



Joseph Bellacera, *Over Yolo #2*

# Managing mycorrhizas on your farm

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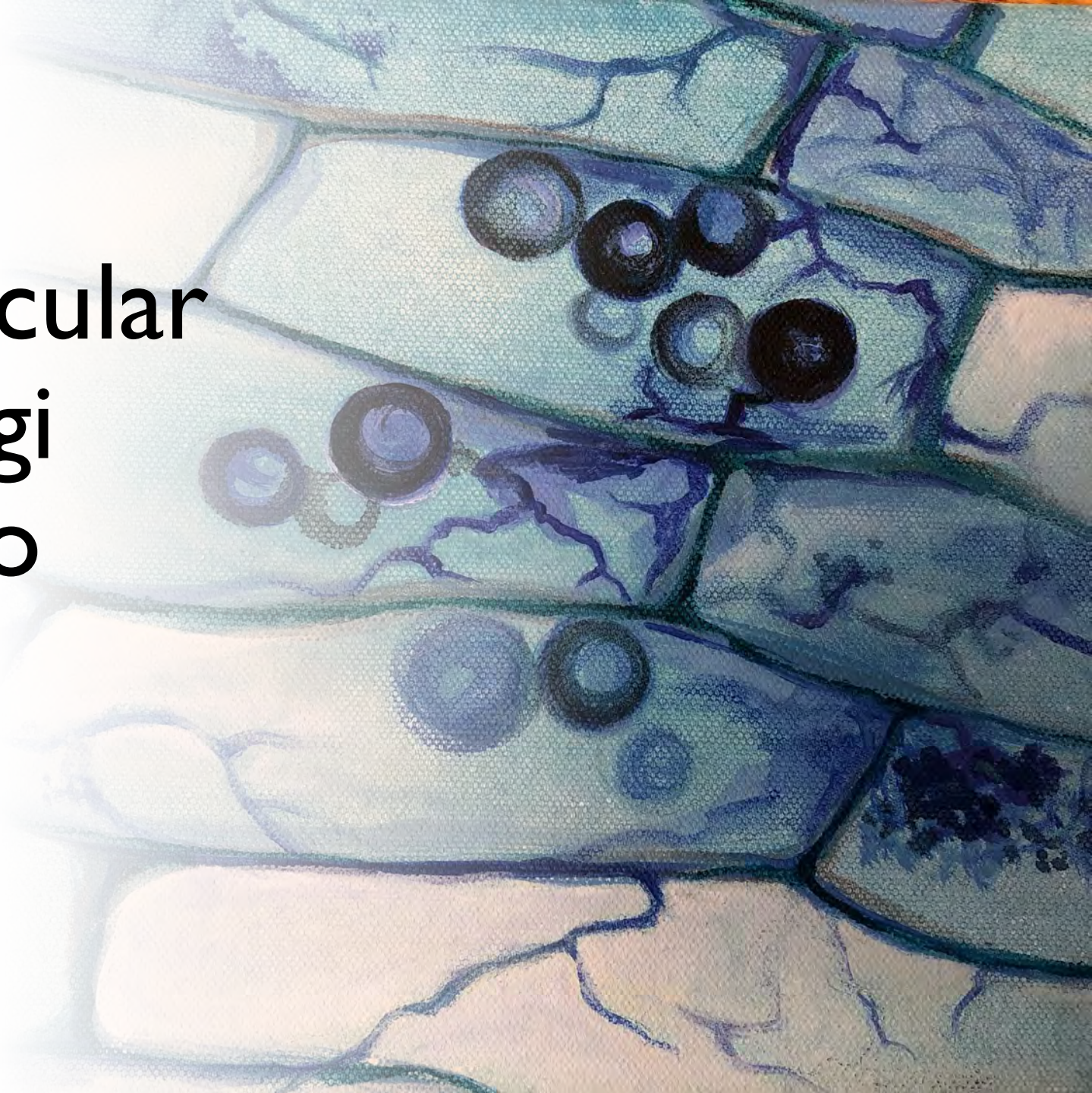
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**What word or phrase comes to mind when you hear the word "mycorrhizae"?**

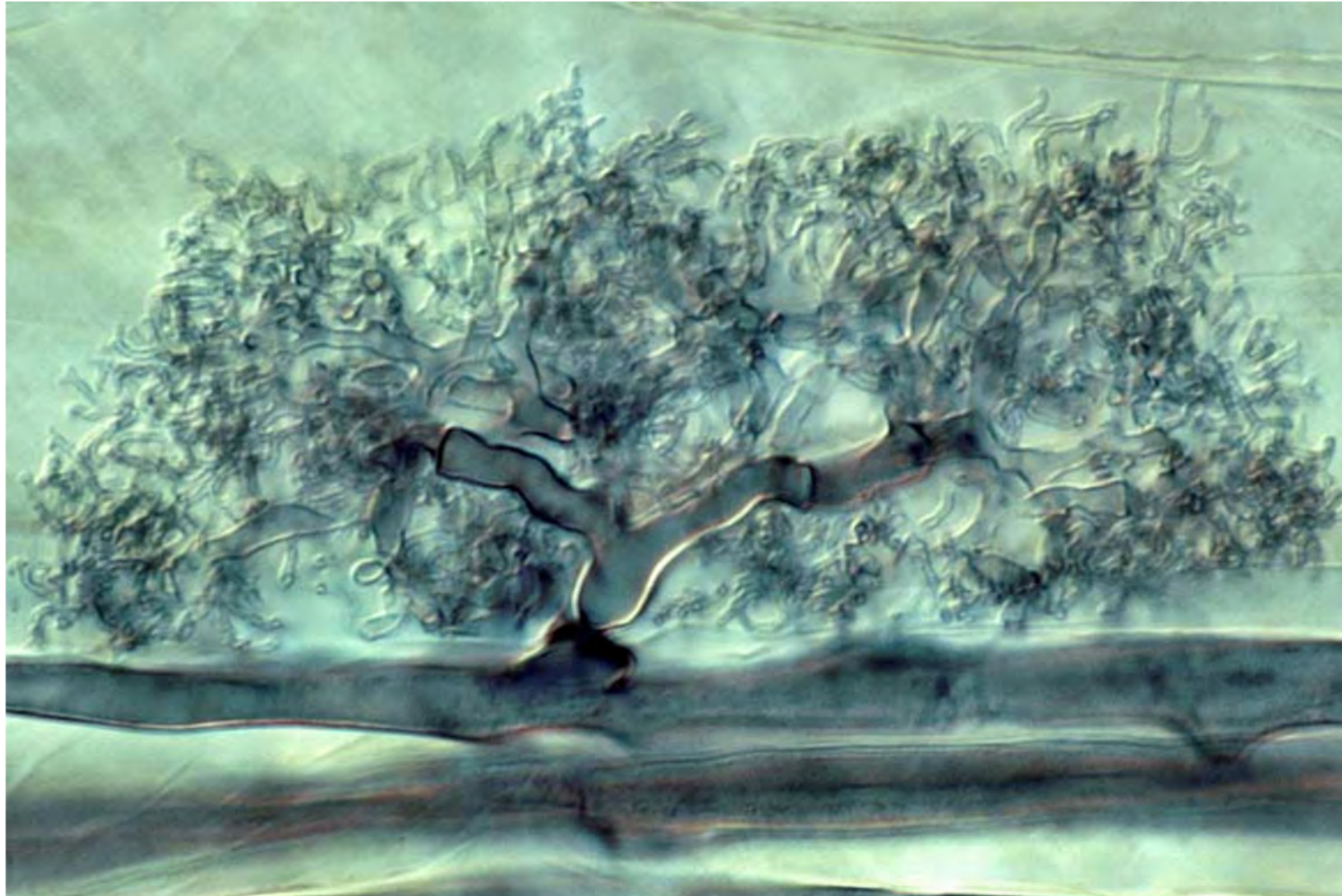
 Mentimeter



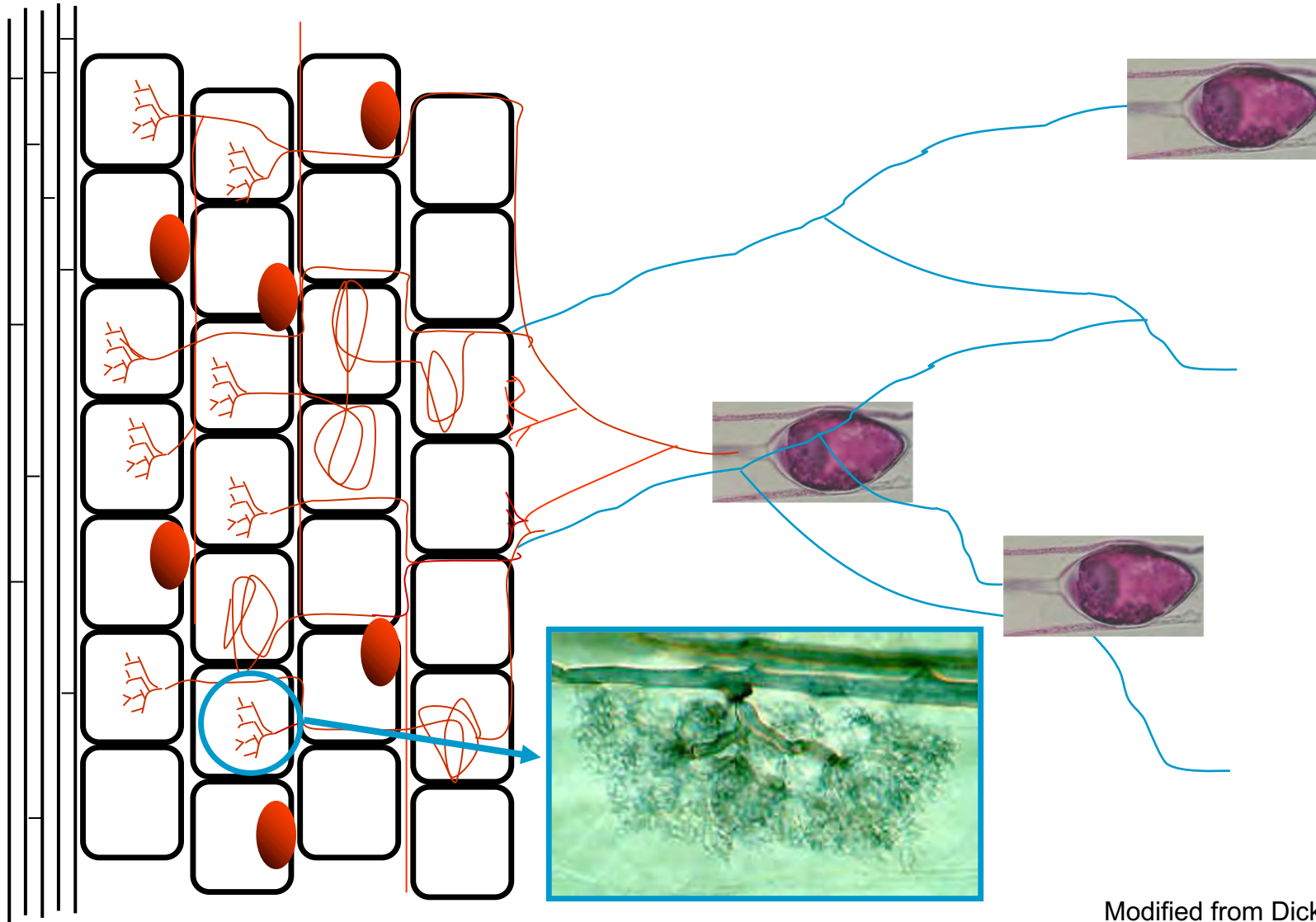
What are arbuscular  
mycorrhizal fungi  
(AMF)? What do  
they do?



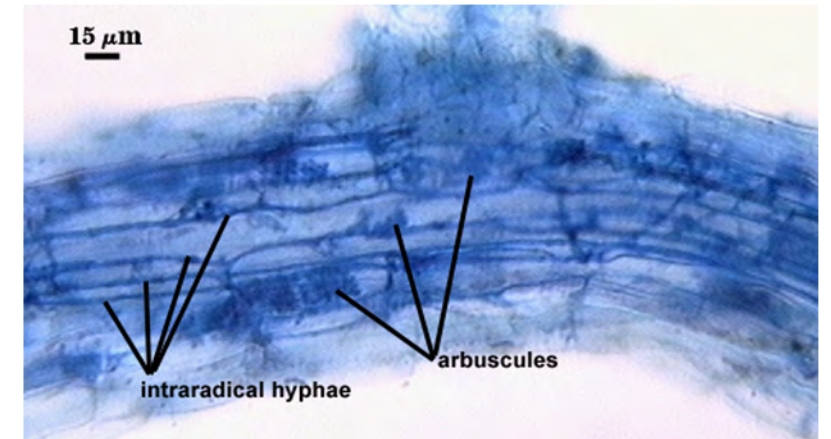
# Arbuscule: the namesake of AMF



# Arbuscular mycorrhizal fungi: Ancient plant symbionts

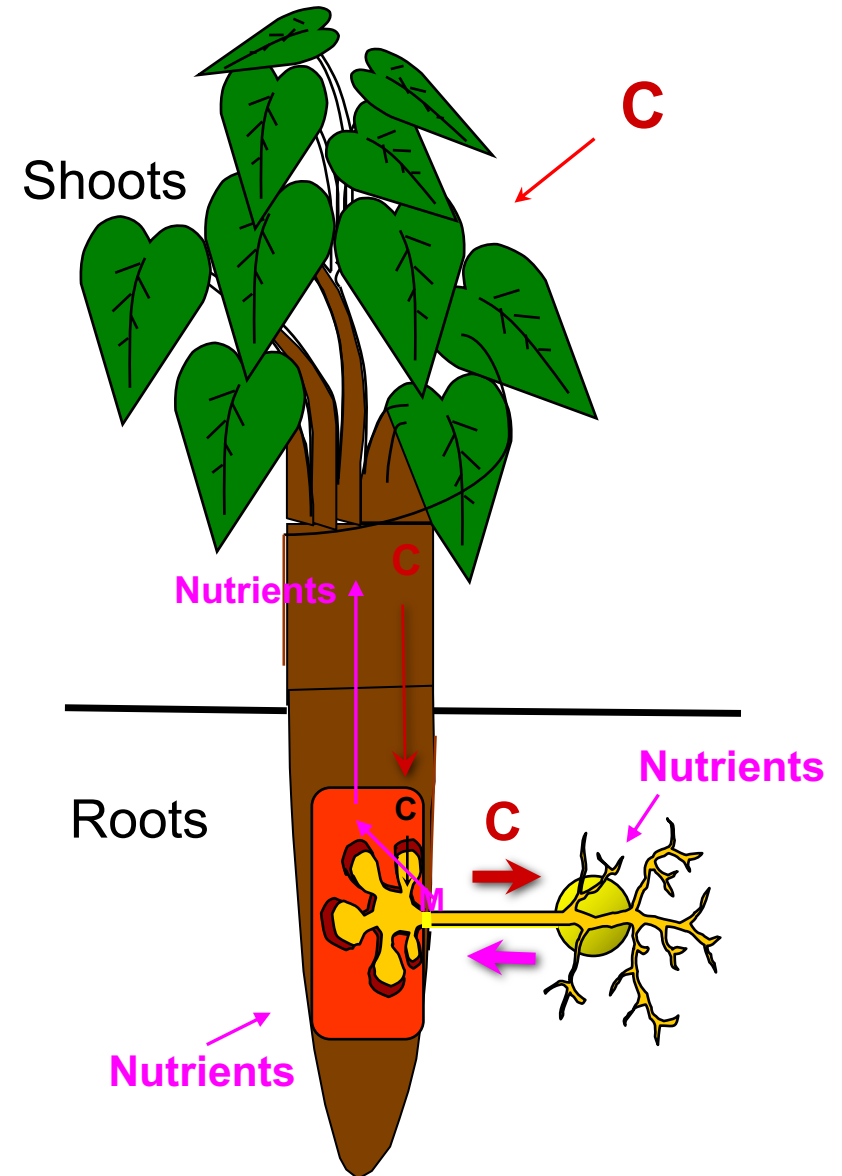


*Rhizophagus irregularis* in corn roots



# Mycorrhizal symbiosis (overview)

- Energy and nutrient trade
- Sugars (carbon) move from plant to fungus and inorganic nutrients from fungus to plant
- Nutrients are absorbed from soil and transferred to plants (mainly immobile nutrients)
- Increase the efficiency with which roots absorb phosphorus (P), zinc (Zn) and nitrogen (N)
- Also affects plant water relations



# Hyphae vs. Roots

Feature	Hyphae	Roots
Diameter ( $\mu\text{m}$ )	2-10	>300
Specific length (m/g soil)	2-40	<0.1 (excl. root hairs)
Radius of influence (cm from root)	25	<1 (incl. root hairs)

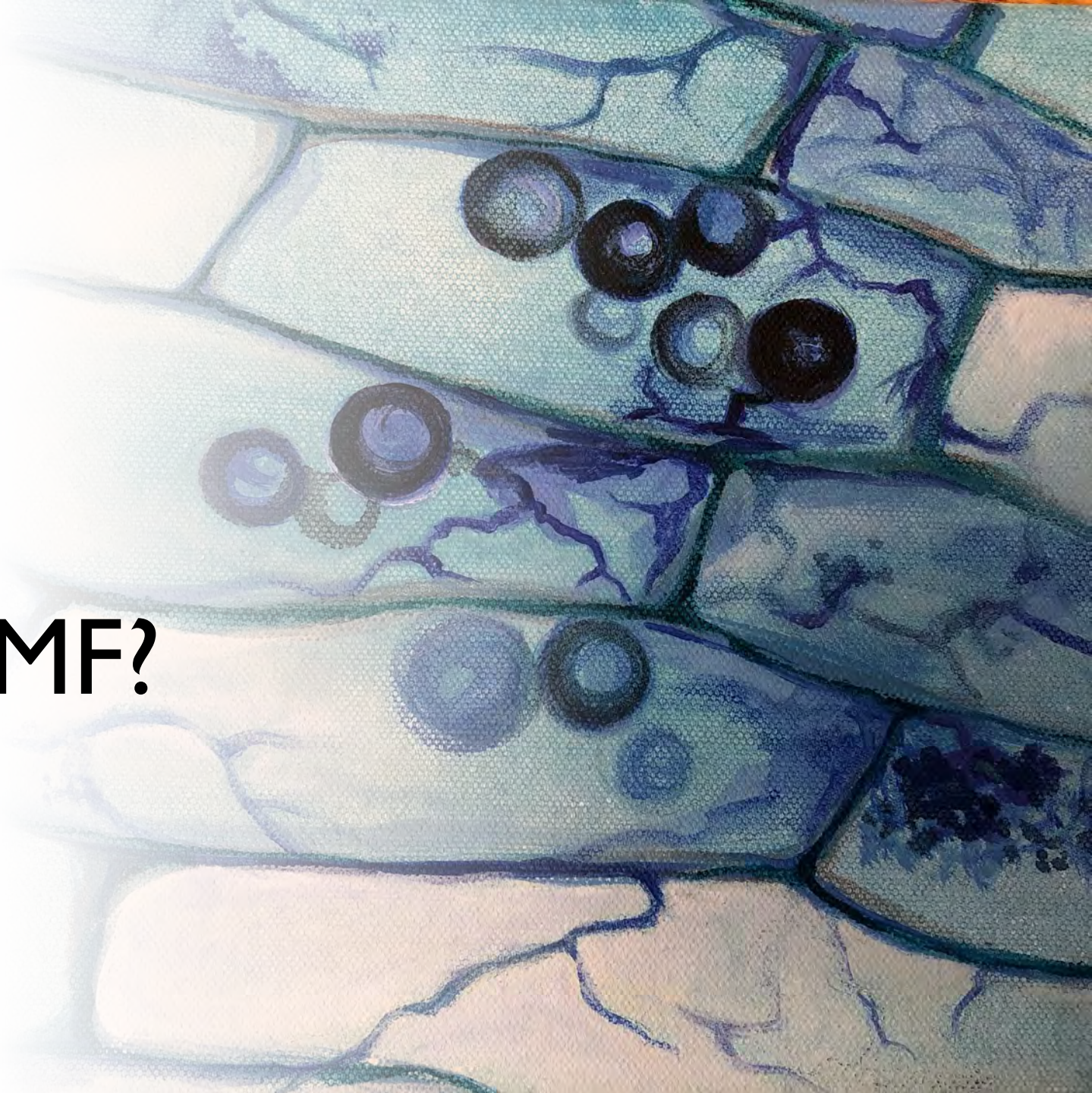


Relative size of AMF hyphal strand and root



A human hair is  $\sim 60\text{-}200 \mu\text{m}$  thick

How does  
agriculture in  
general affect AMF?





# AMF require living roots to reproduce and have three sources of inoculum

- AMF are ‘obligate biotrophs’: Require living roots to complete life cycle and produce spores
- 3 sources of AMF inoculum:
  - Spores
  - Root fragments
  - Intact hyphal network
- Loss of native vegetation, monocultures, fallow periods, soil disturbance, fungicide applications all reduce the abundance and diversity of AMF

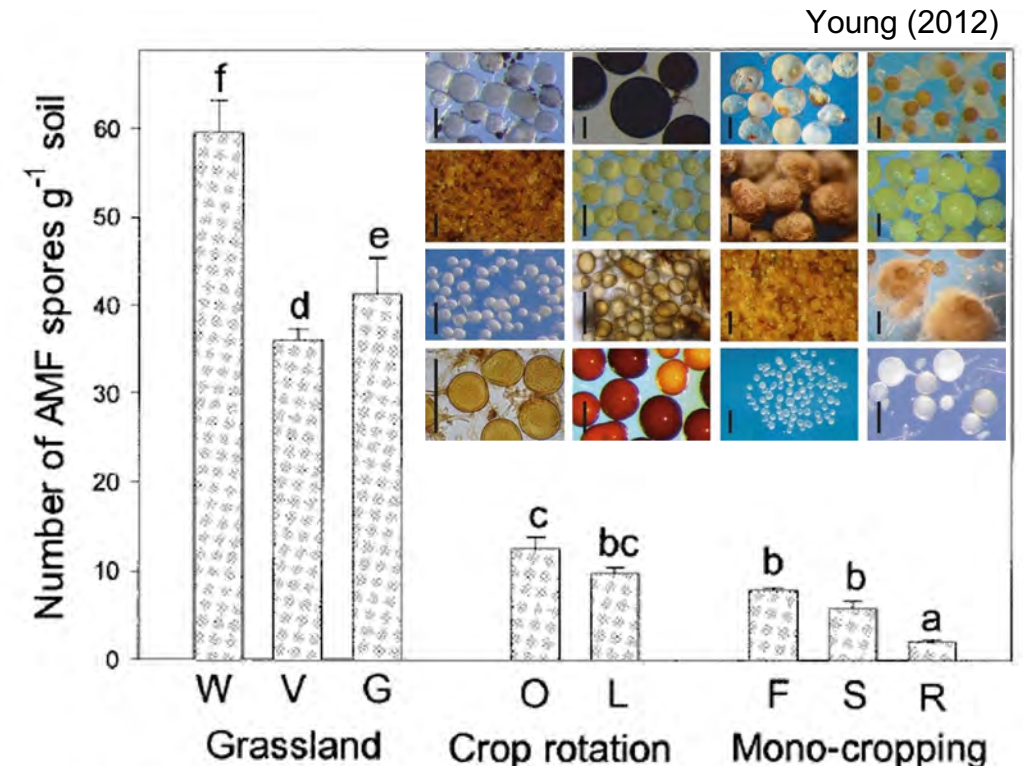
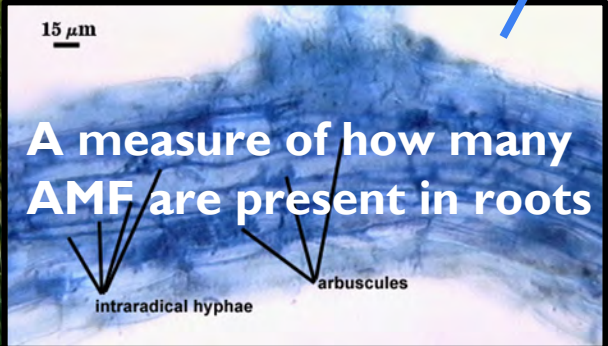
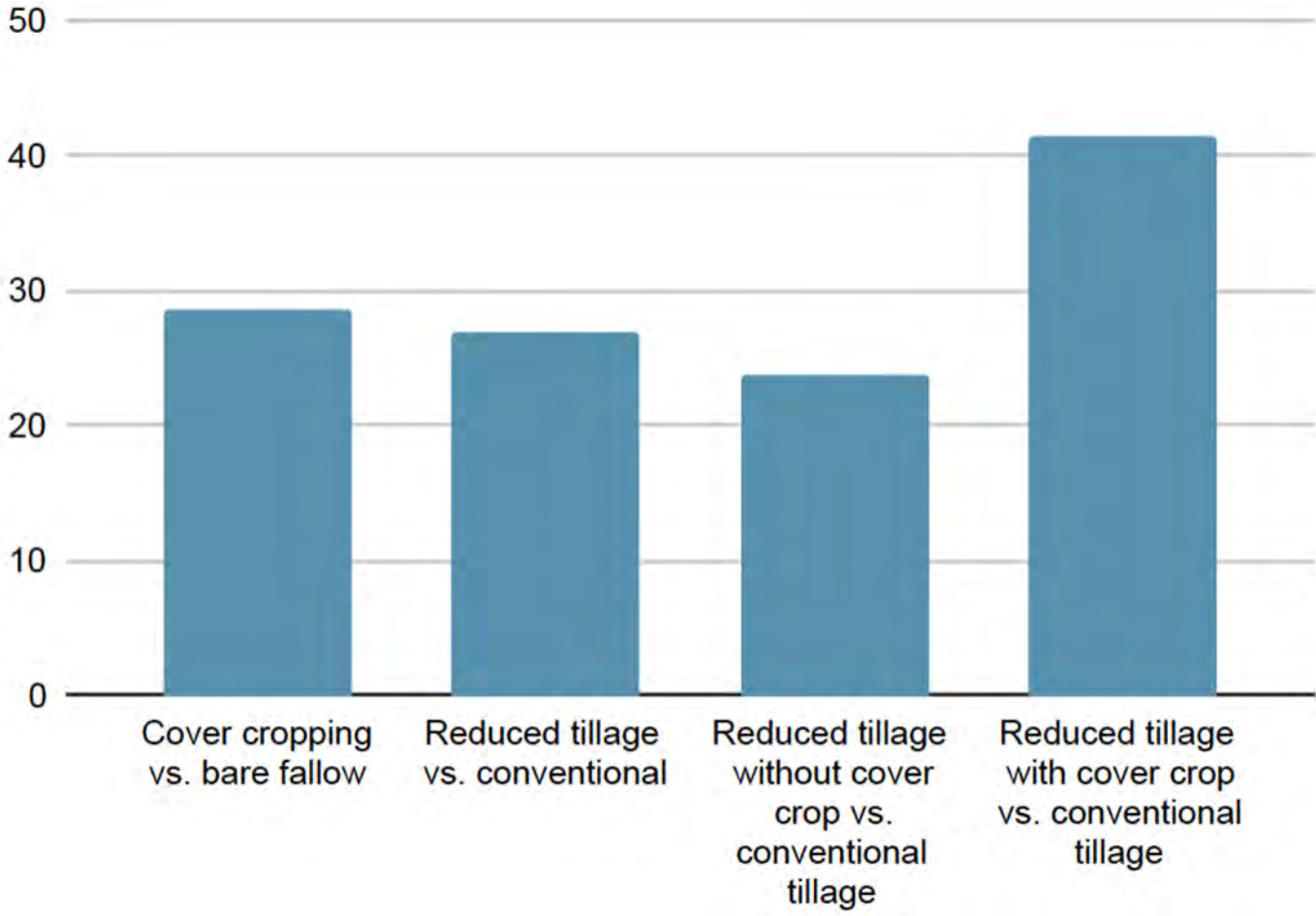


FIG. 1. AMF spore abundance at field sites (W, V, G, O, L, F, S, and R) with different cultivation practices. Input and management intensity increase from left to right. Data are reported as averages and standard deviations for four replicate plots per site. Nonsignificant differences between sites are indicated by identical letters above the bars and were determined by using Fisher's LSD test at the 5% level after a one-way ANOVA.

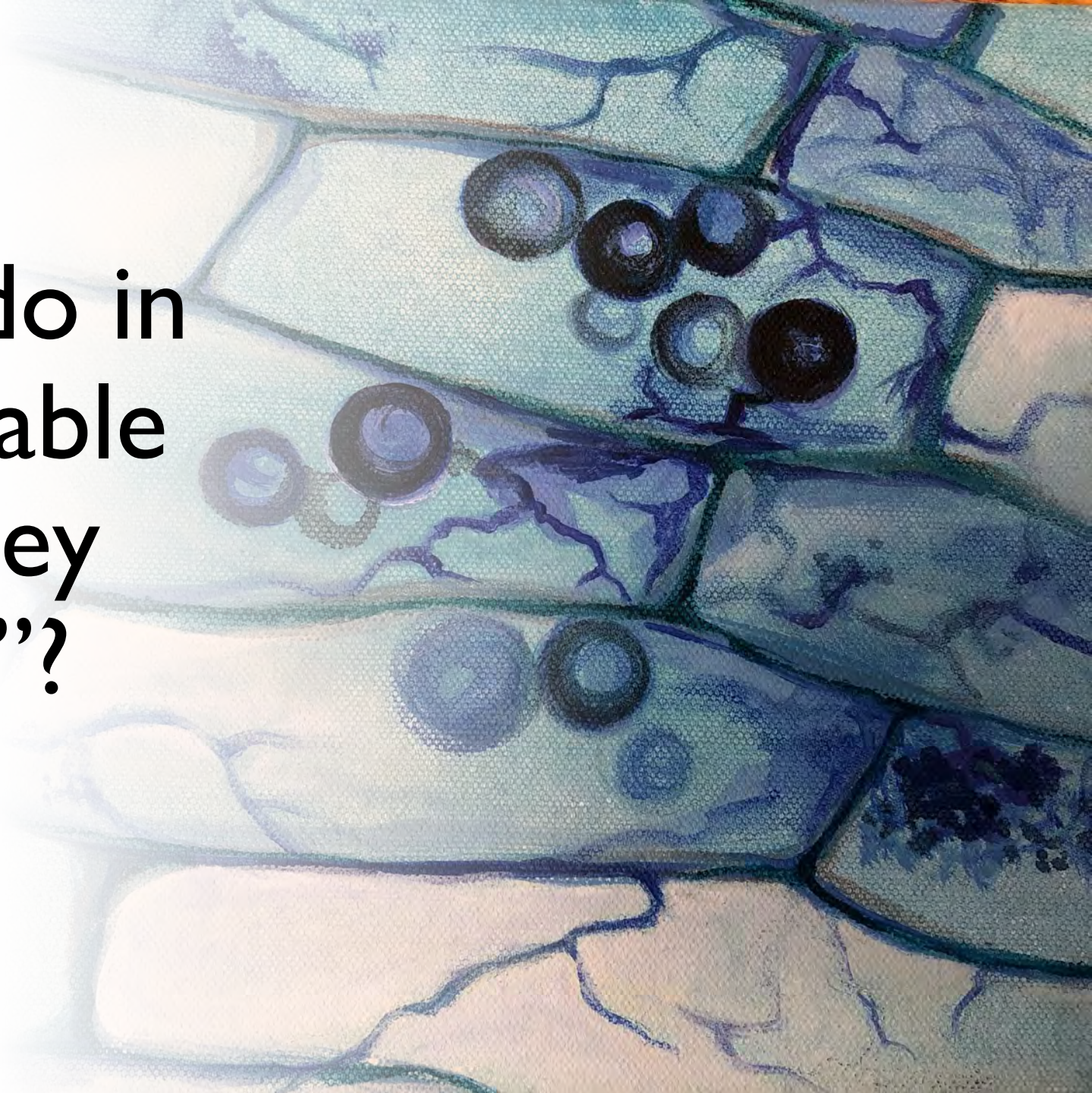
# Effects of key agricultural practices from global meta-analysis



Change in % AMF colonization



What do AMF do in California vegetable systems? Are they always “friendly”?

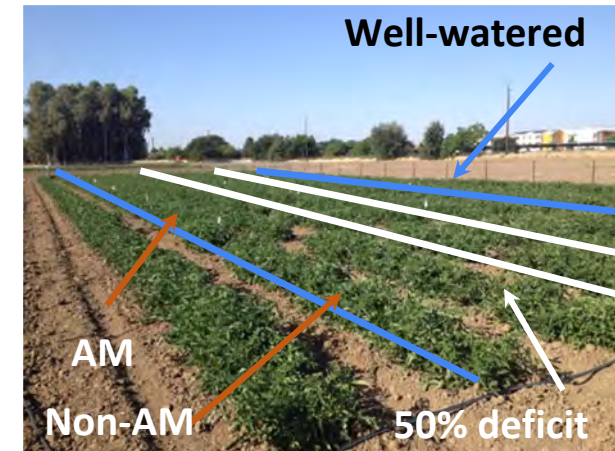
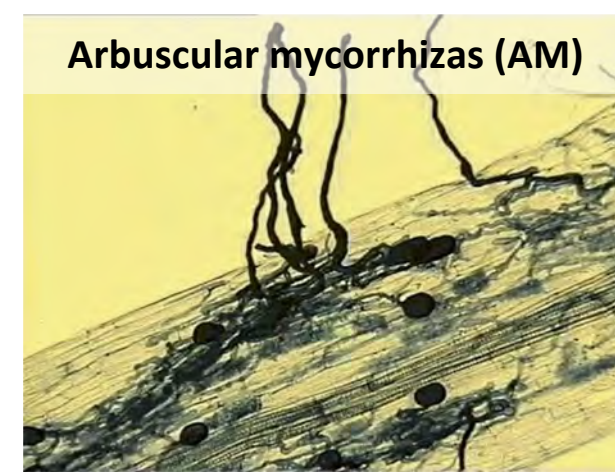


# AMF can increase crop water use efficiency

- Field trial at Student Farm in Davis, CA
- AM and non-AM tomatoes
- 50% deficit irrigation
- Higher water use efficiency (WUE) in plants associated with AM fungi:

Crop WUE (Mg yield ha <sup>-1</sup> cm <sup>-1</sup> water applied)		
	100% irrigation	50% irrigation
AM+	2.46	3.72
Without AM	1.85	2.94

- More crop yield per drop



# Case study – can soil health management promote AMF functioning?

System	Cash crop rotation	Winter cover-crops	Fertilization	Plant protection
ACT	Alf.-Alf.-/Corn/Tomato	yes	synthetic	Conv.
CMT	Corn/Tomato	no	synthetic	Conv.
LMT	Corn/Tomato	yes	red. synthetic	Conv.
OMT	Corn/Tomato	yes	organic	Org.



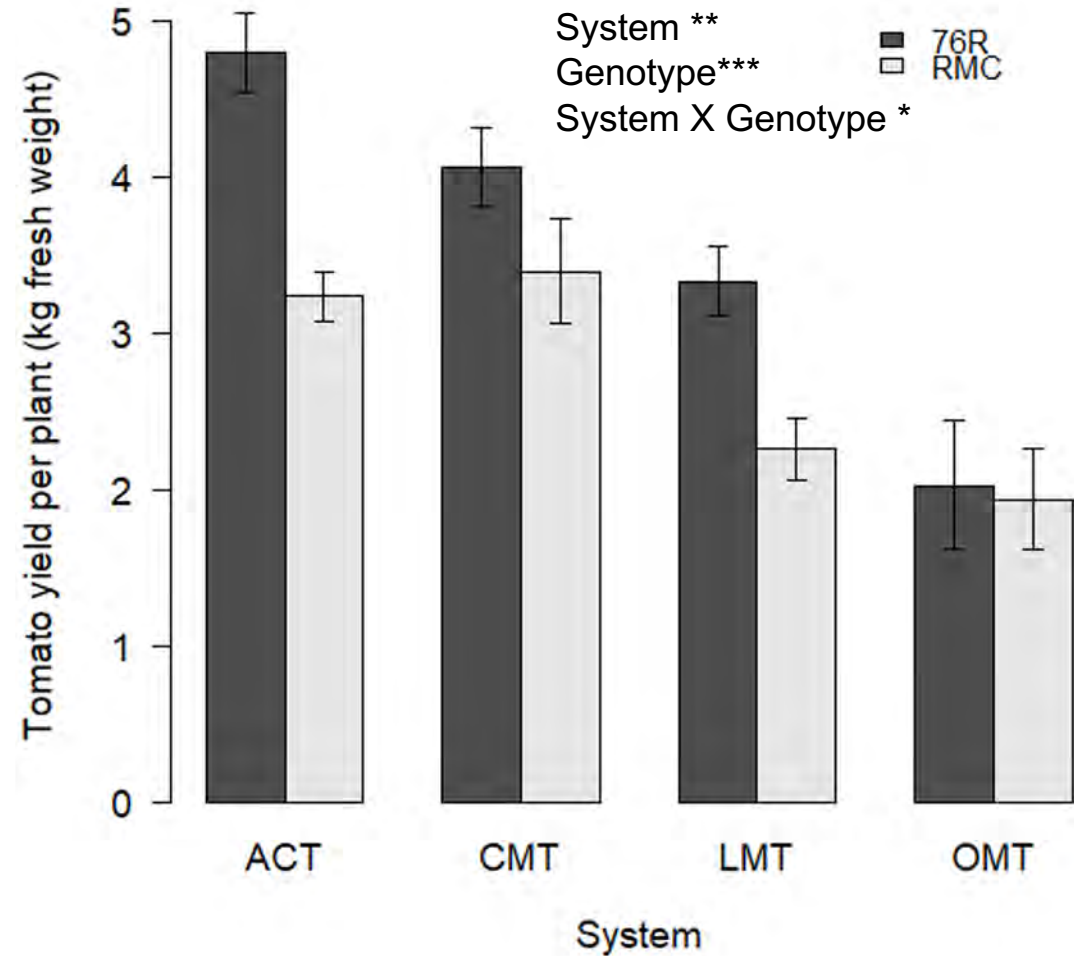
Century experiment, Russel Ranch, Davis, CA  
Long term comparison of different cropping systems for 25 years



Franz Bender,  
former postdoc  
UC Berkeley



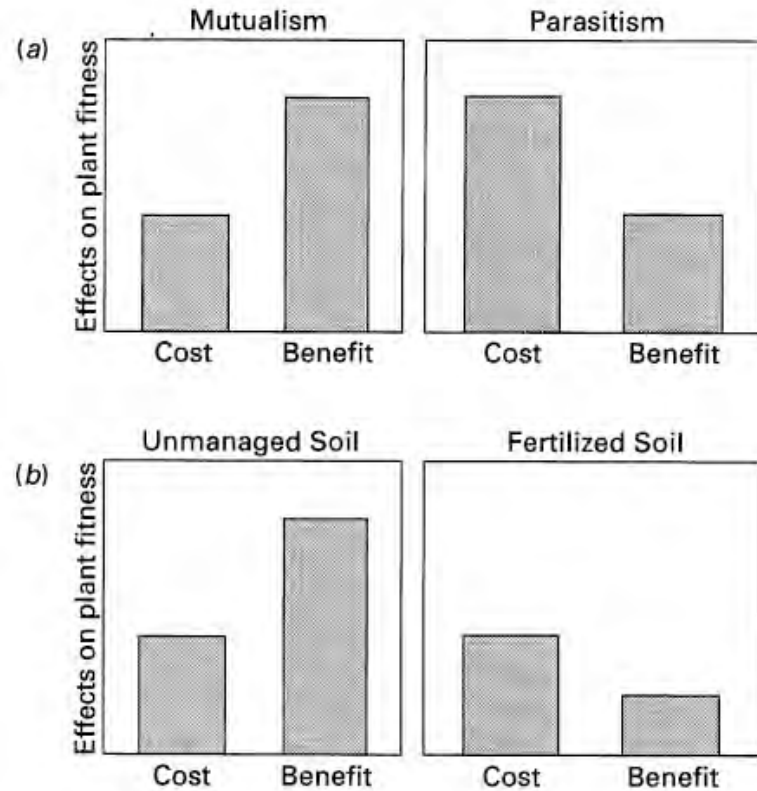
## Tomato yield (fresh weight)



- **76R (dark bars)**: Paste-type tomato
- **rmc (light bars)**: “reduced mycorrhizal colonization”  
– slightly different genotype used only for research

# AMF are not always mutualists

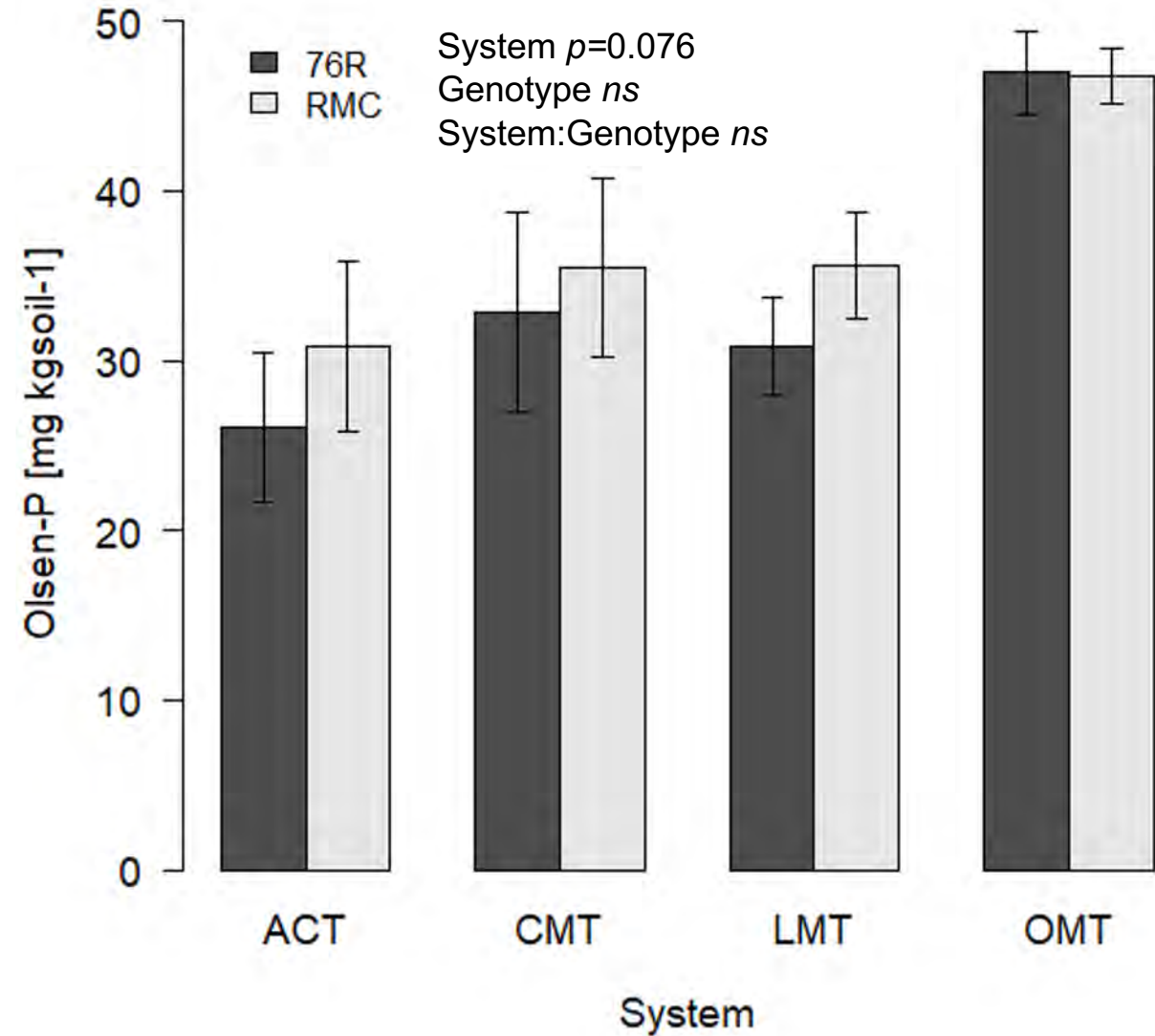
Costs and benefits for a plant associated with AMF



Costs of AMF are the carbon (energy) that the plant delivers. The benefits are the nutrients the AMF deliver to the plant, which may or may not increase plant growth. For plants, the effects of AMF can be positive, negative or neutral.

The organic system at this long-term experiment receives composted manure, which has more phosphorus relative to nitrogen than plants need → build up of phosphorus in soil

## Soil phosphorus levels

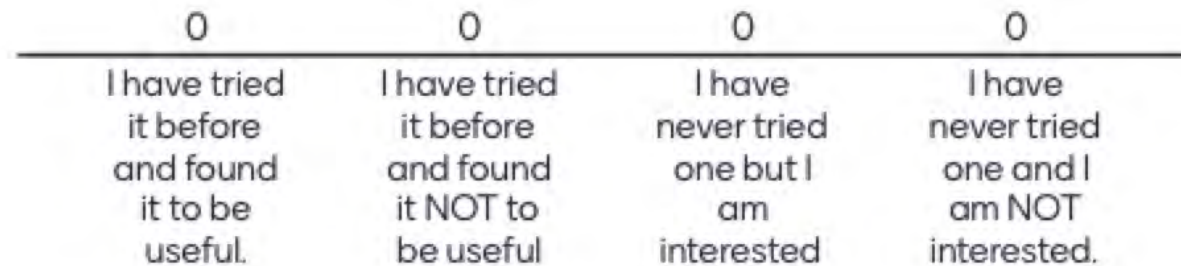




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# Have you ever tried a commercial AMF inoculant?



# Commercial AMF inoculation

- Agriculture can negatively affect AMF.
- AMF can improve yields & stress tolerance.
- Can AMF inoculation of tomato seedlings improve yields & tolerance to water stress?

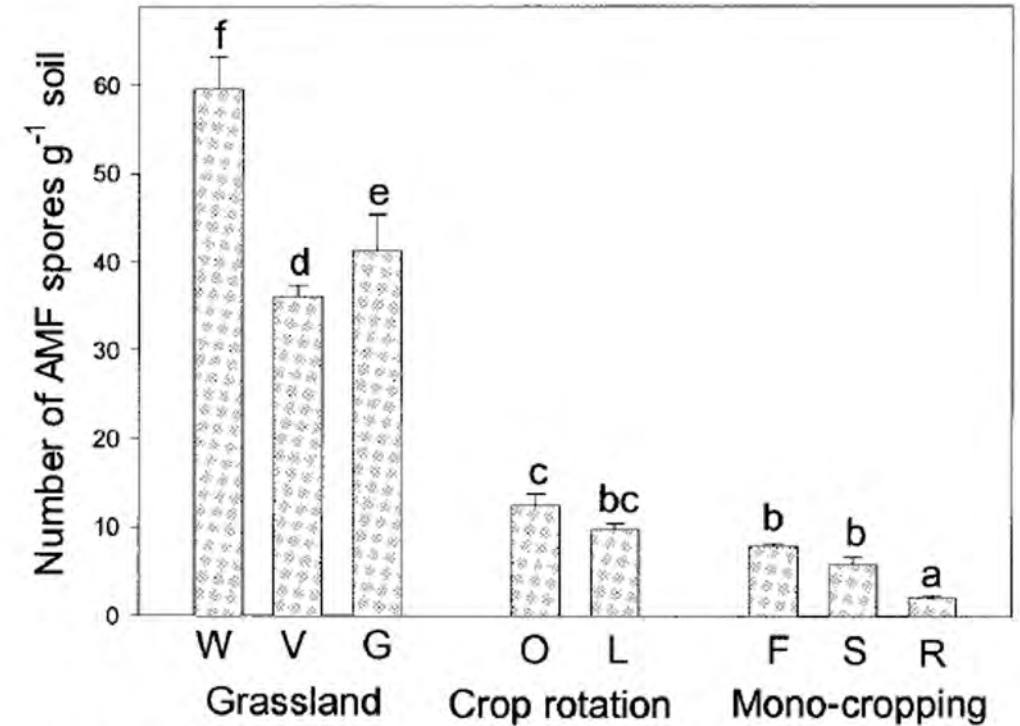


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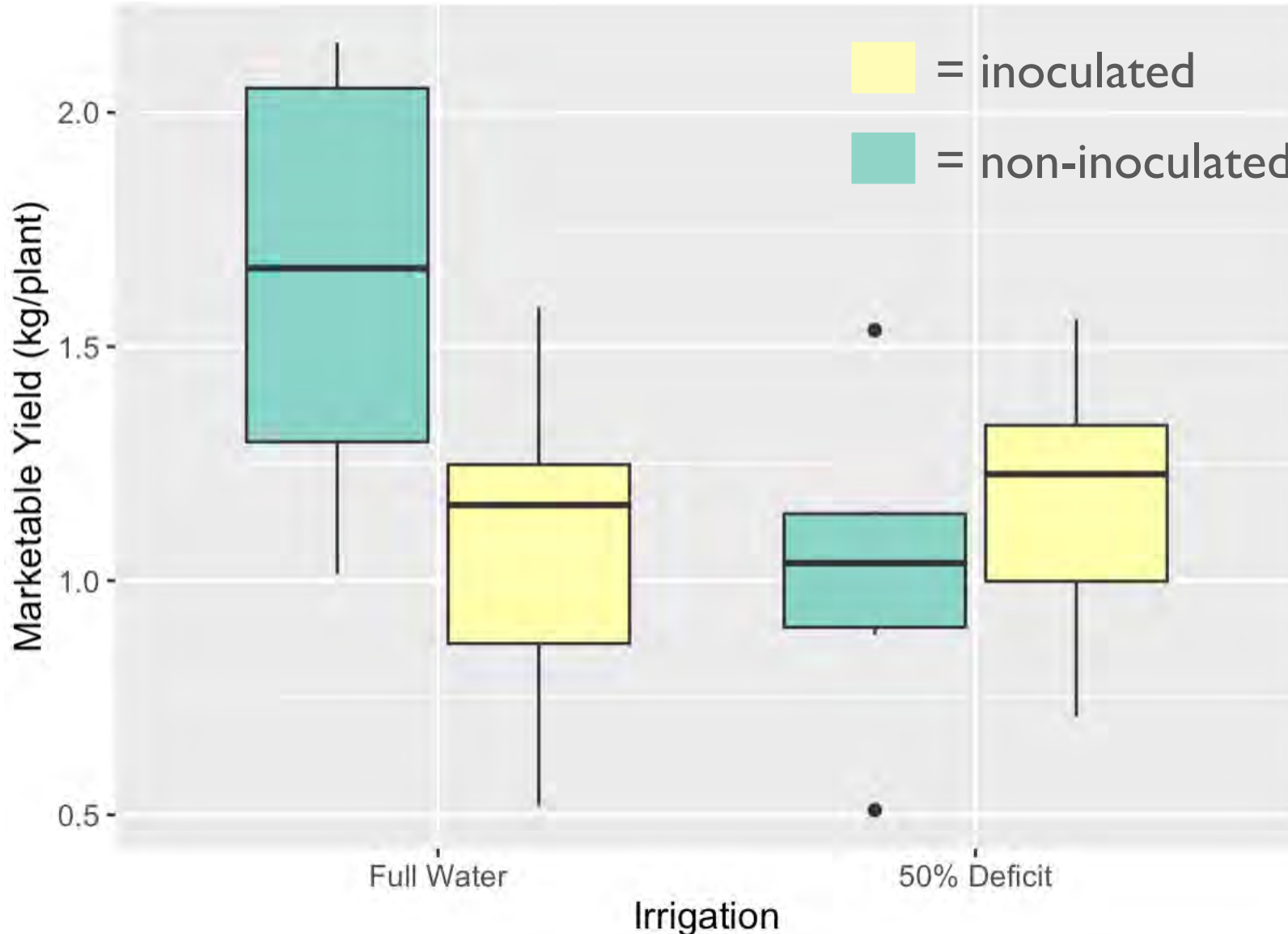
# 2020: On-farm field experiment



- Organic tomato field in Yolo Co.
- Grew fresh market paste tomatoes
- Inoculated vs. non-inoculated.
- Fully watered vs. 50% deficit irrigation.

Does AMF inoculation increase tomato yields under water stress?

# Inoculation impact on marketable yields



- Full water:  
Inoculation **decreased** yields by 34%.
- 50% deficit irrigation:  
Inoculation **increased** yields by 14%.

# 2021: Landscape-scale on-farm experiment

- 20 processing tomato fields across Yolo Co.
- Fully watered.
- Inoculated vs. non-inoculated.
- 6 soil management practices.

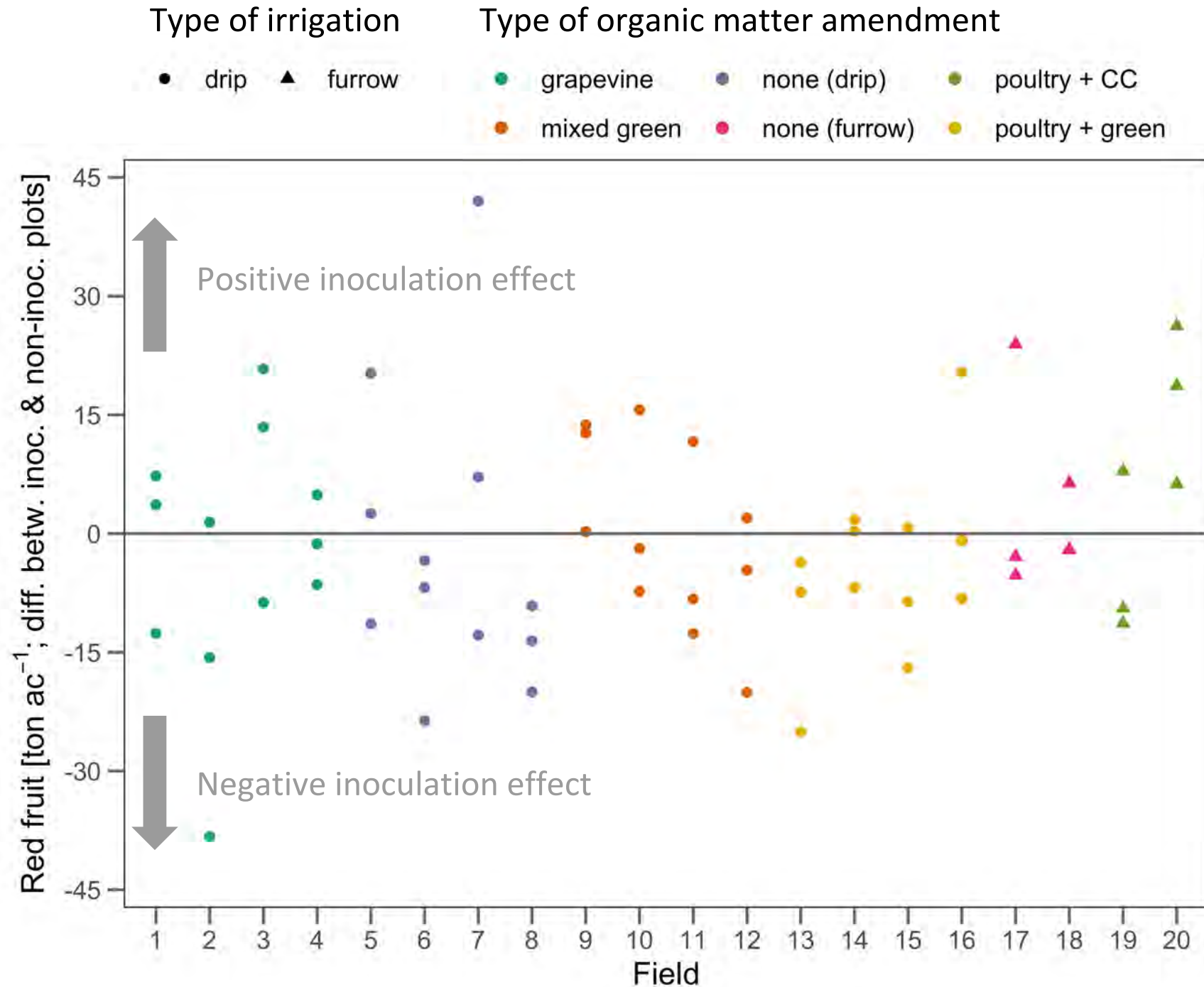
Does AMF inoculation increase tomato yields across soil management practices?

- Conventional: Greenwaste (grapevine OR mixed)
- Conventional: No organic matter amendment (drip OR furrow irrigation)
- Organic: Poultry manure (+ greenwaste OR + winter cover crop)



# No inoculation impact on marketable yields

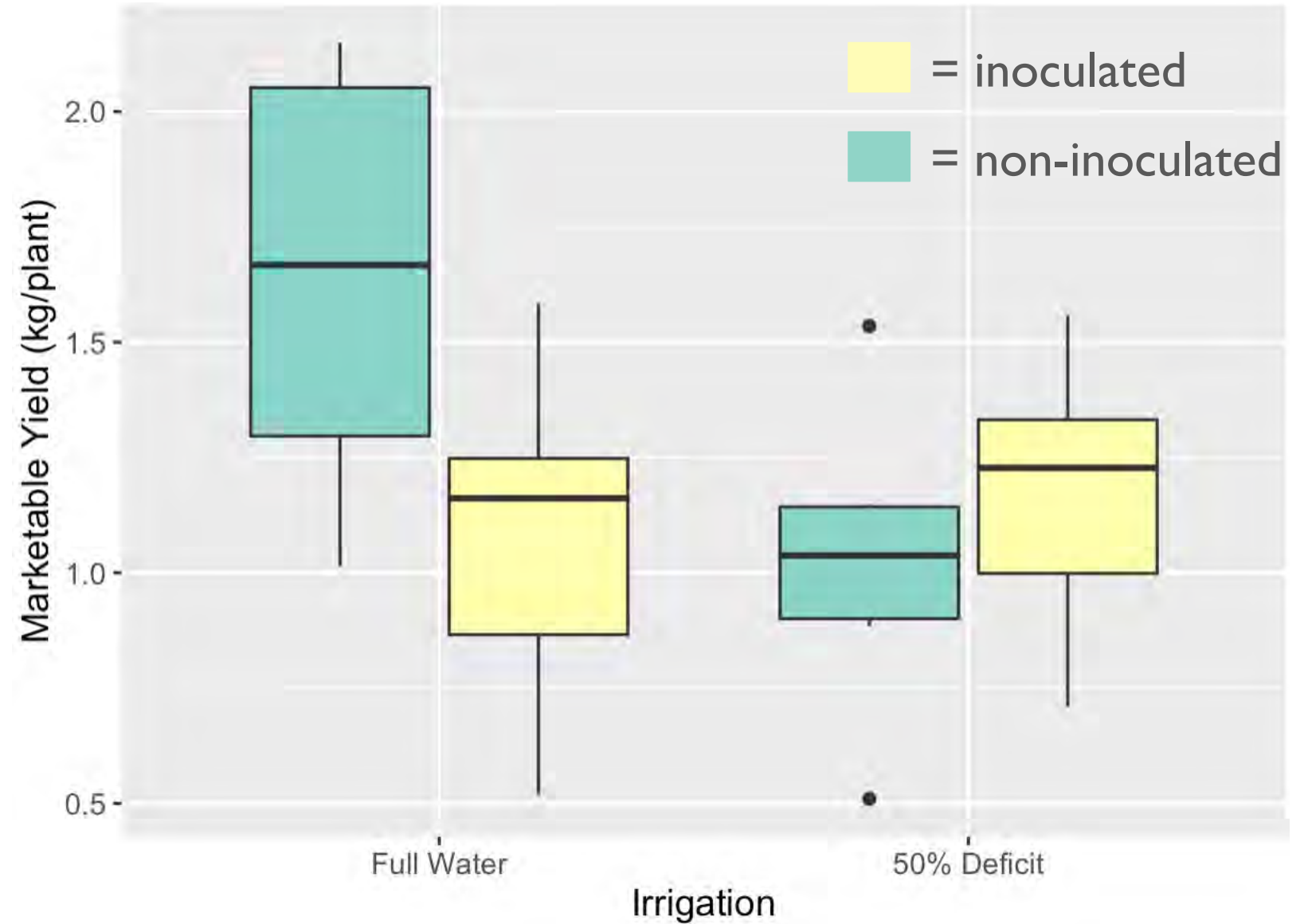
Yields and fruit quality not affected by AMF inoculation regardless of soil management.



# What about water stress?

Results from 2020  
on-farm field experiment:

- 50% deficit irrigation:  
Inoculation **increased**  
yields by 14%.



# What about water stress?





# What is dry farming?

- Extremely limited water inputs
  - Typically 1-2 irrigation events for the whole season
- Relies on soil “water bank” recharged by winter rains
- Suite of management practices involved
  - Cover crop
  - Dust mulch
  - Nutrient delivery



# How do dry farm systems respond to inoculation?



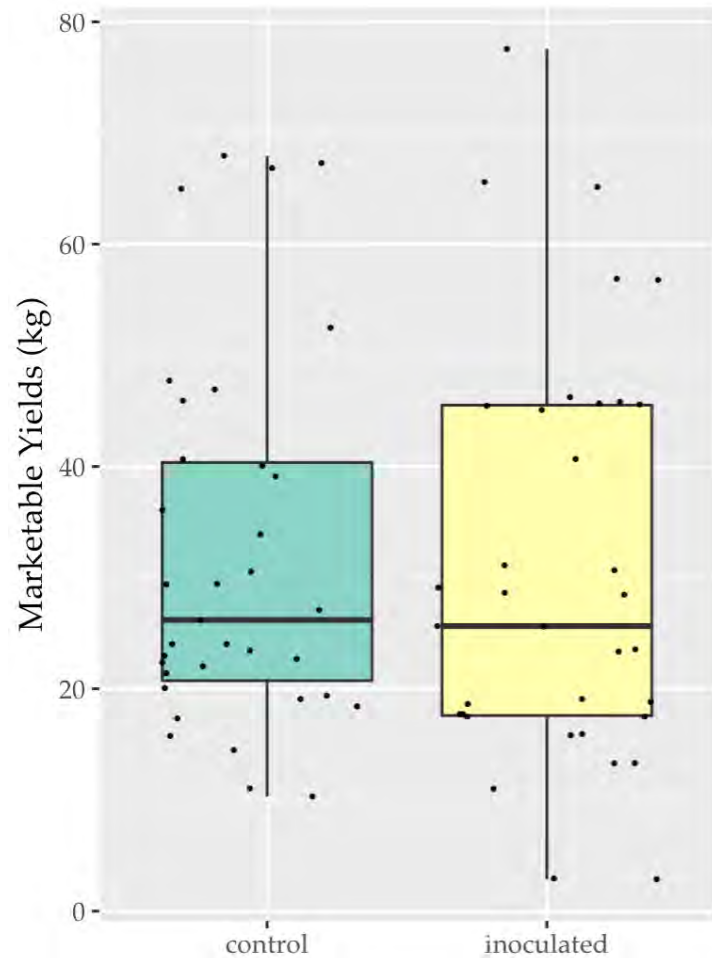
- Seven fields on Central Coast
- Inoculated vs. non-inoculated plots in each field



# How do dry farm systems respond to inoculation?



- Preliminary results say ...not at all!



# Potential reasons for lack of inoculation impact



- Sufficient nutrient supply may result in negligible AMF-derived benefits.
- Resident AMF may be well functioning.
- Introduced AMF may fail to become established.

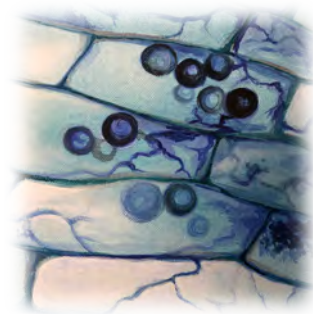


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VS



# Take-home messages

- AMF inoculation of processing and dry-farmed tomato plants had no effect on yields and fruit quality.
- Cover cropping is an effective way to boost AMF populations. Reducing tillage will give some added benefit, but cover cropping can help compensate for intensively tilled systems.
- Since AMF benefits appear to go down when there is a lot of phosphorus, caution with organic amendment with low N:P ratios.
- Still curious to experiment with AMF inoculation?

If so, start where plants are stressed.