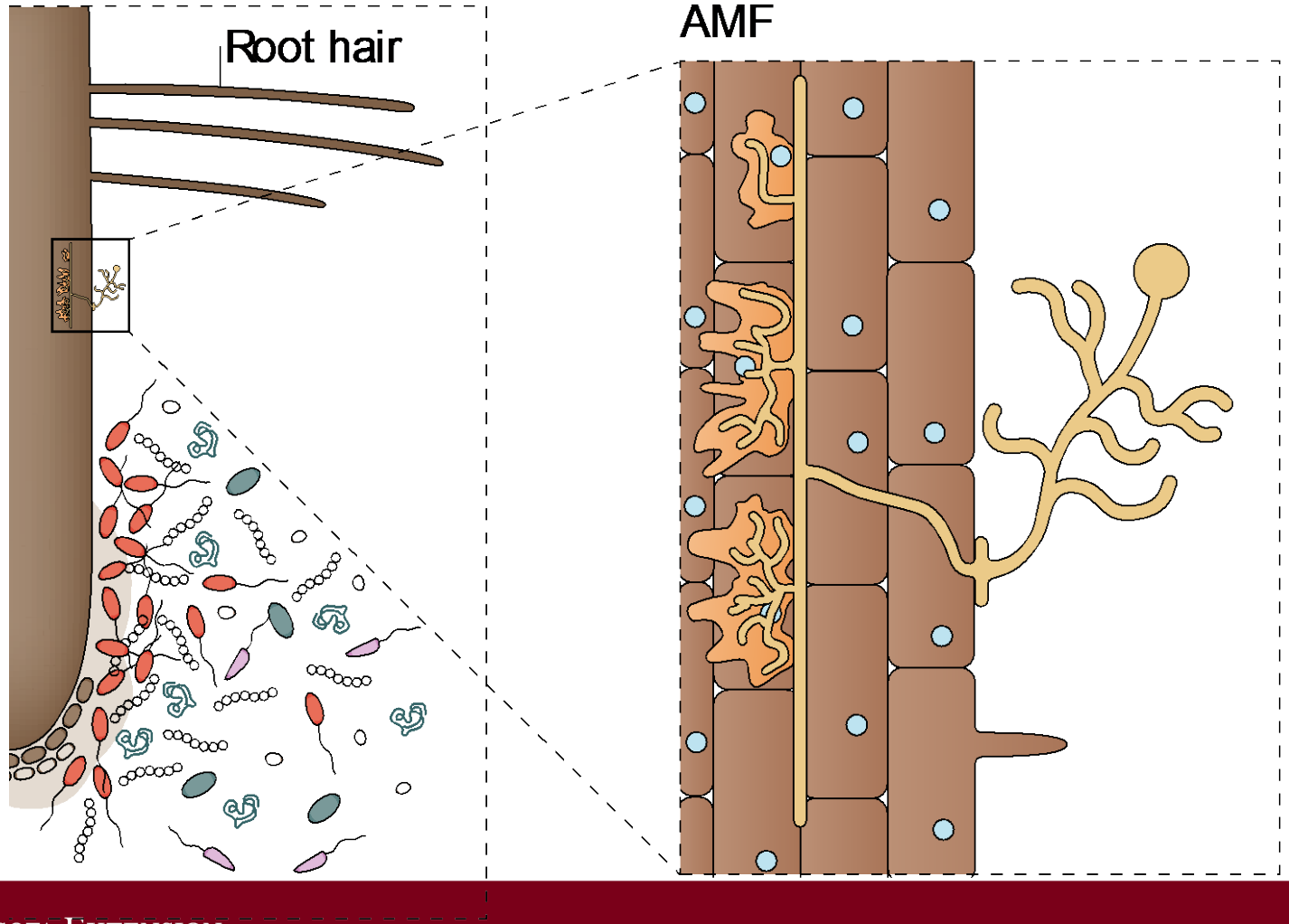
Ectomycorrhizal fungi (EMF)



EMF – mostly in forests

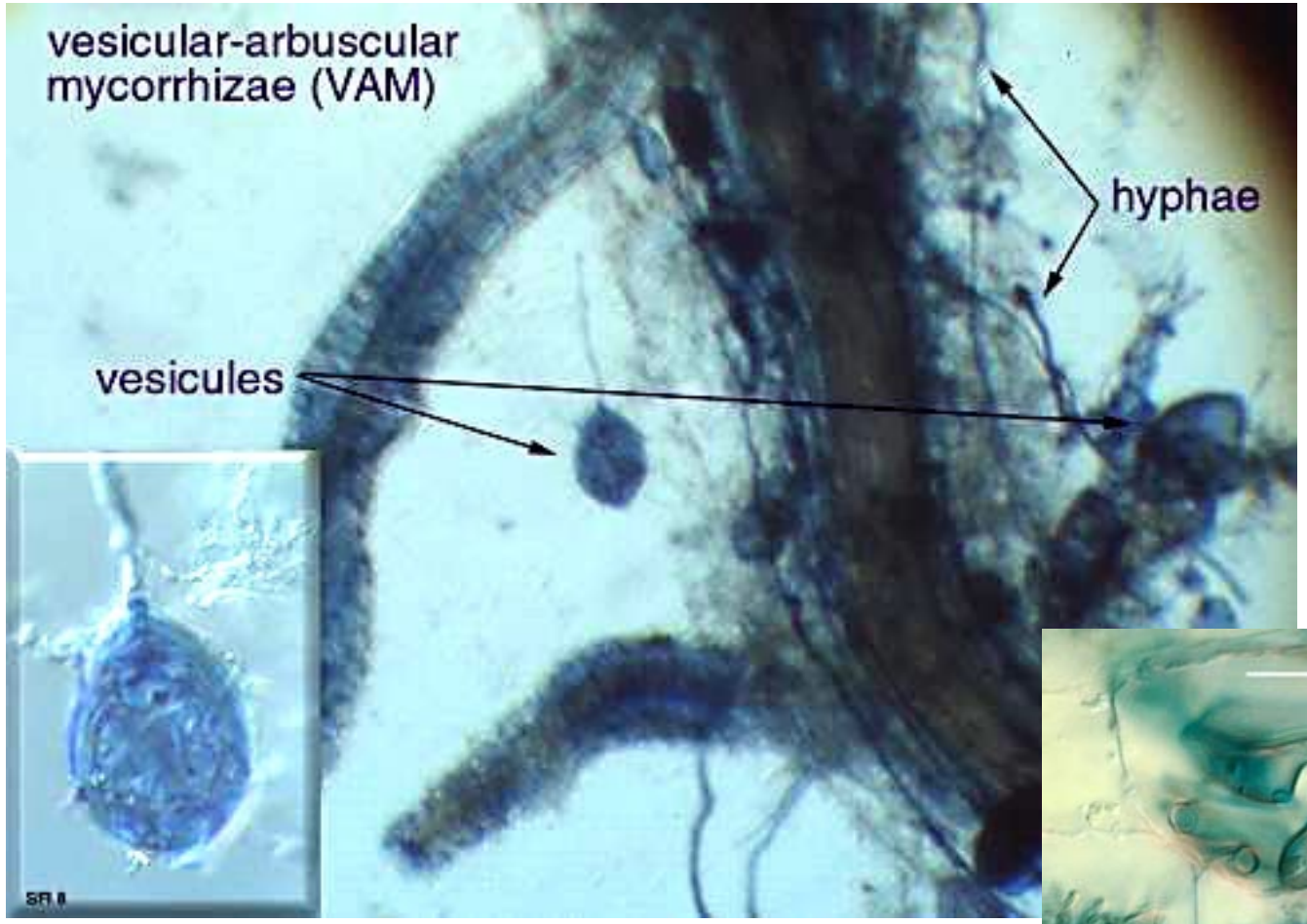
- Mostly gymnosperms (nonflowering, mainly cone producing), some angiosperms (flowering, fruit bearing)
- ~8000 woody species, but dominate whole ecotypes
- Mostly Basidiomycetes fungi, but widespread
- Can also act as saprotrophs
- Produce enzymes, can both acquire and mineralize nitrogen and other nutrients-
- Dominate plant nutrient uptake

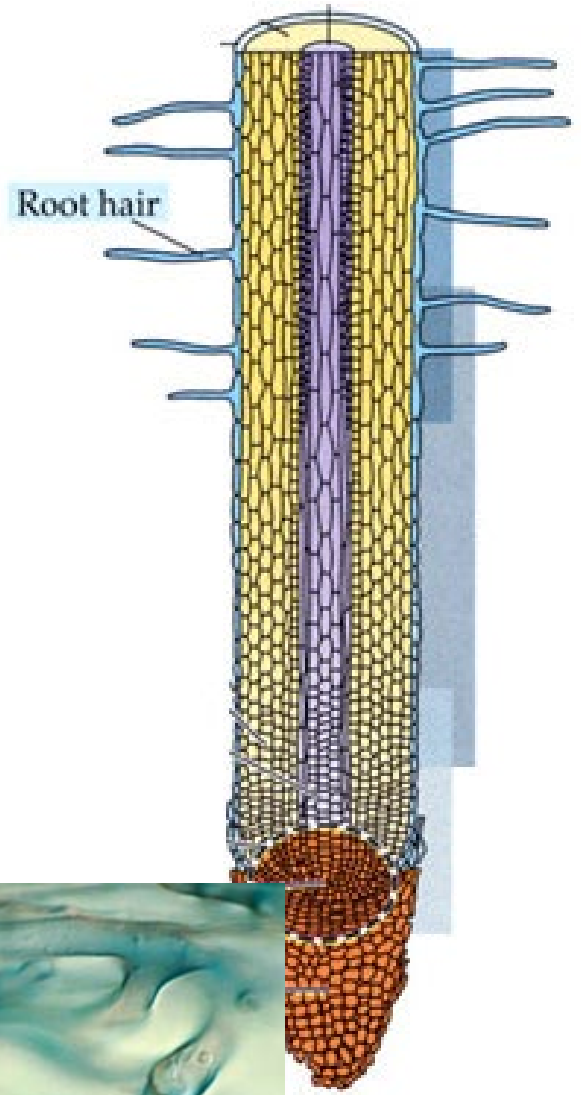
Arbuscular Mycorrhizal Fungi

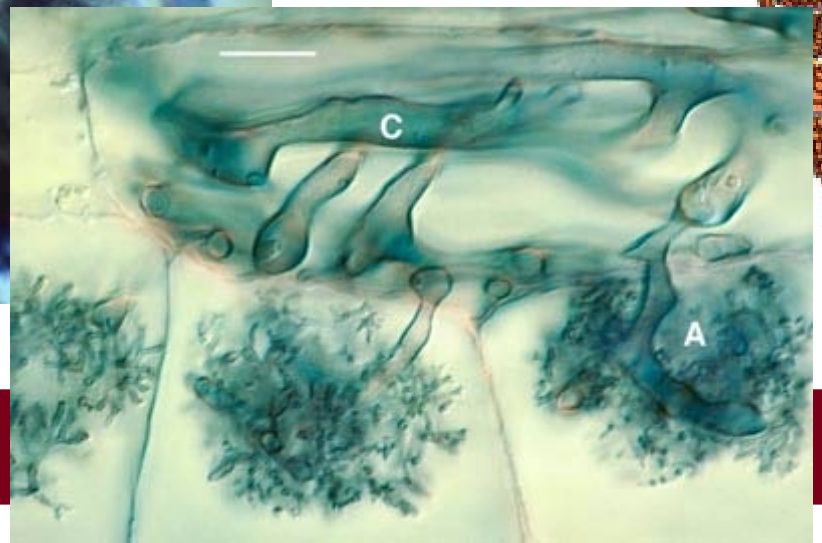


Phillipot et al 2013

AMF structures







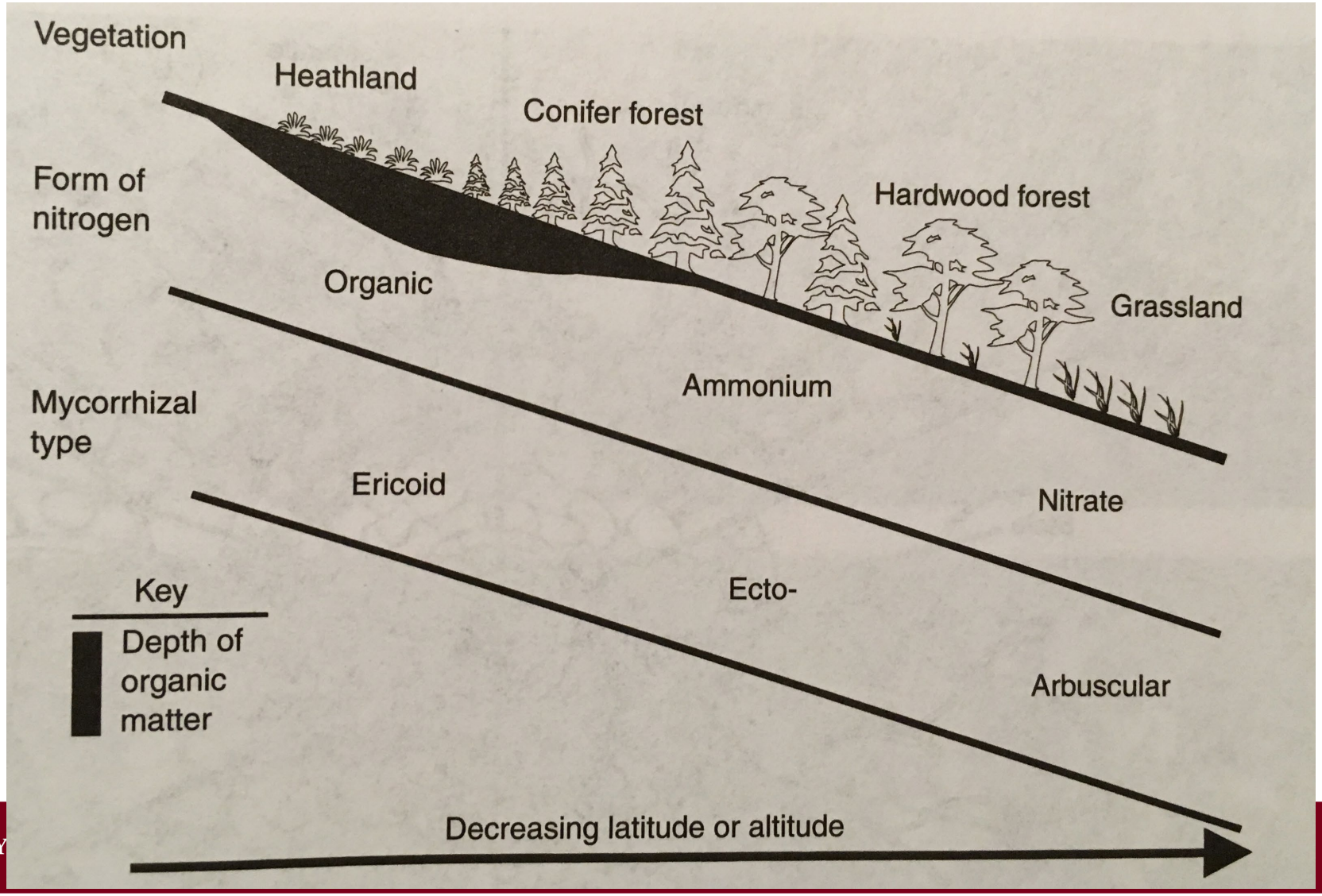
AMF are everywhere, but a little less powerful

- Many angiosperms, some gymnosperms, bryophytes, other plant families
- Dominate non-forested, some forested ecosystems
- Major crops (corn, wheat, rice, soybean, tomato)
- Only Glomeromycota fungal family
- Host-AMF symbiosis is specific
- Only acquire nutrients, notably phosphorus. Little active mineralization

Ericoid mycorrhizal fungi- rare and specific

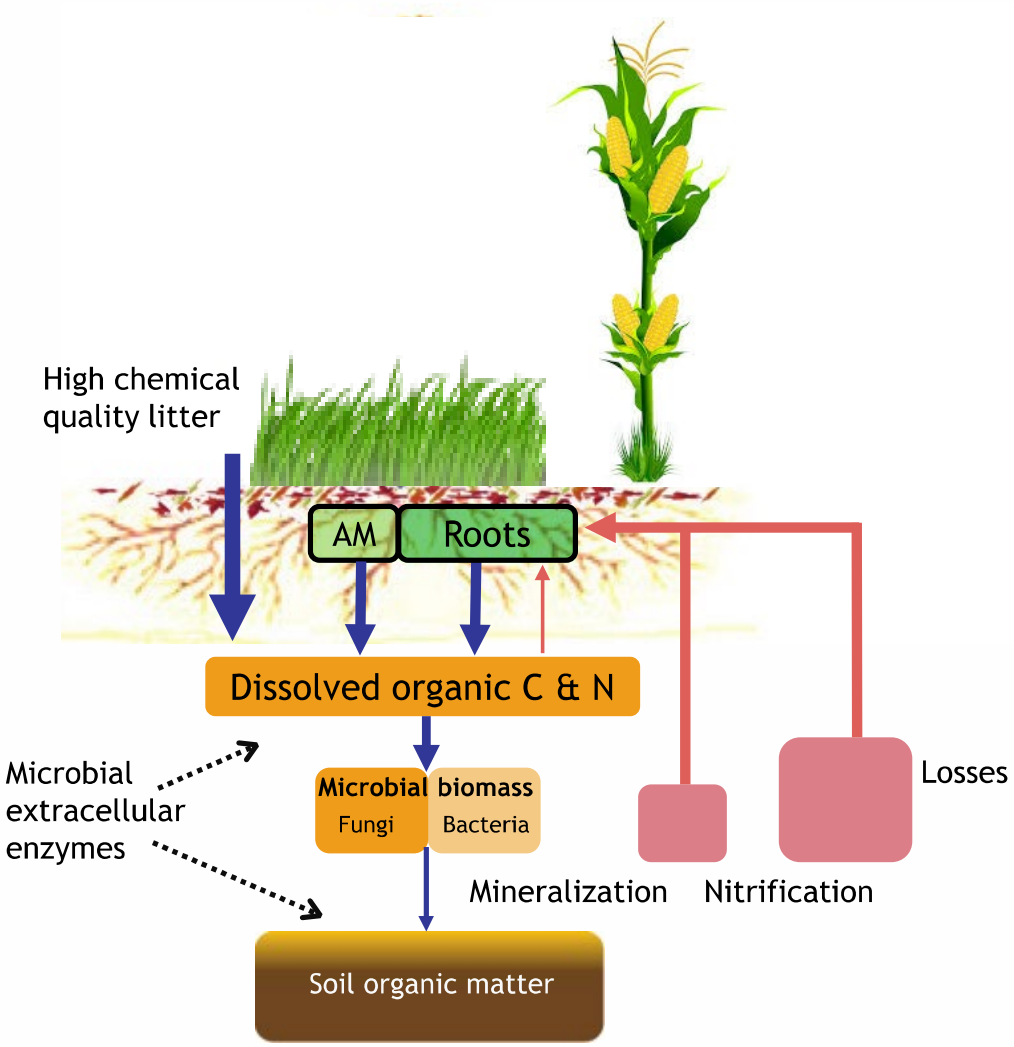
- Associate with Ericaceous plants, found in heathlands, peatlands
  - *Vaccinium* (Blueberries), Heather, *Rhododendron*
- Very thick hartig net of hyphae around cells, no mantle (only a thin layer of hyphae on the root)
- Mainly Ascomycetes
- Less studied than other mycorrhizae

Mycorrhizae type controlled by altitude and nutrient limitations

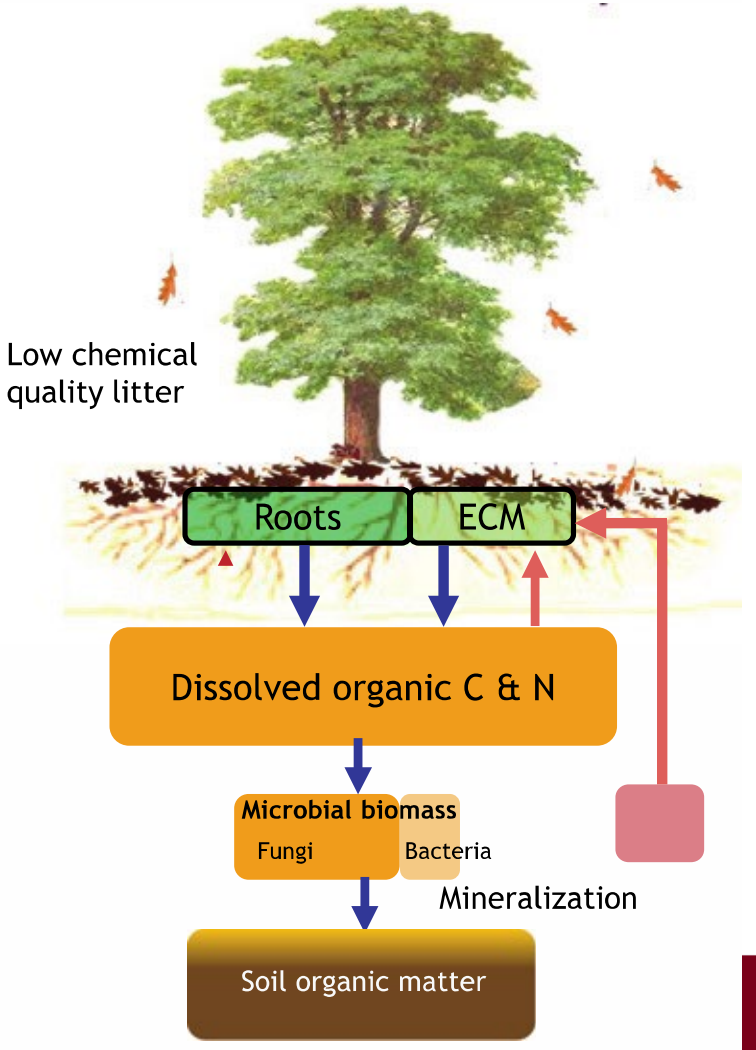


Consequences for ecosystem

AM-dominated plots
Inorganic nutrient economy



ECM-dominated plots
Organic nutrient economy



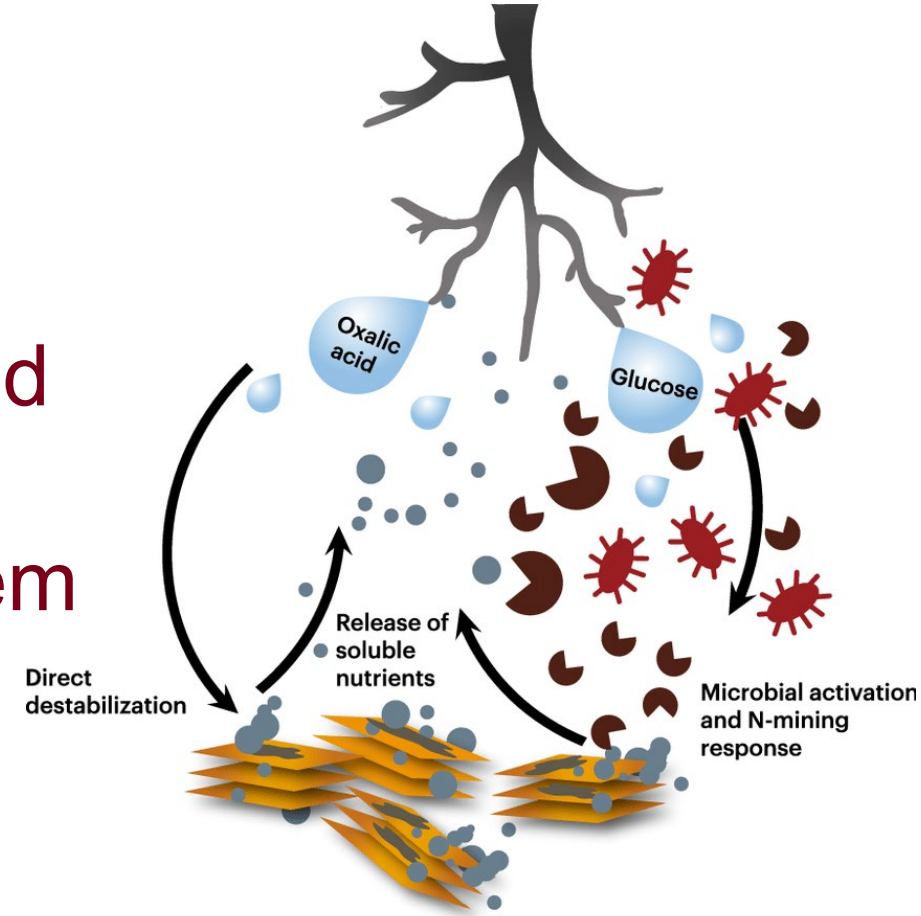
Features	AM fungi association	Ectomycorrhizal fungi association
Transport of nutrients to plant	Specifically important for phospho-rus transport, also contribute to nitrogen transport	Specifically important for nitrogen Transport but also have significant Contribution in P transport
Occurrence of fungi	Mainly in warm and dry climates where phosphorus availability is low	Climates with low temperature and high humidity, where nitrogen availability is low
Plant host range	Associates with a very wide range of hosts	Associates with comparatively lower portion of plant species
Type of fungal nutrition	Obligate biotrophophic fungi	Facultative saprotrophytic fungi
Structural ele-ments in fungi	Arbuscules, ERM, and vesicles in some types	Mantle, Hartig net, and ERM
Fungal mode of penetration in host plant	Both inter- and extracellular penetration	Only intercellular penetration
Pathway of nutrient uptake	Both plant and mycorrhizal pathway	Mainly mycorrhizal pathway

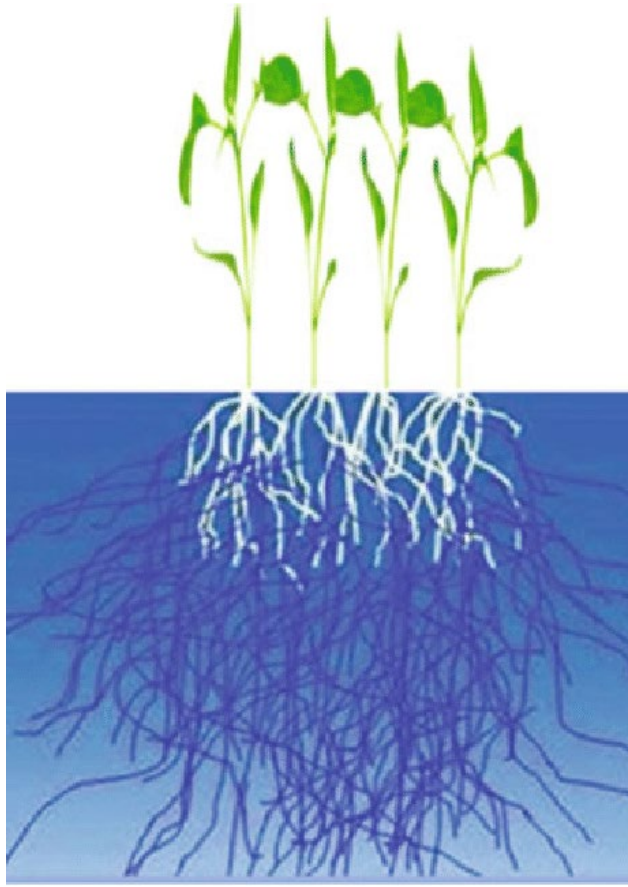
Roles of AMF in managed lands, crops

- Source of nutrients P for plants
- Move C and bacteria from roots to bulk soil
- Build structure

How do AMF get nutrients to plants?

- Location- hyphae go places roots don't!
- Enzymes- fungi produce enzymes and acids to solubilize nutrients, release them from clays





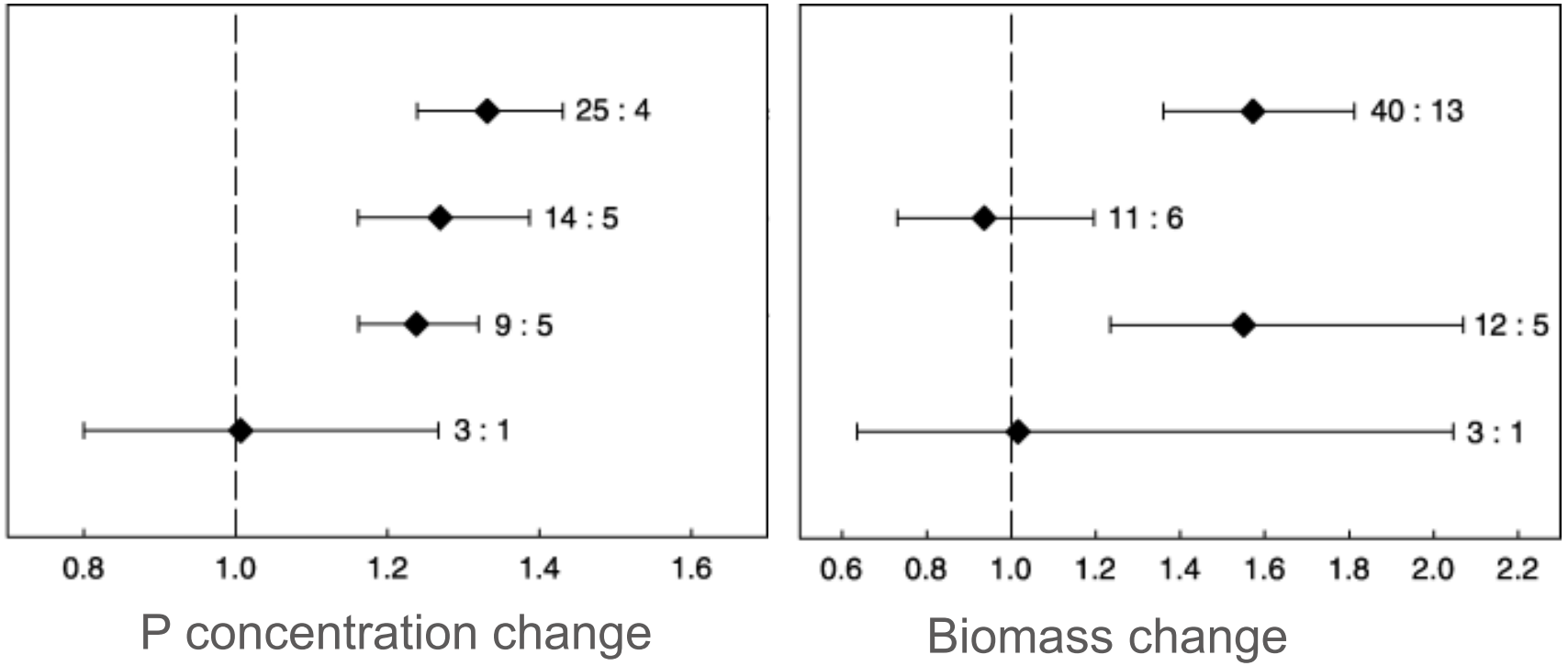
AMF can increase crop P concentration, sometimes yield

Inoculation w/ AMF

Reduced disturbance

Shorter fallow

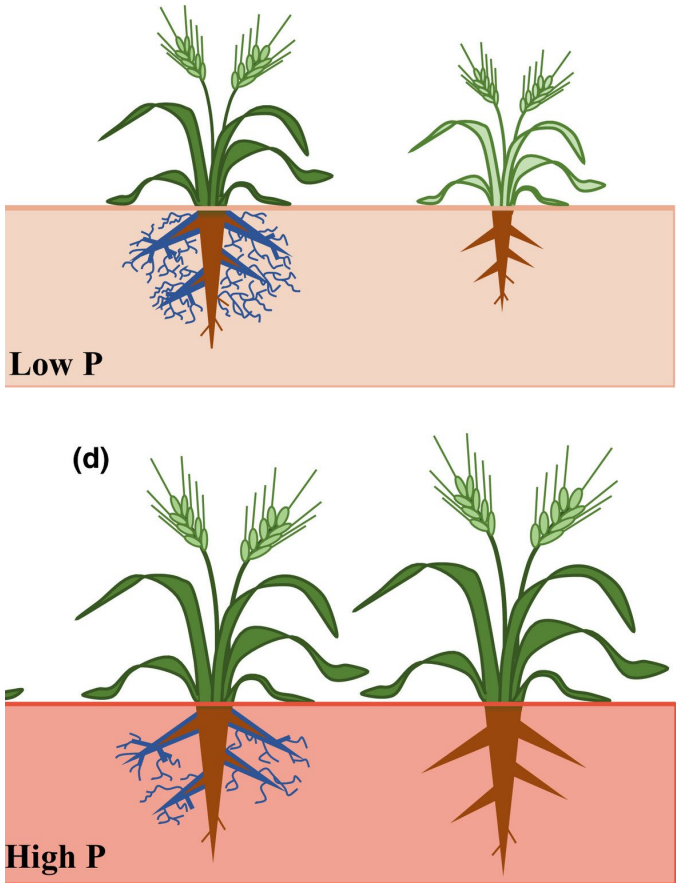
Mycorrhizal plants in rotation

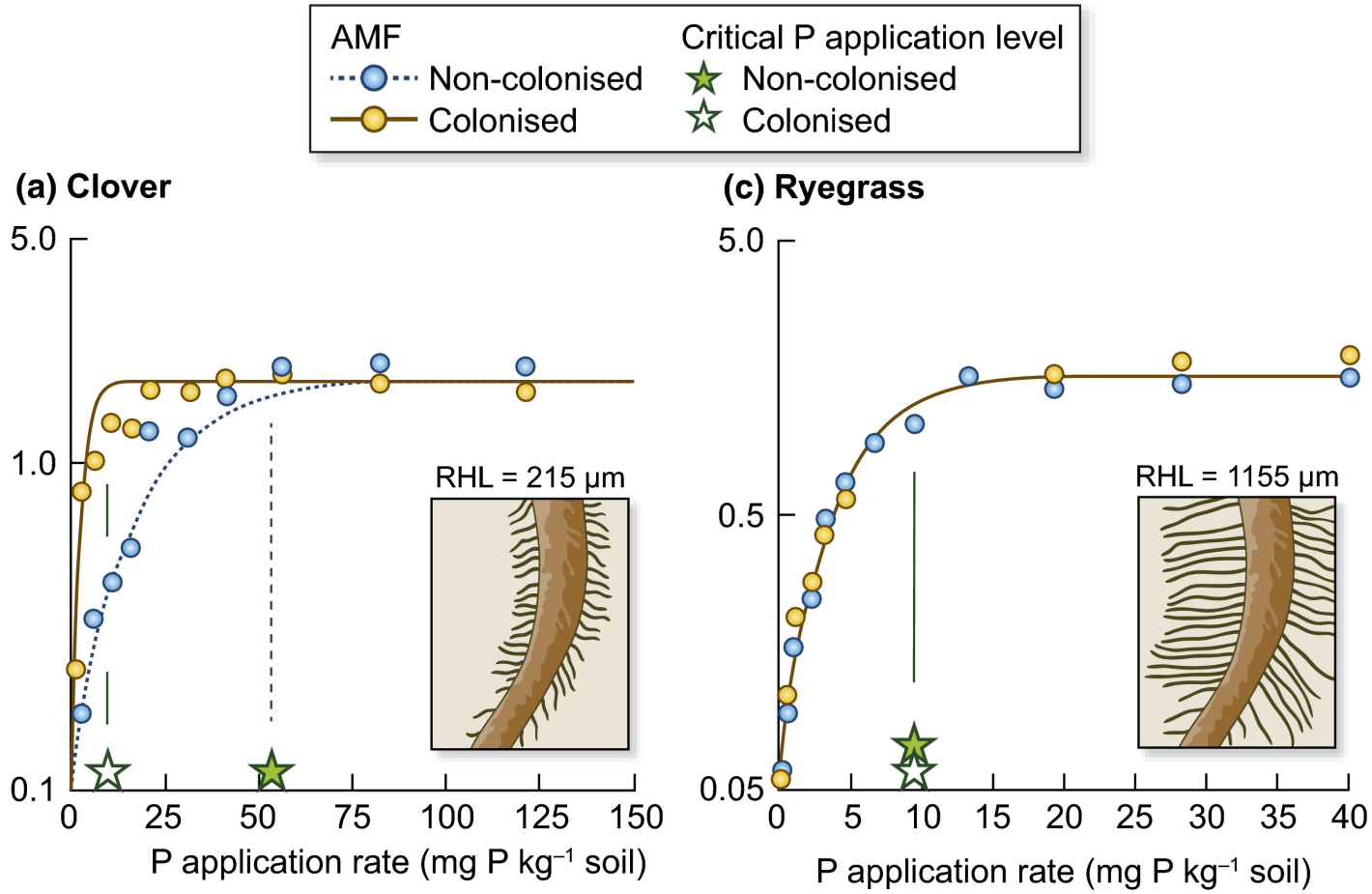


P concentration change

Biomass change

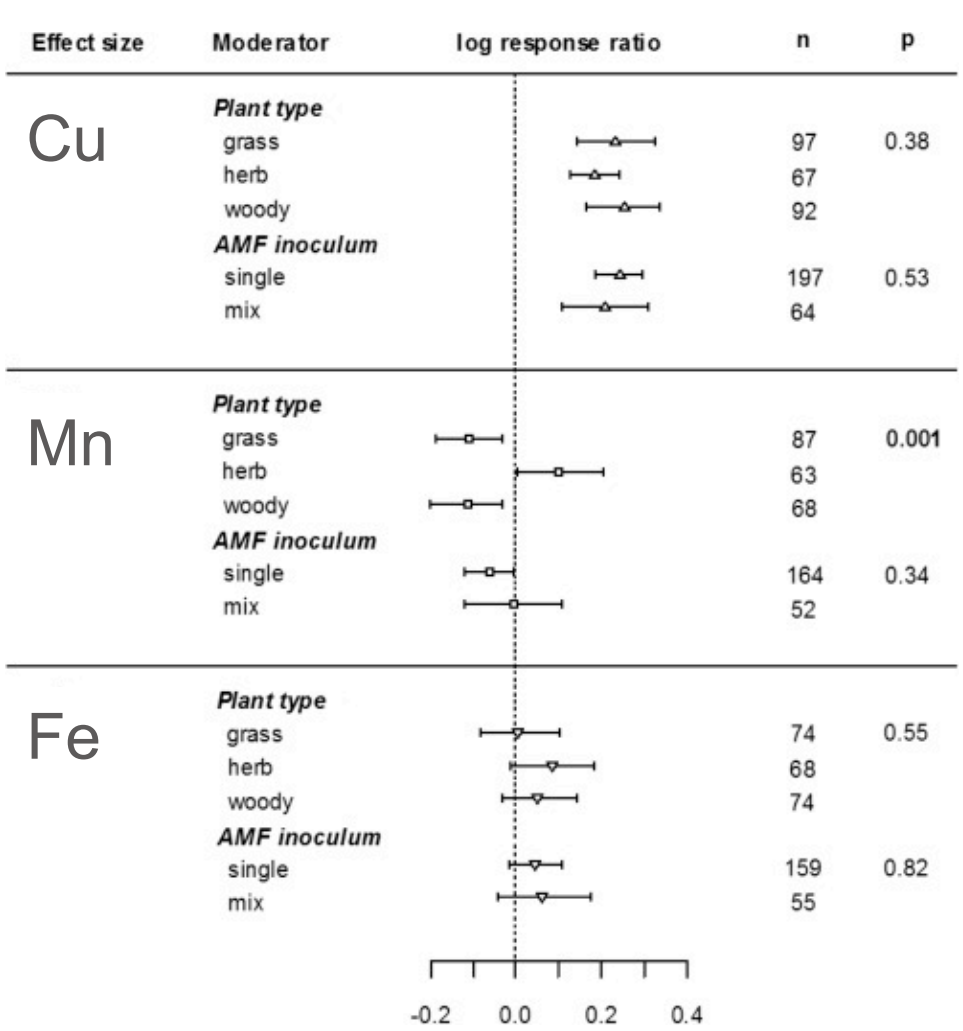
AMF help plants take up P when it's needed

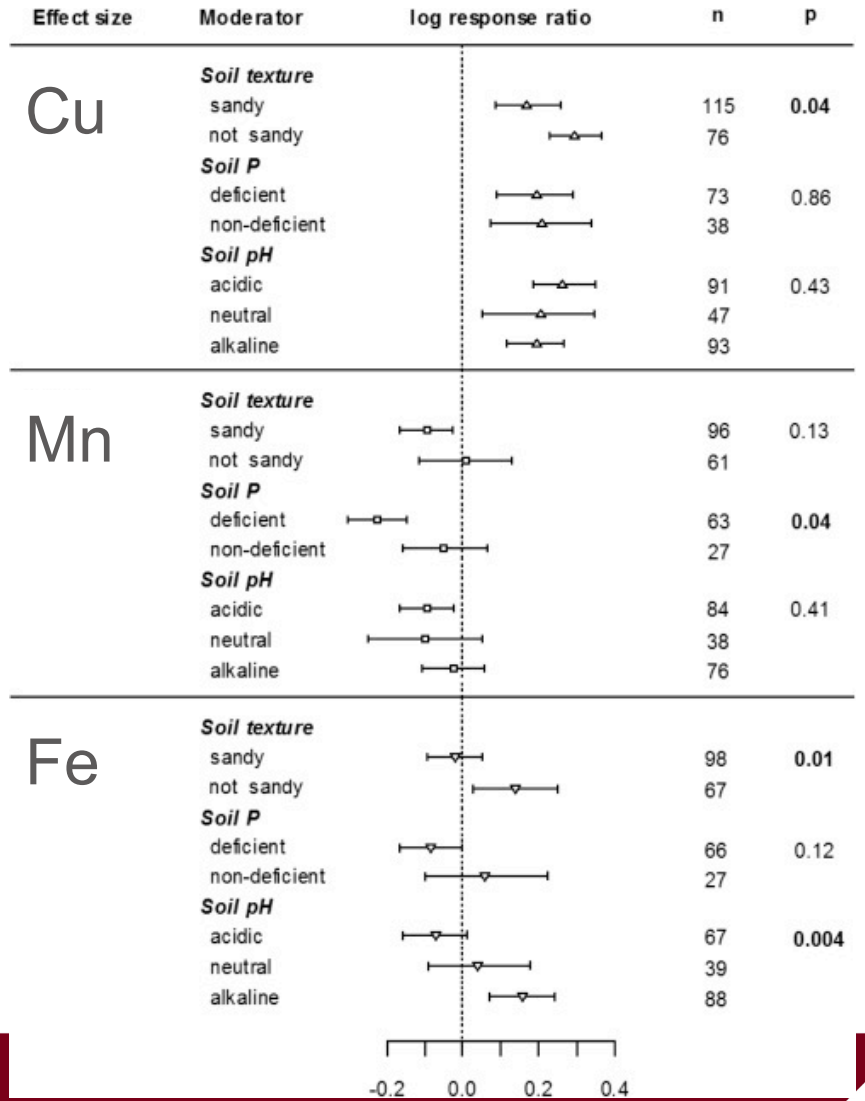




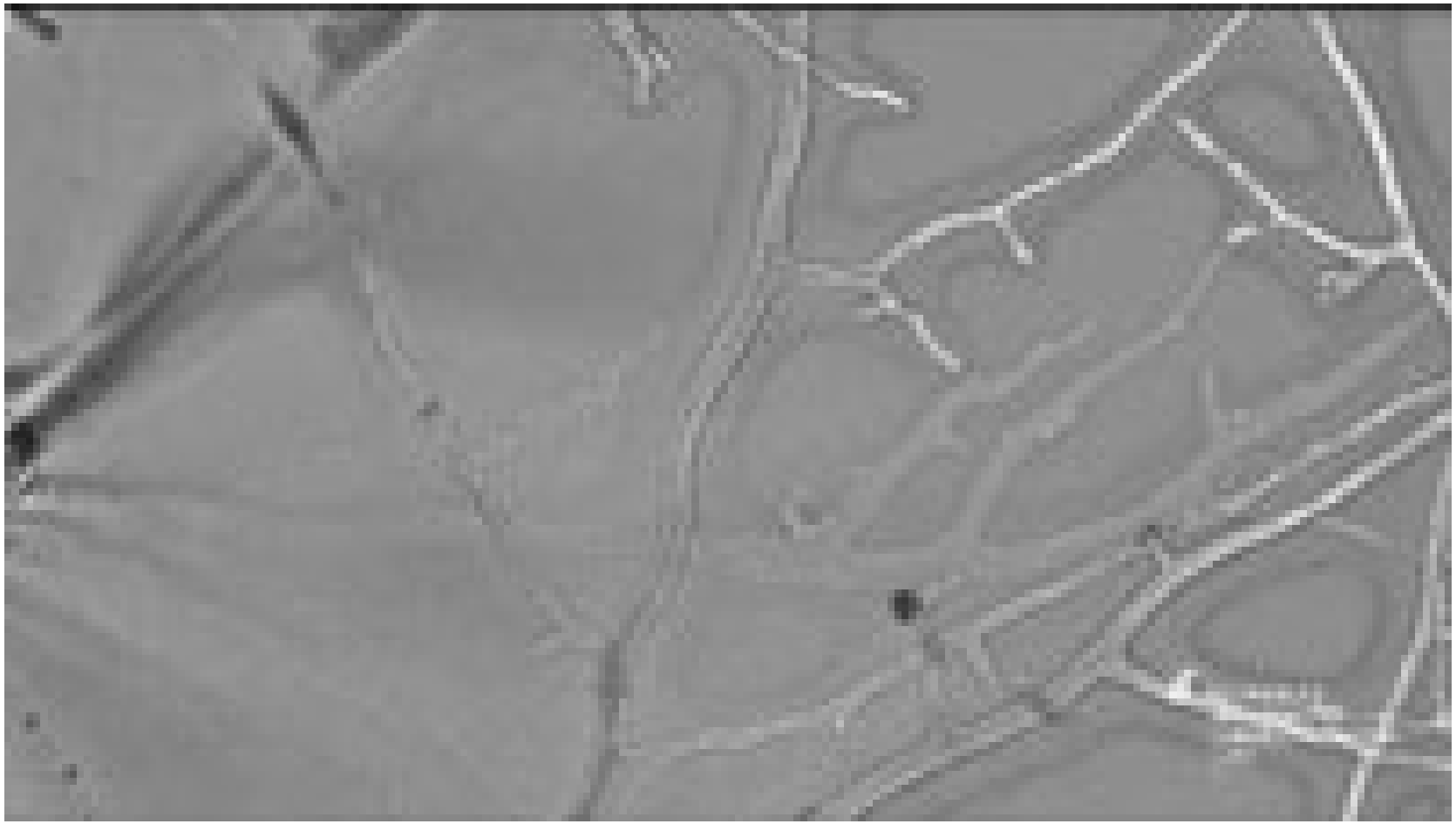
Martin-Robles et al. 2018, Sandral et al. 2015

AMF may increase uptake of Cu, Fe, Mn, Zn





Fungal hyphae move bacteria and leave stable C in the soil



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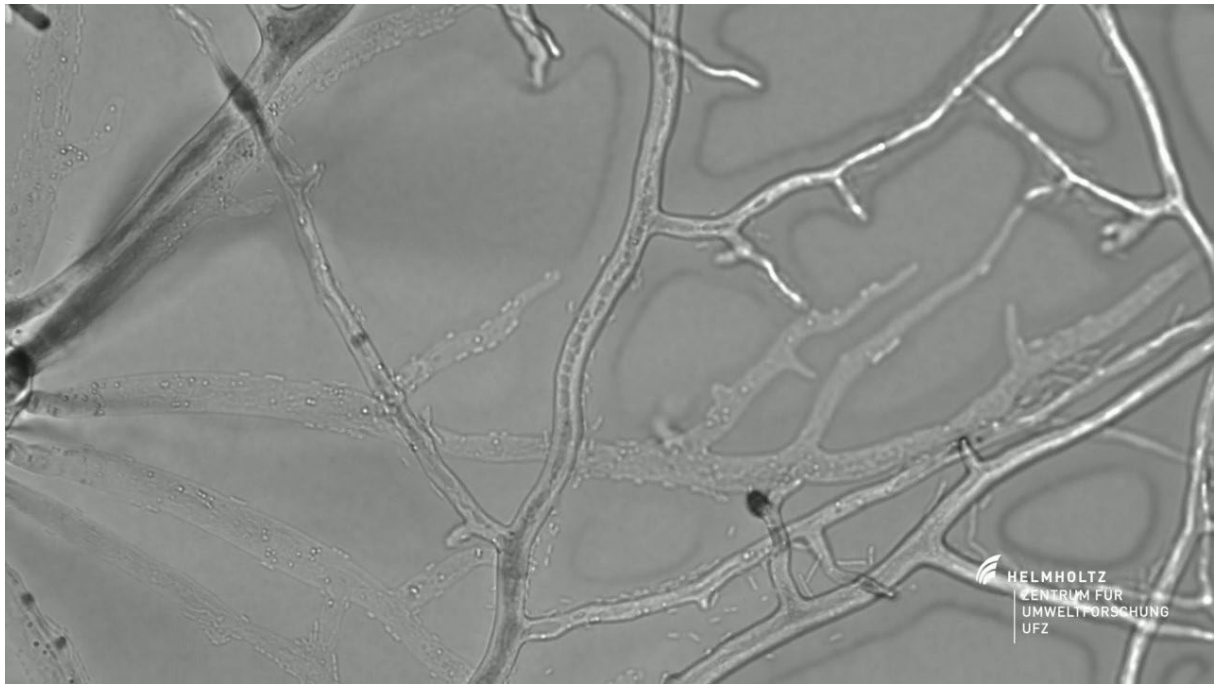
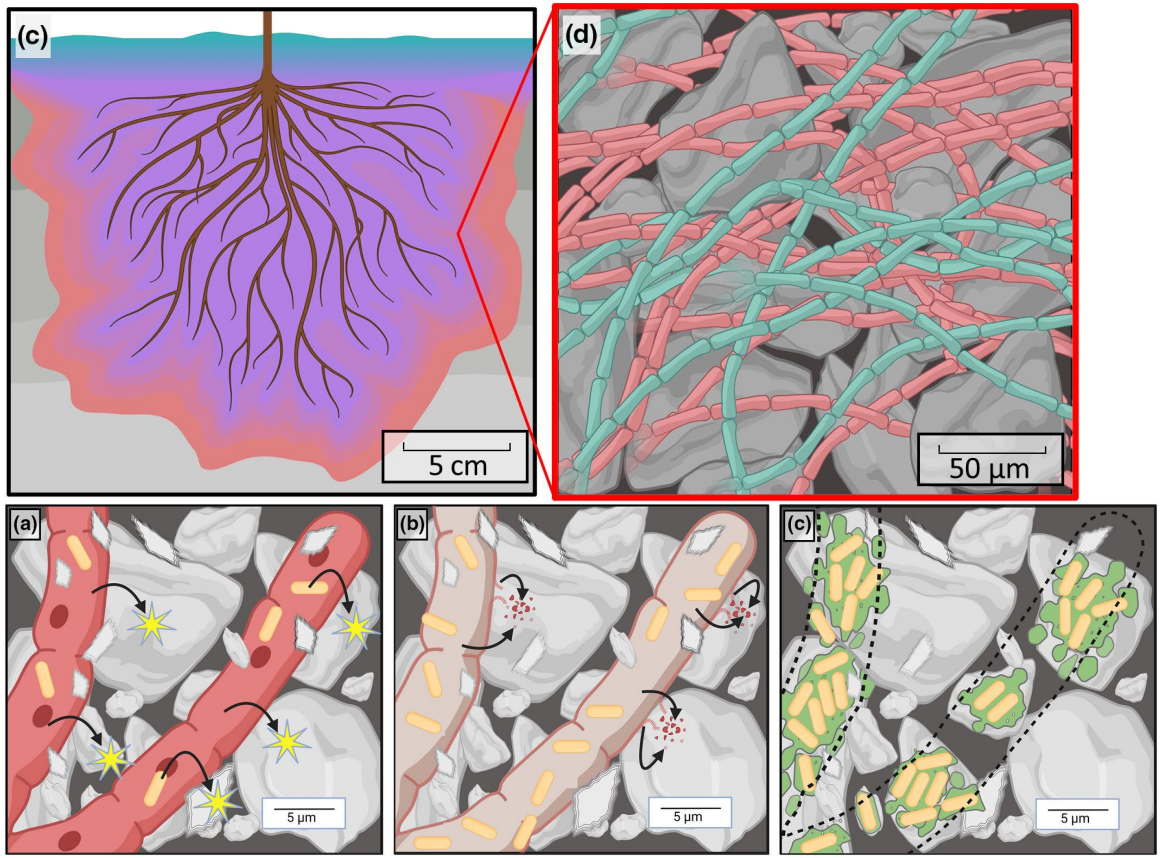
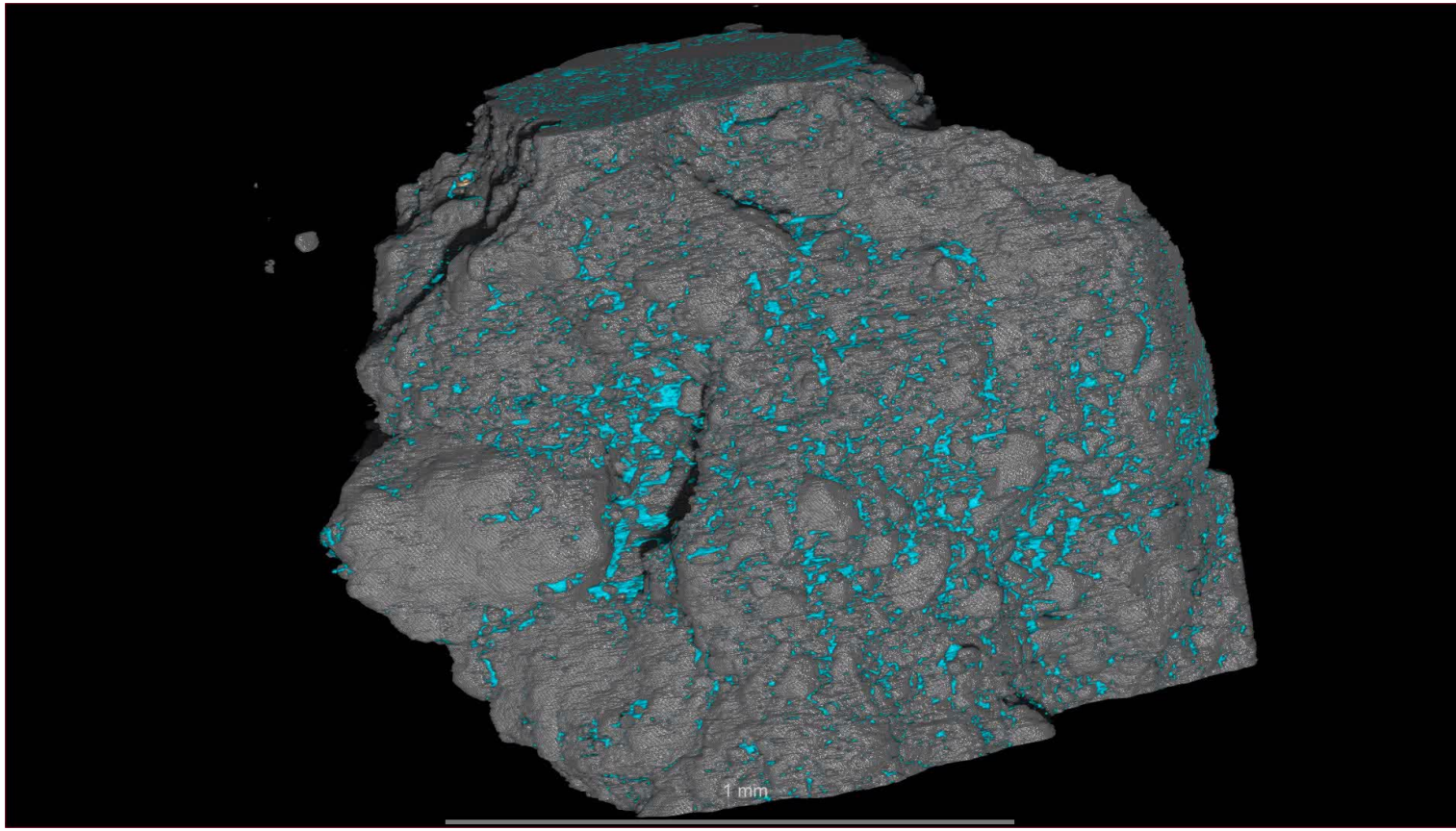


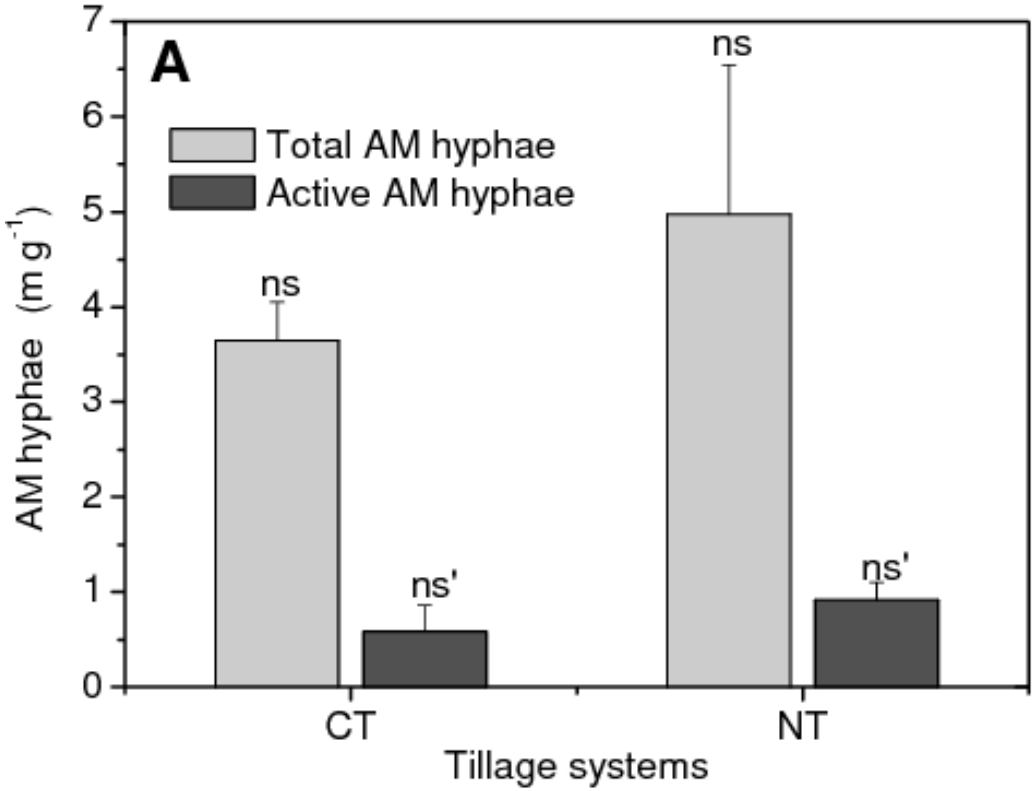


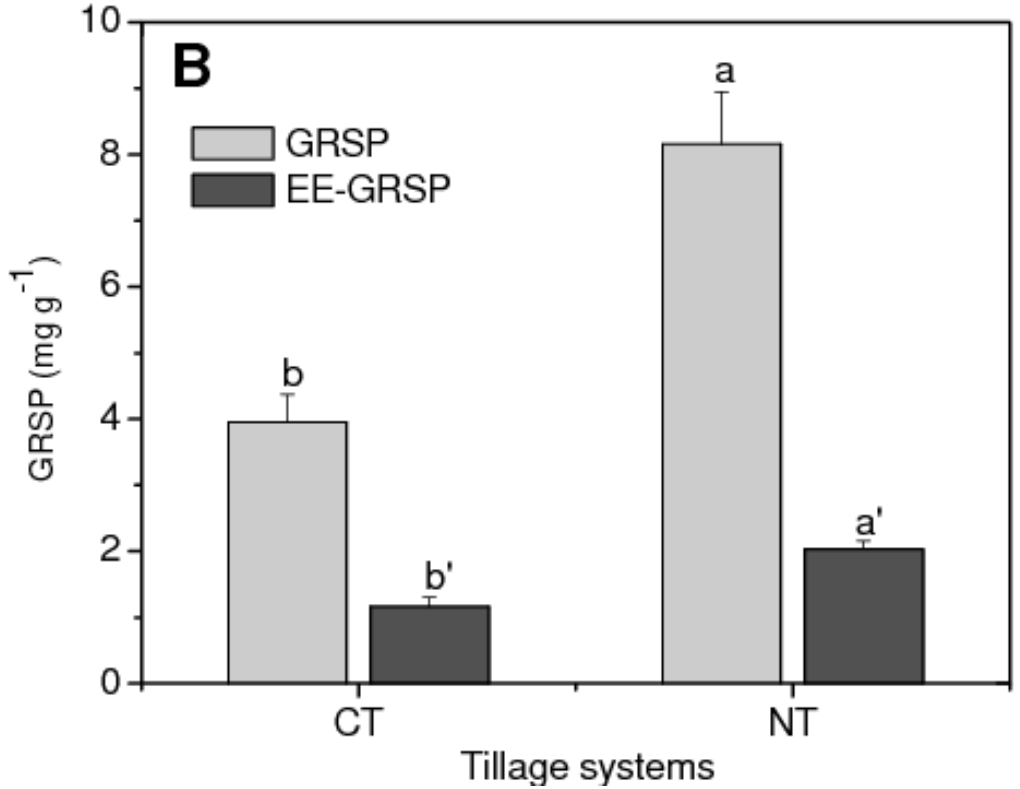
See et al. 2021

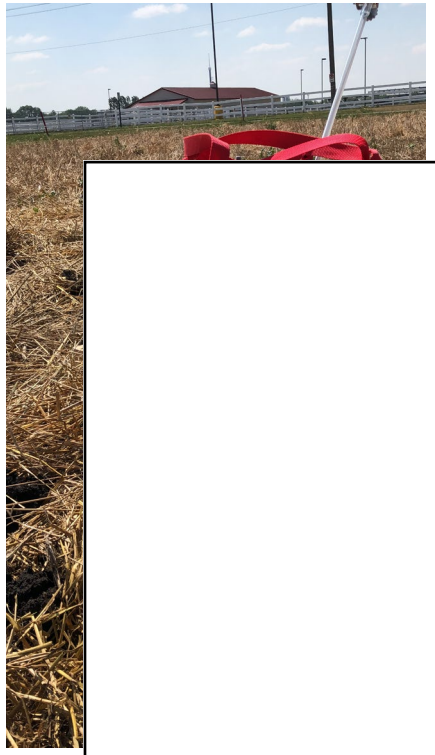
Sticky carbon-coated clay builds aggregates, roots + hyphae bind them



Hyphae are vulnerable to tillage







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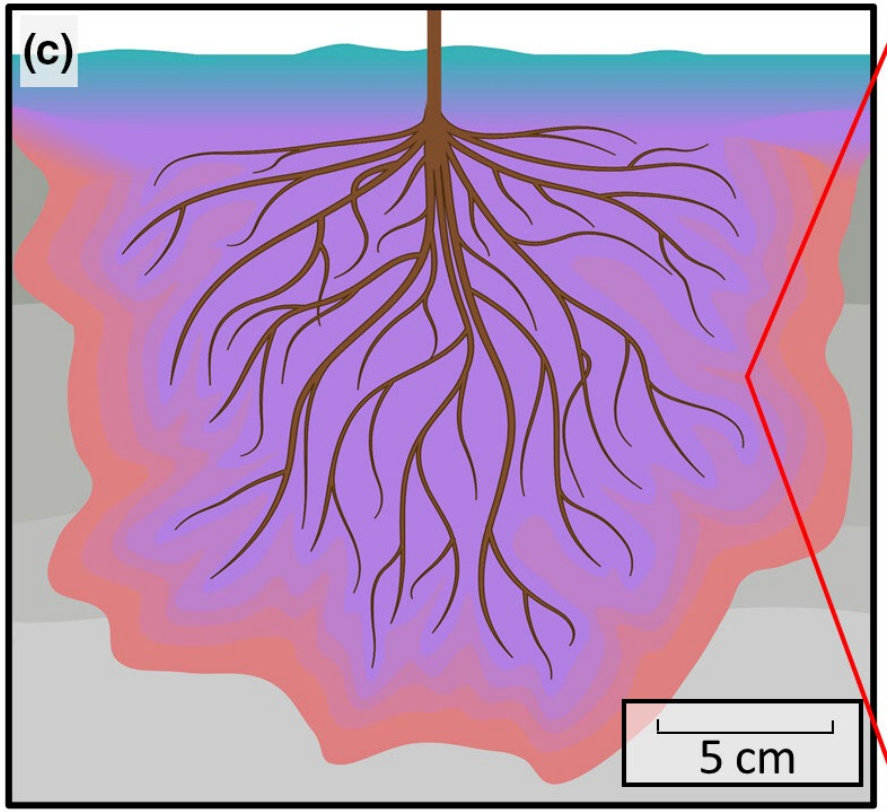
Summary

- Mycorrhizal associations vary by physical structure of fungal invasion (AMF, ericoid, EMF)
- AMF most important for agriculture:
  - collect water, nutrients for plants
  - move C into soil
  - Build structure



Questions?

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