



Joseph Bellacera, *Over Yolo #2*

Managing mycorrhizas on your farm

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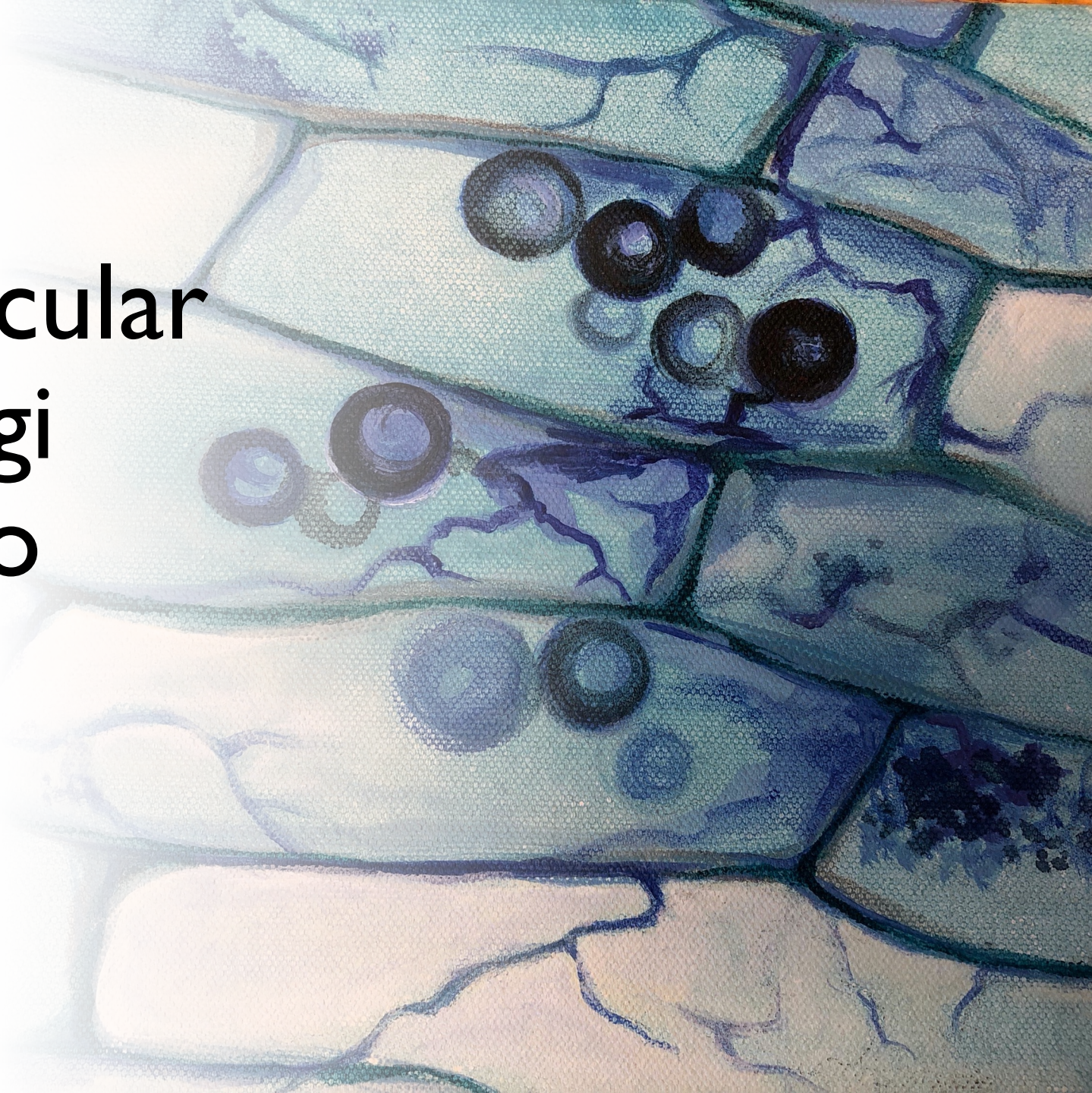
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What word or phrase comes to mind when you hear the word "mycorrhizae"?

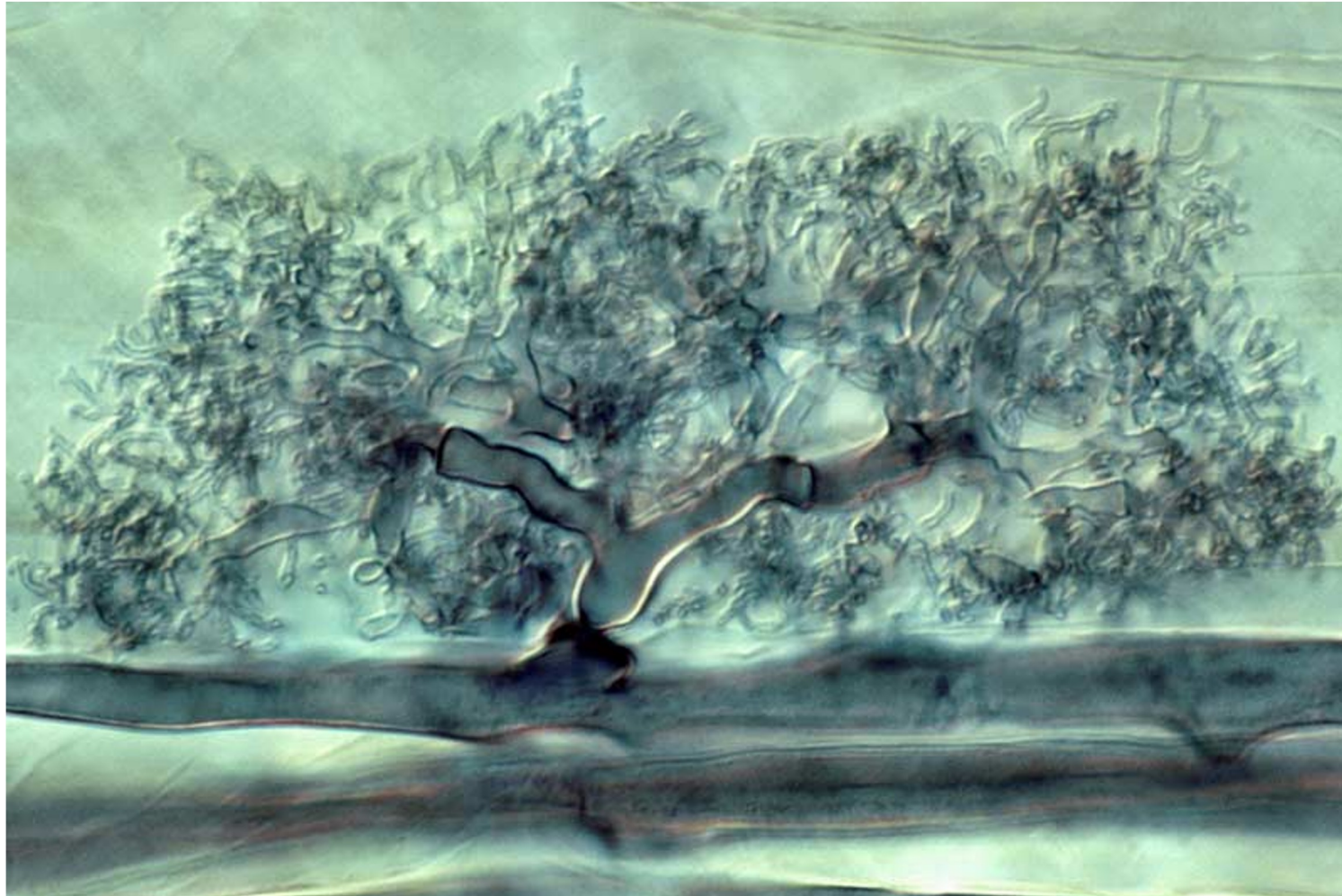
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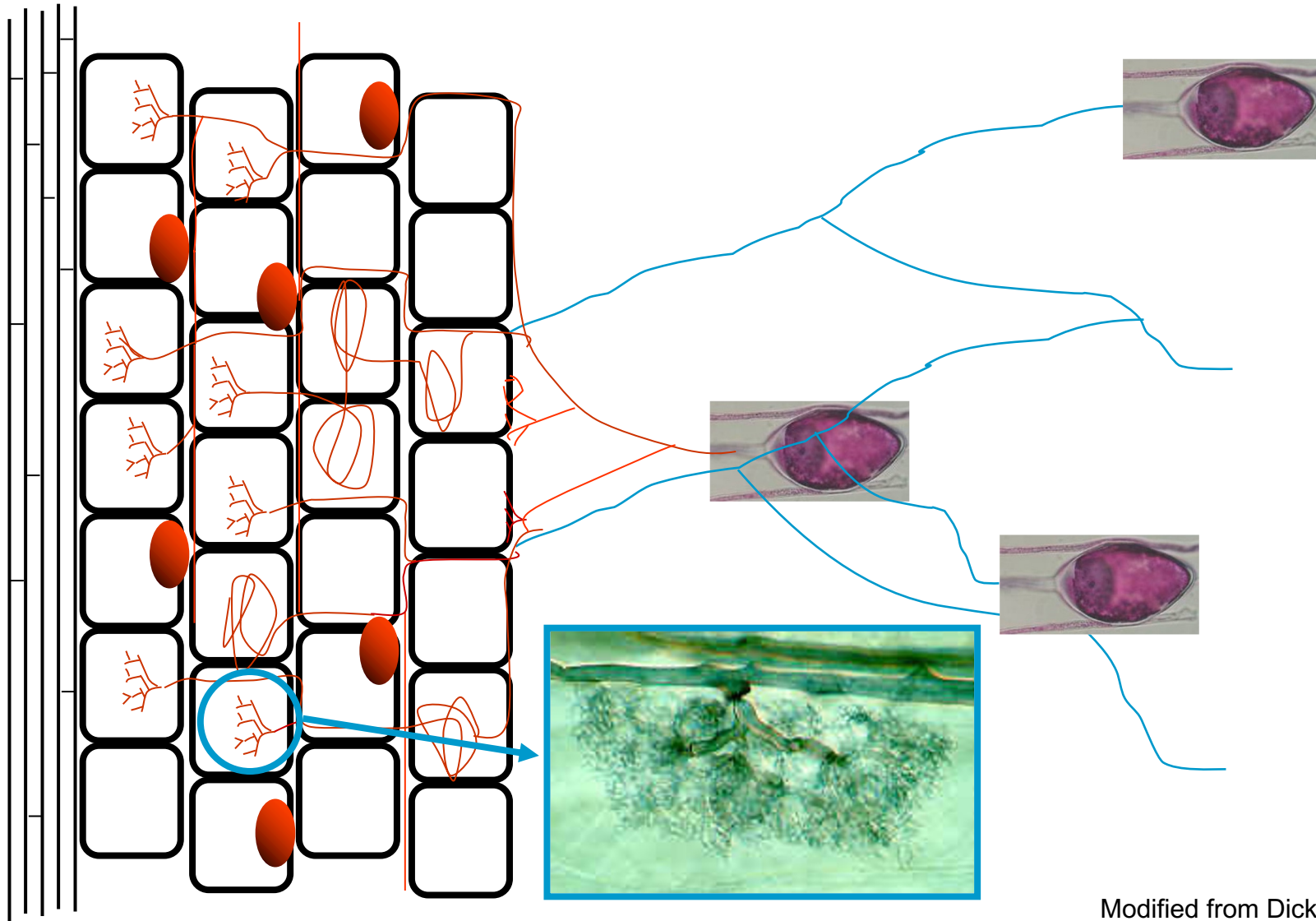
What are arbuscular
mycorrhizal fungi
(AMF)? What do
they do?



Arbuscule: the namesake of AMF

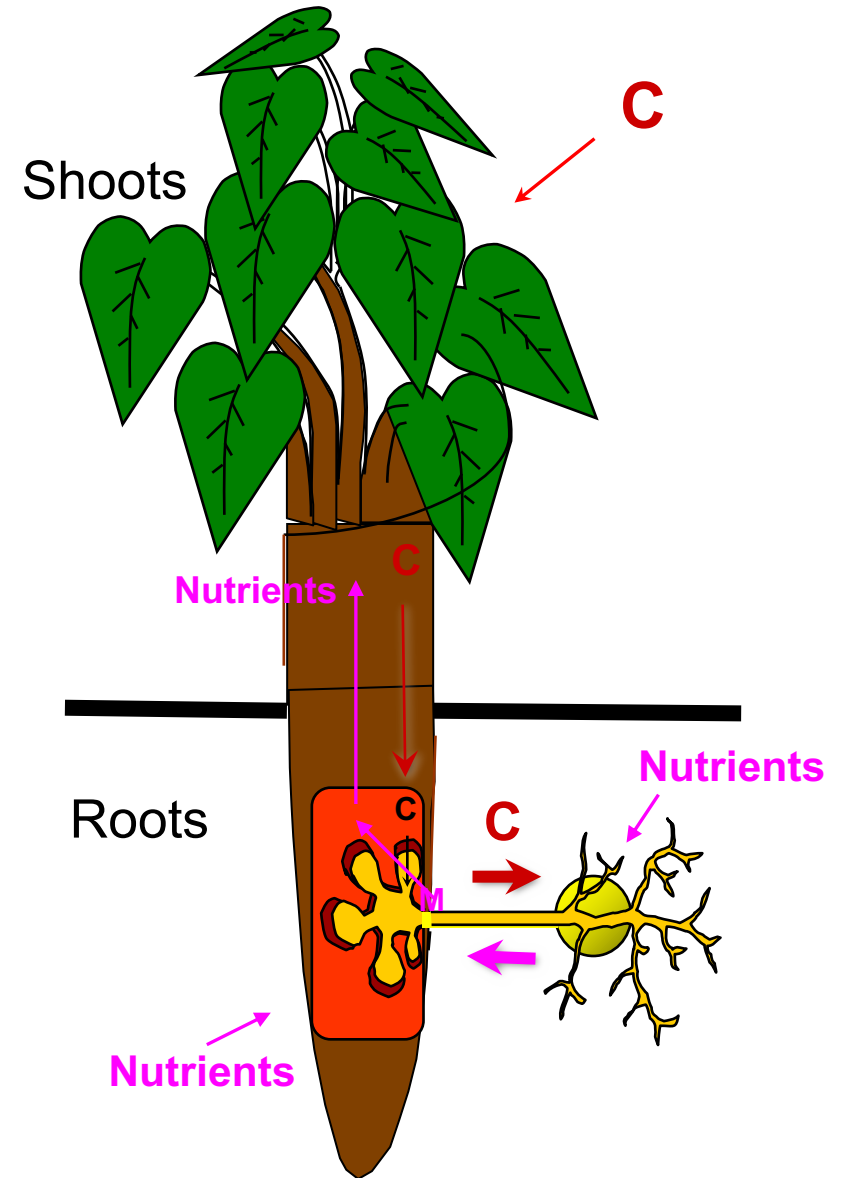


Arbuscular mycorrhizal fungi: Ancient plant symbionts

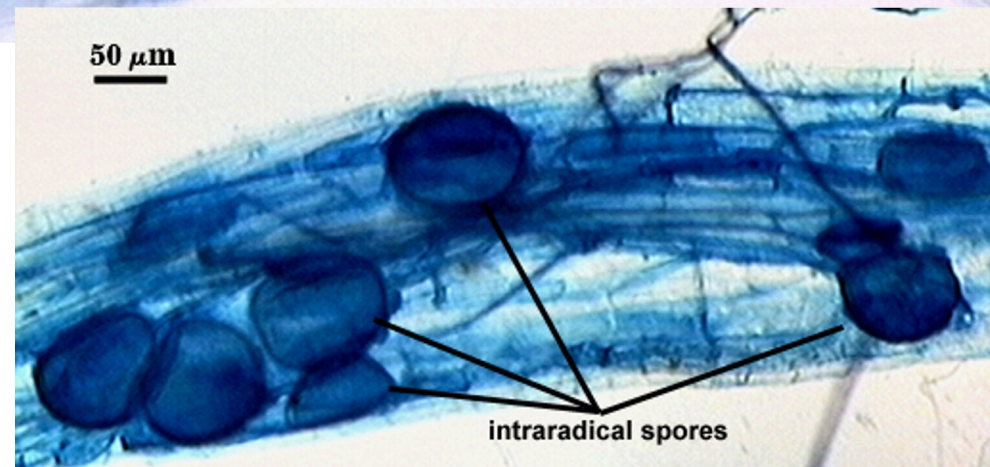
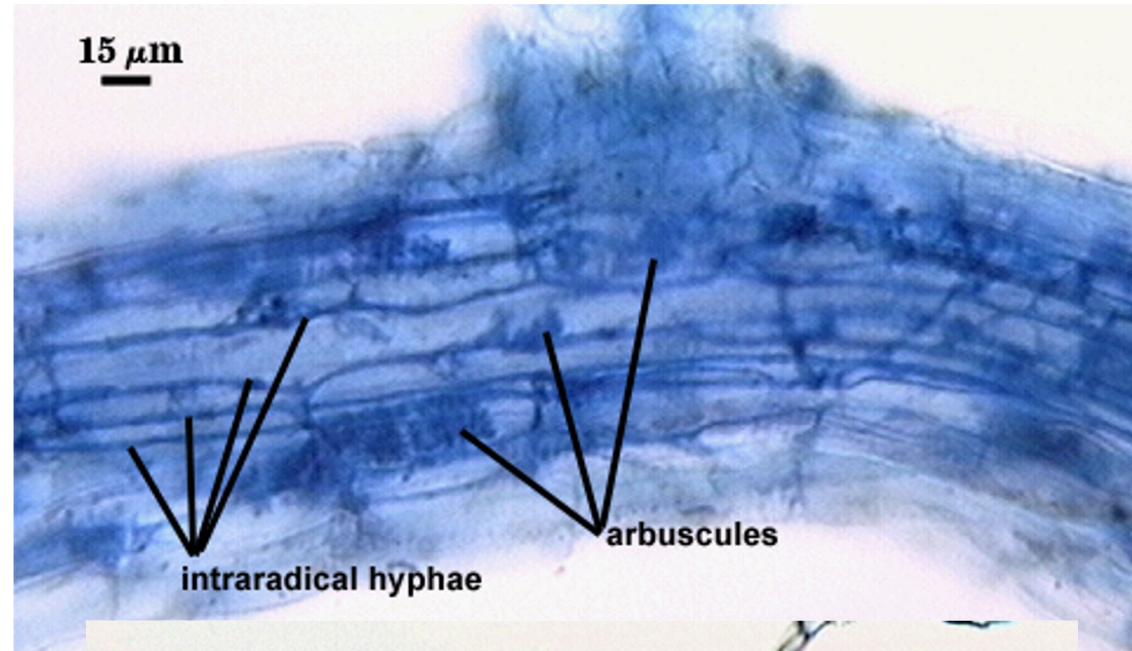


Mycorrhizal symbiosis (overview)

- 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)



Rhizophagus irregularis in corn roots

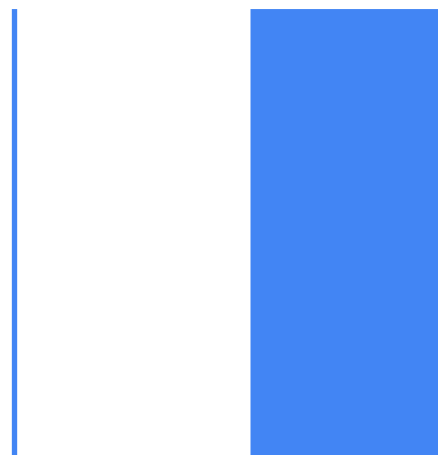


Hyphae vs. Roots

| Feature | Hyphae | Roots |
|---|------------|-------------------------|
| Diameter (μm) | 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) |
| Inter-hyphal or inter-root distance (μm) | \sim 130 | 2000 |

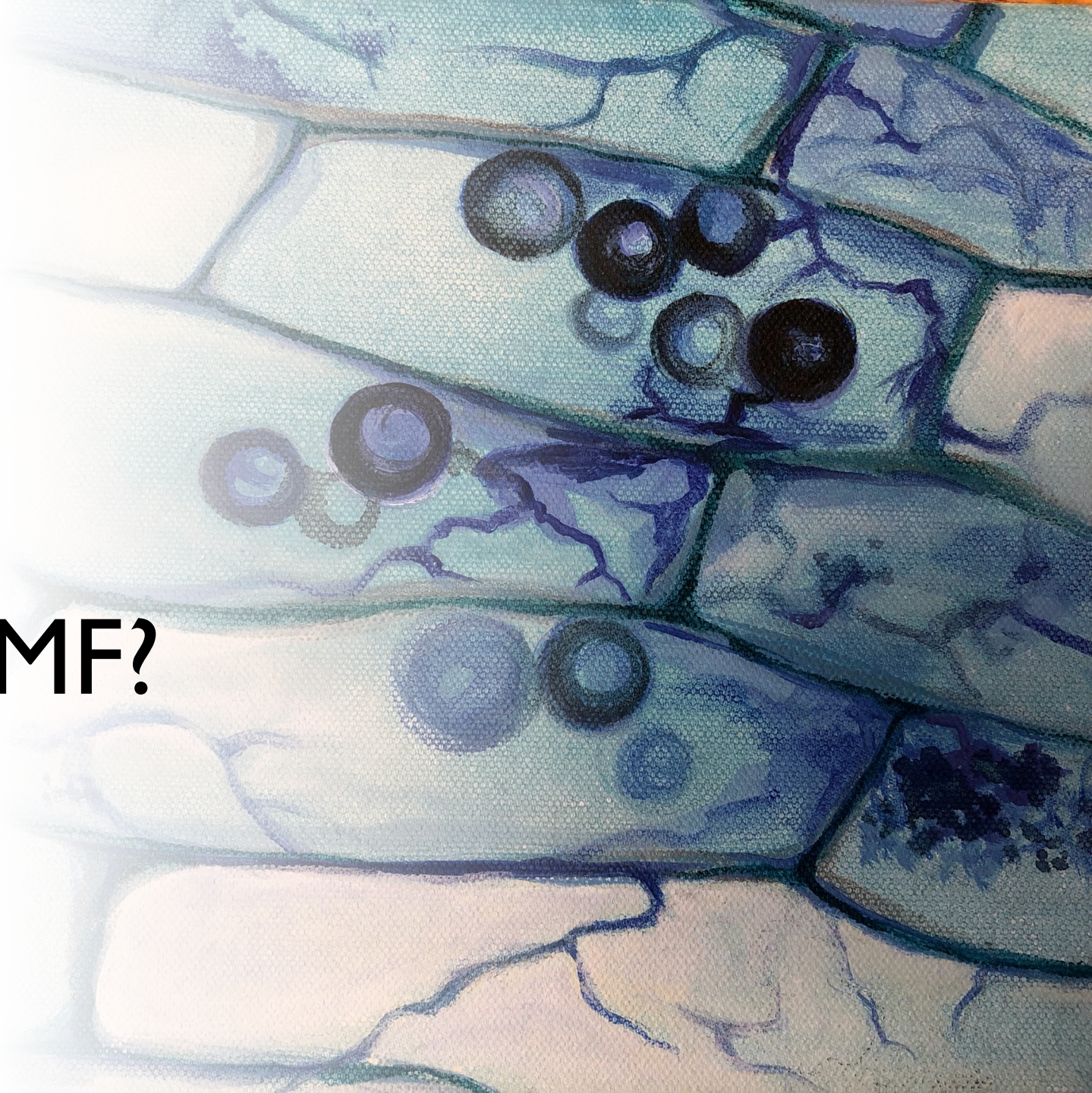


Relative size of AMF hyphal strand and root



A human hair is \sim 60-200 μm 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

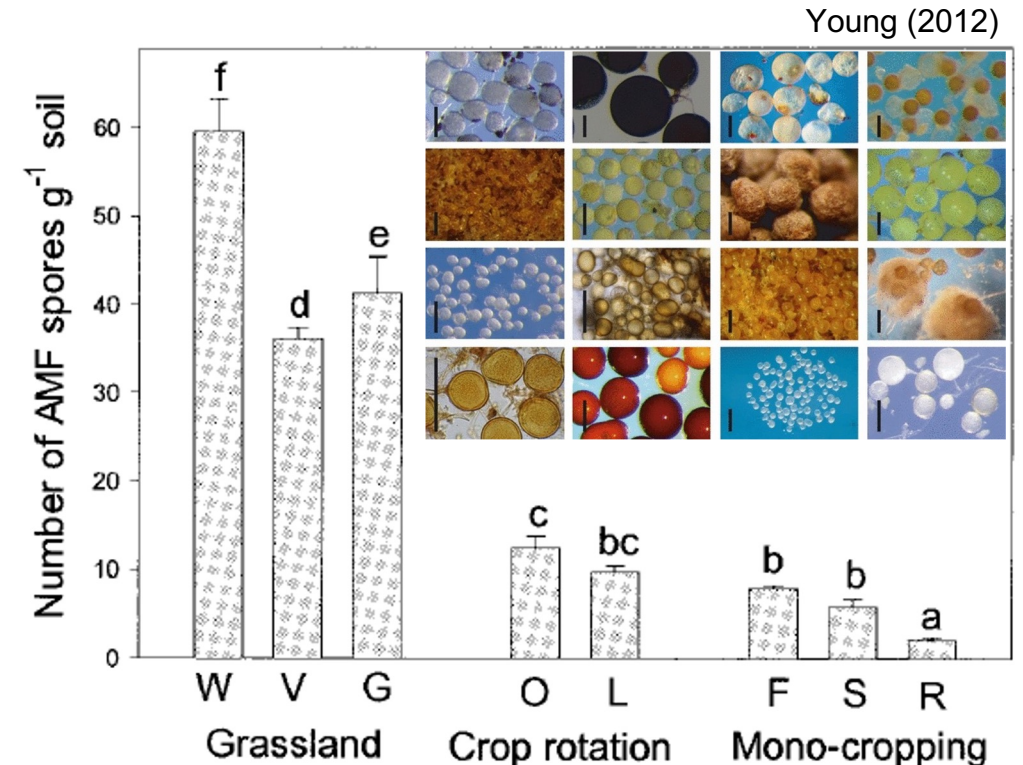
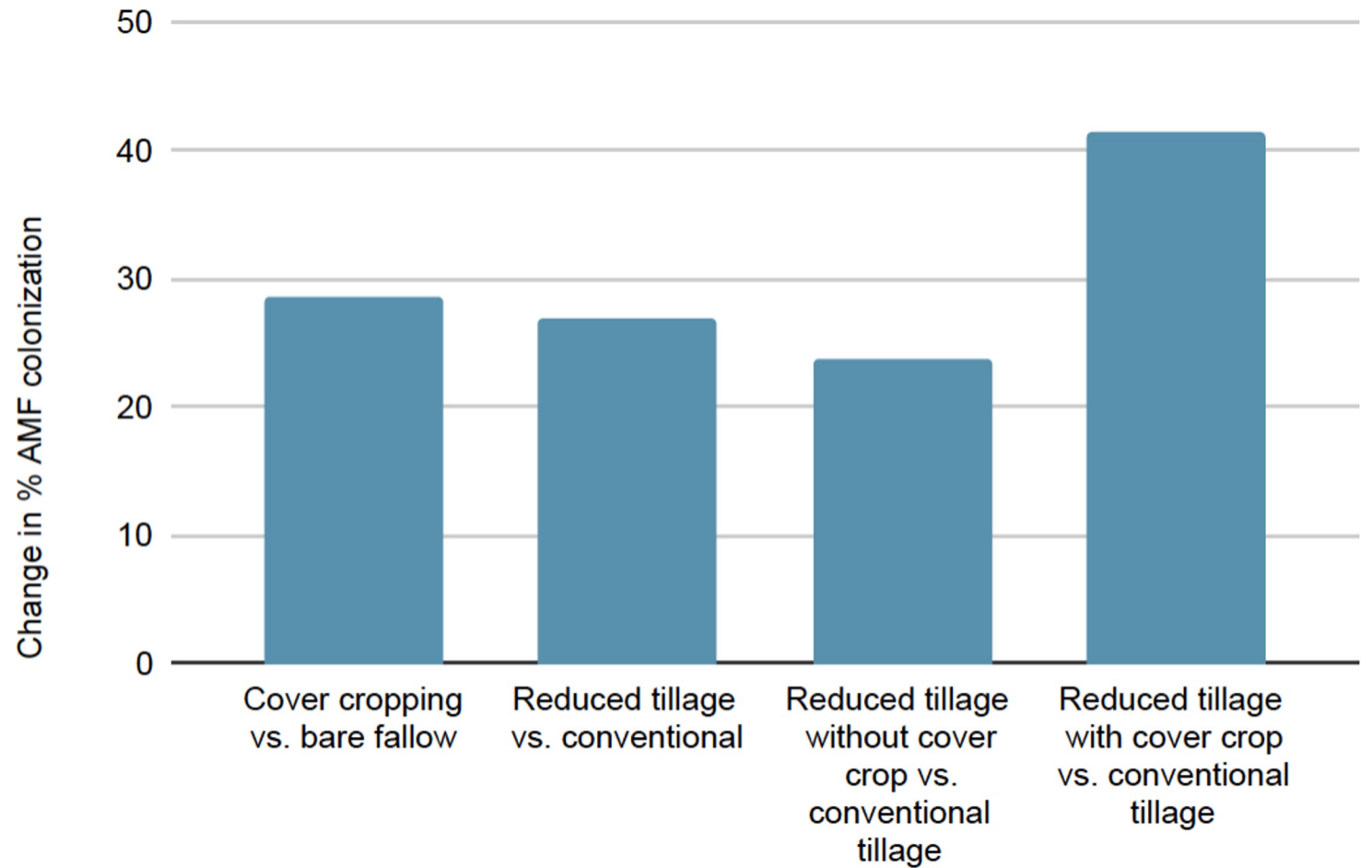


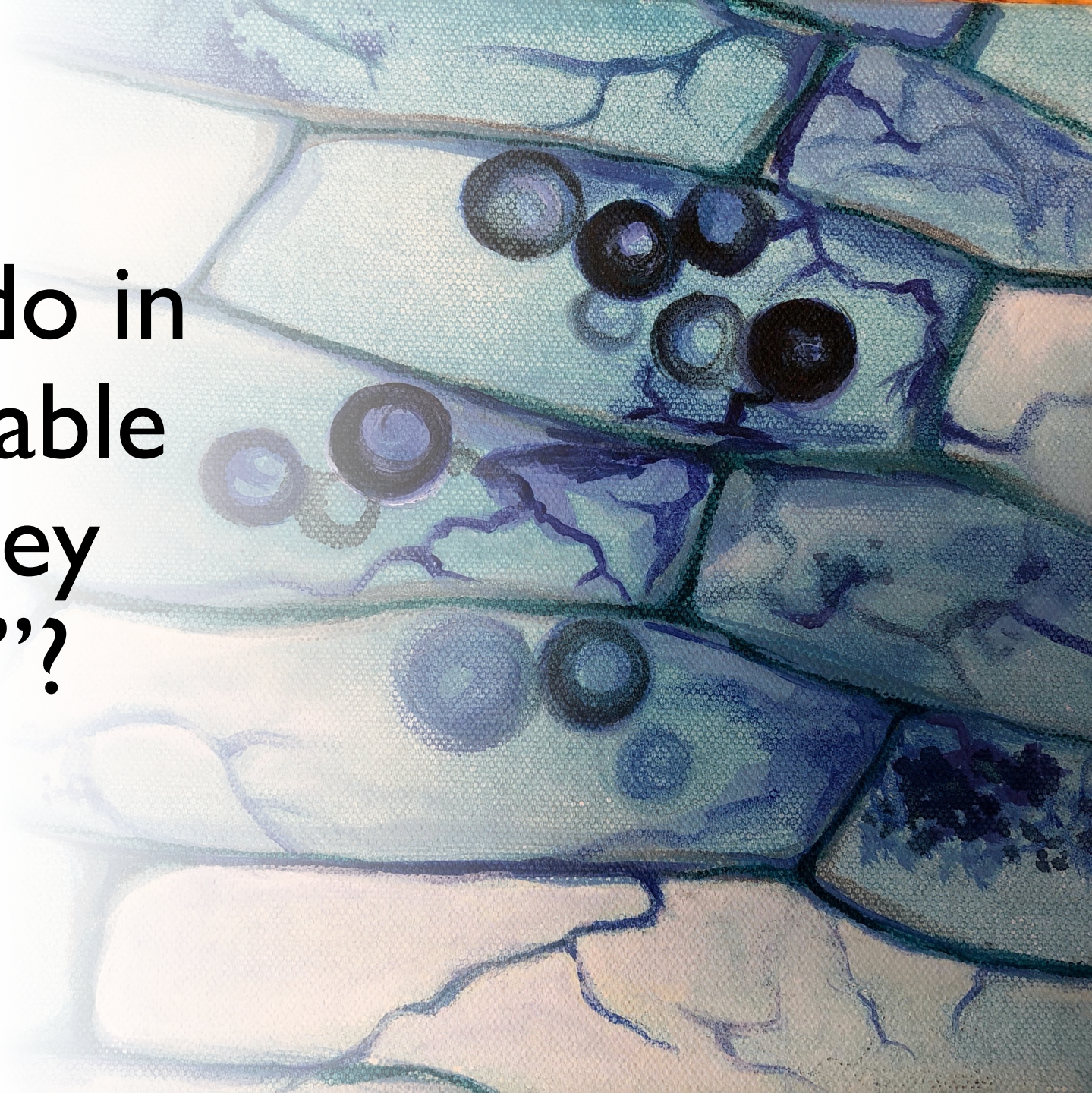
FIG. 1. AMF spore abundance at field sites (W, V, G, O, L, F, S, and R) with different cultivation practices. Input and management intensity increase from left to right. Data are reported as averages and standard deviations for four replicate plots per site. Nonsignificant differences between sites are 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



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

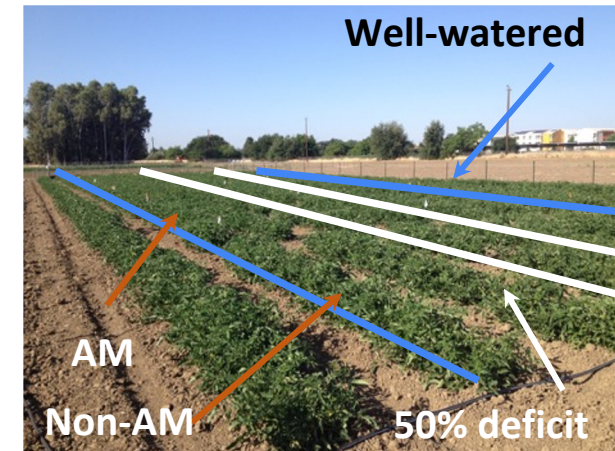
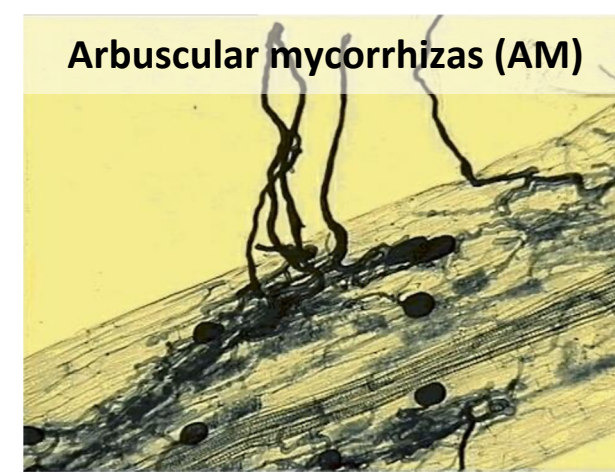


AMF can increase crop water use efficiency

- 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 ⁻¹ cm ⁻¹ 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?

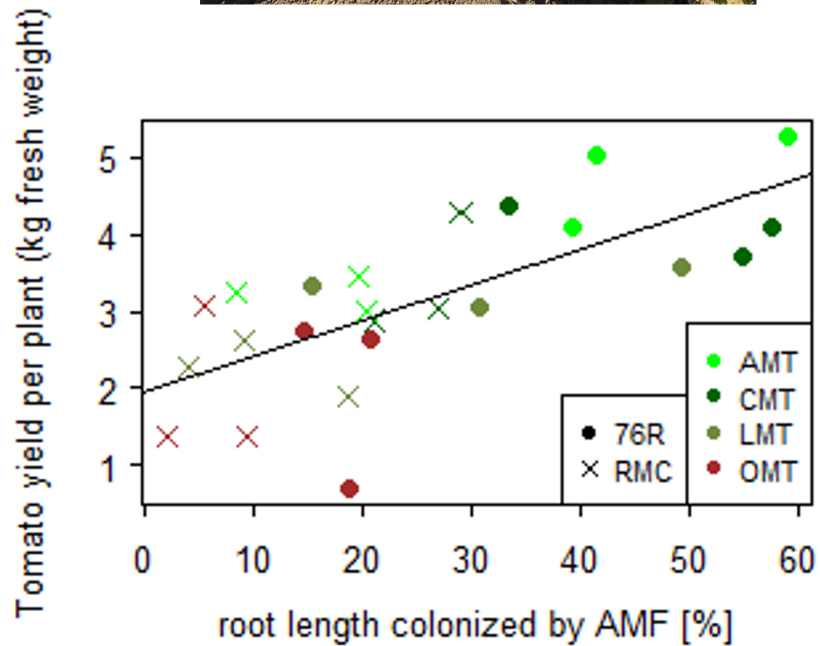


Century experiment, Russel Ranch, Davis, CA
Long term comparison of different cropping systems for 25 years

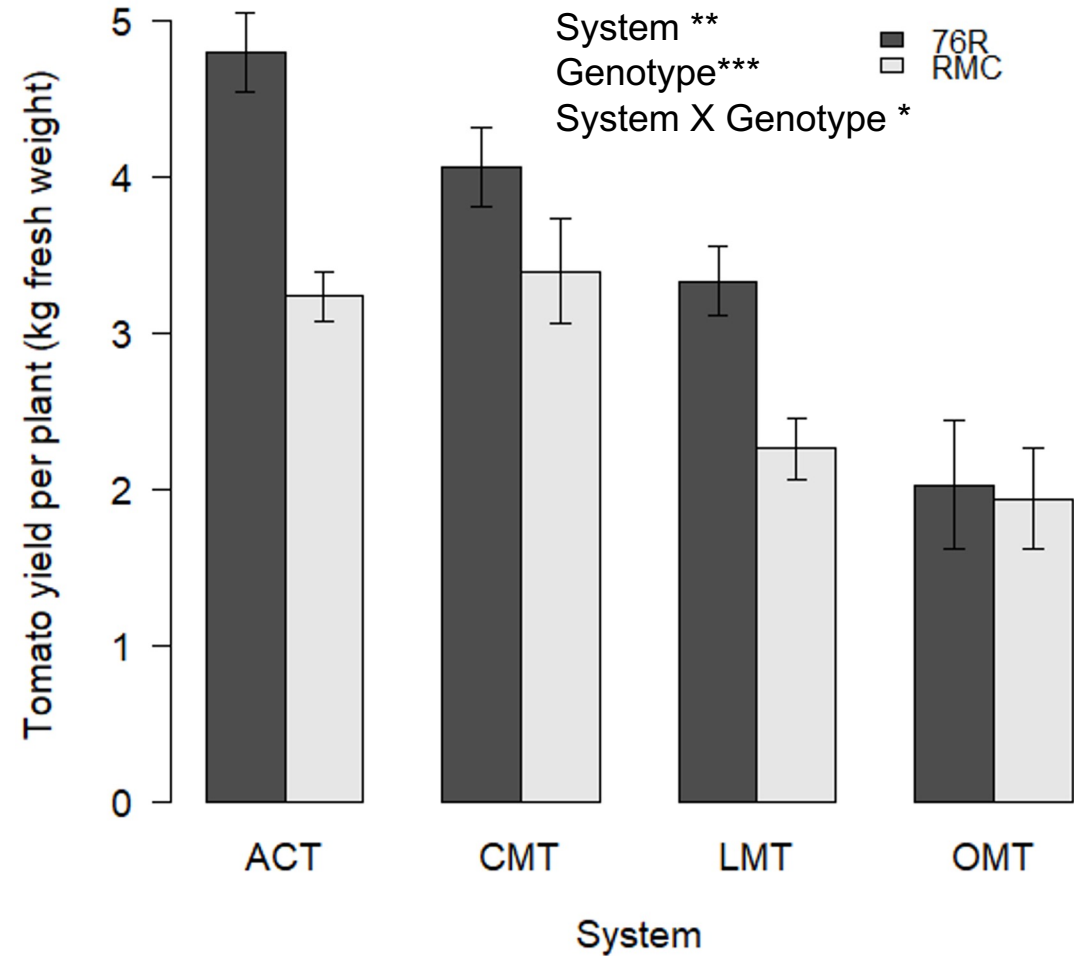


Franz Bender,
former postdoc
UC Berkeley

| 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. |



Tomato yield (fresh weight)

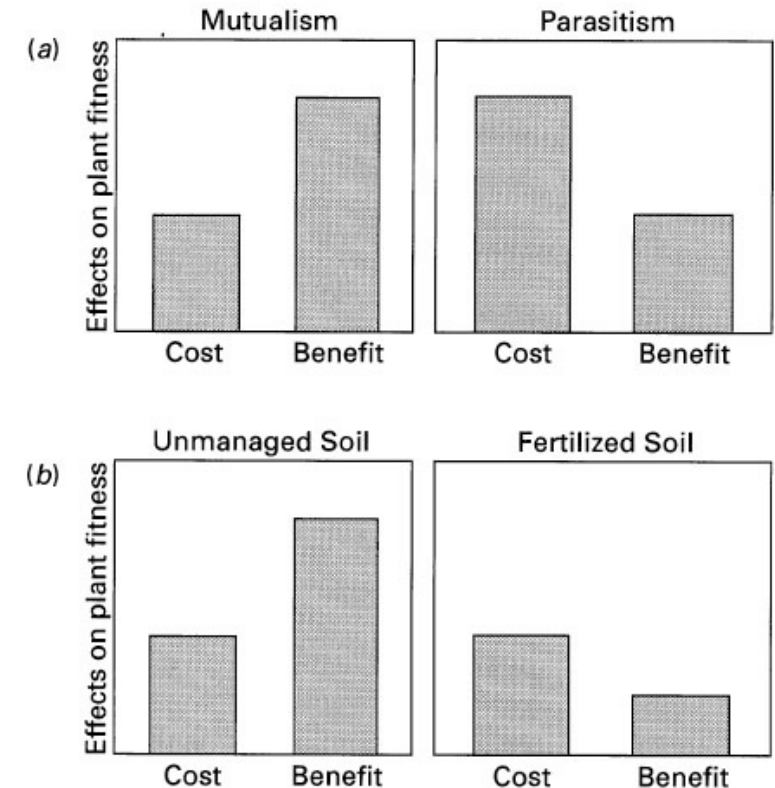


- **76R (dark bars):** Paste-type tomato
- **rmc (light bars):** “reduced mycorrhizal colonization” – slightly different genotype used only for research

AMF are not always mutualists

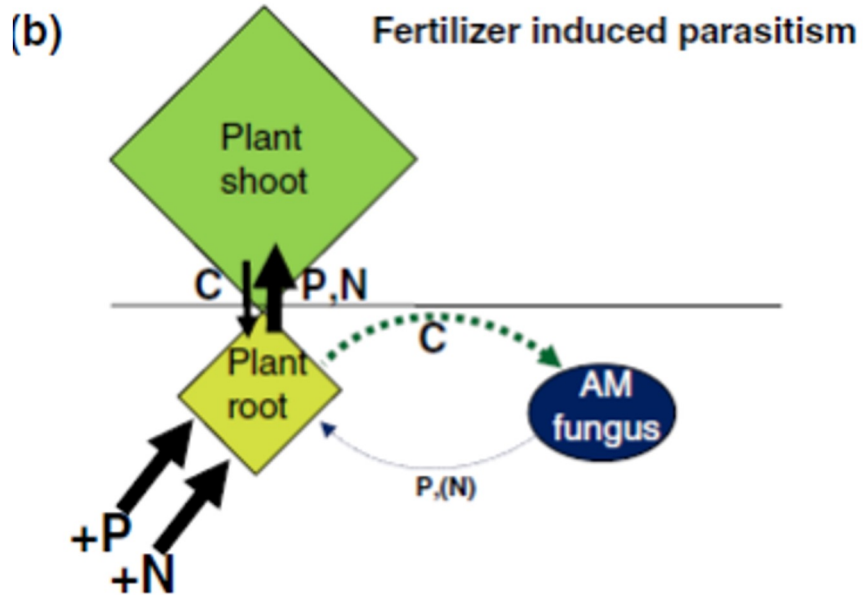
Species interactions are **context dependent**

| | | | | |
|---|---|---------------------|------------------------|-----------------------|
| Gradient of fungal responses | - | | | Competition (-, -) |
| | 0 | | Neutralism (0, 0) | Amensalism (-, 0) |
| | + | Mutualism (+, +) | Commensalism (0, +) | Parasitism (-, +) |
| | | + | 0 | - |
| Gradient of plant responses to mycorrhizal associations | | | | |

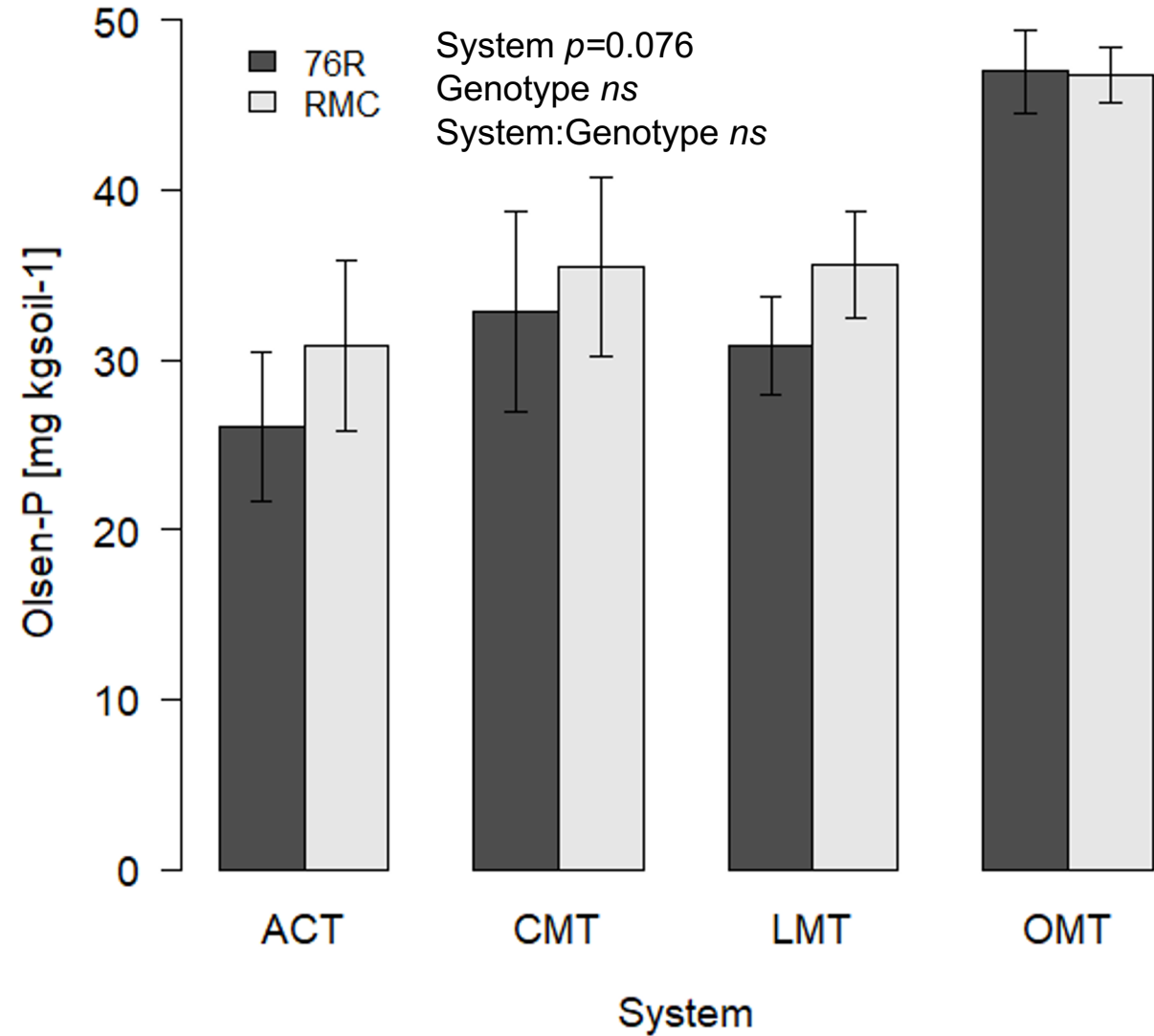


Costs of AMF are the carbon (energy) that the plant delivers. The benefits are the nutrients the AMF deliver to the plant, which may or may not increase plant growth.

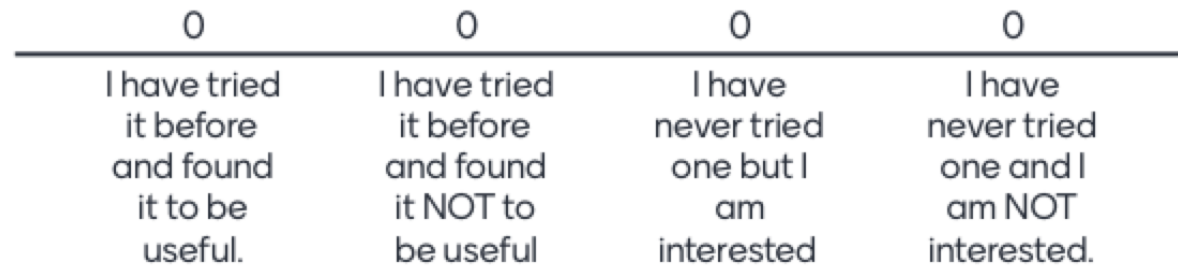
The organic system at this long-term experiment receives composted manure, which has more phosphorus relative to nitrogen than plants need → build up of phosphorus in soil



Soil phosphorus levels



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?

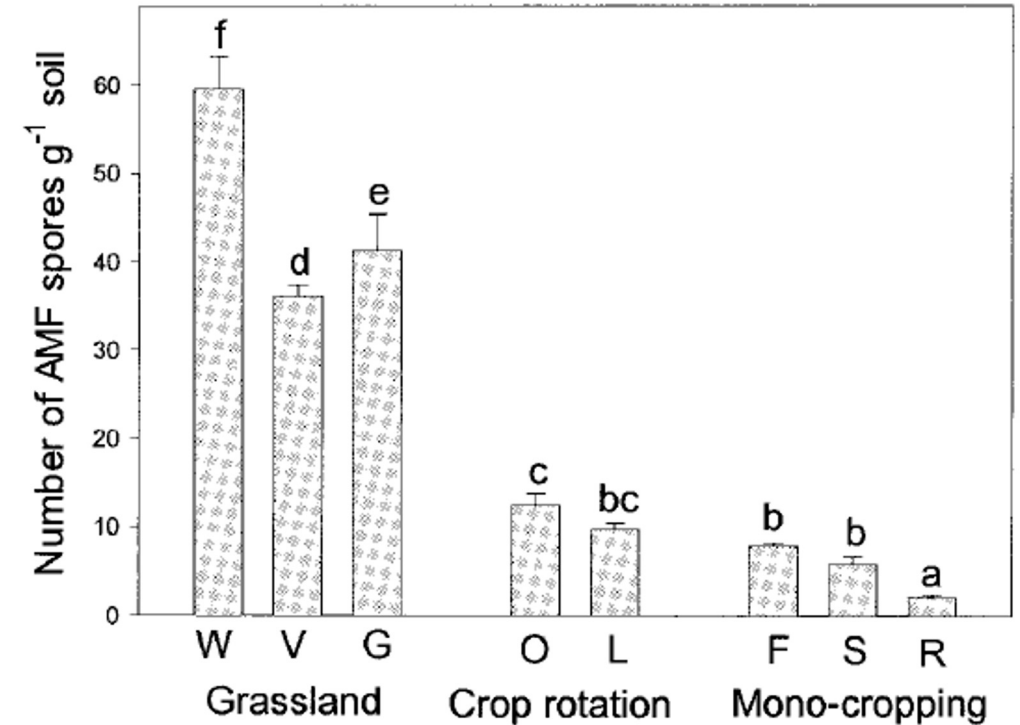
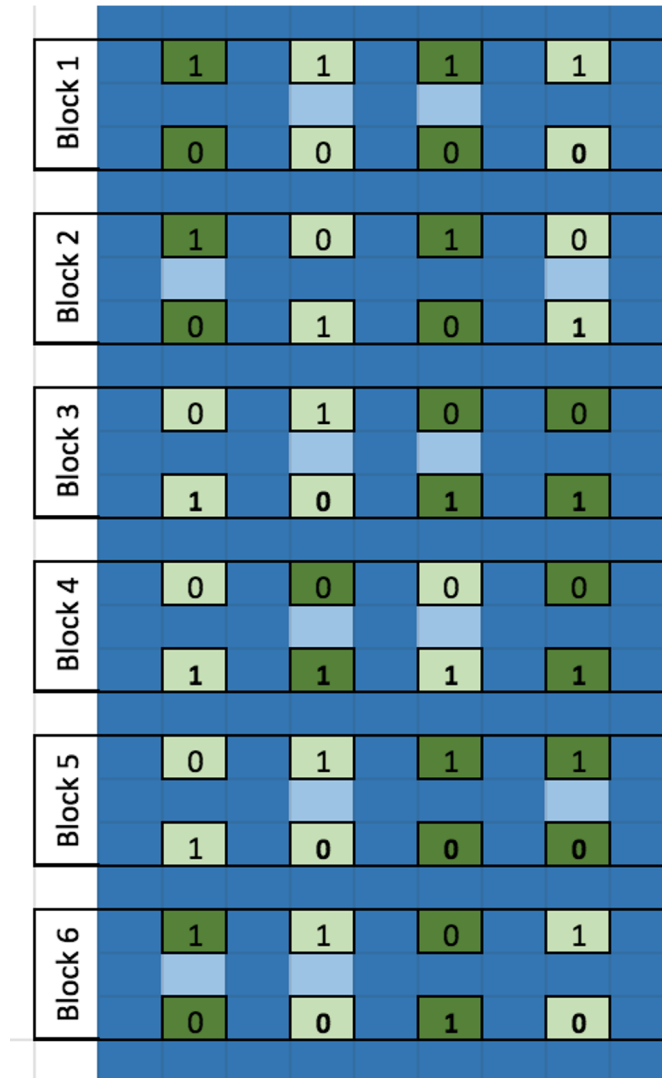


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2020: On-farm field experiment

- Organic processing tomato field in Yolo Co.
- 76R and rmc.
- Inoculated vs. non-inoculated.
- Fully watered vs. 50% deficit irrigation.



Light blue square = 50% deficit irrigation

Dark blue square = fully watered

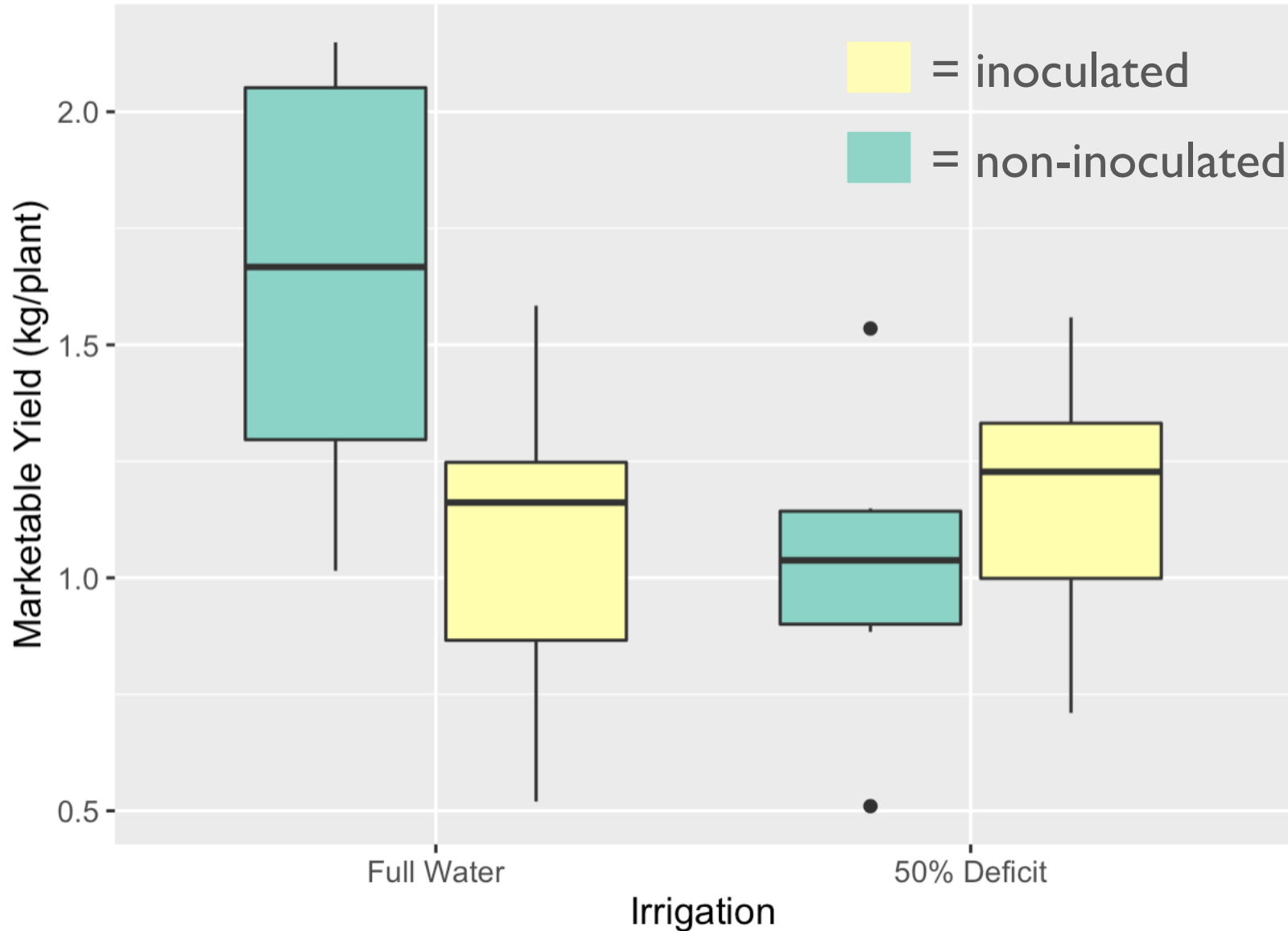
1 = inoculated

0 = non-inoculated

Light green square = rmc



Dark green square = 76R

Inoculation impact on marketable yields

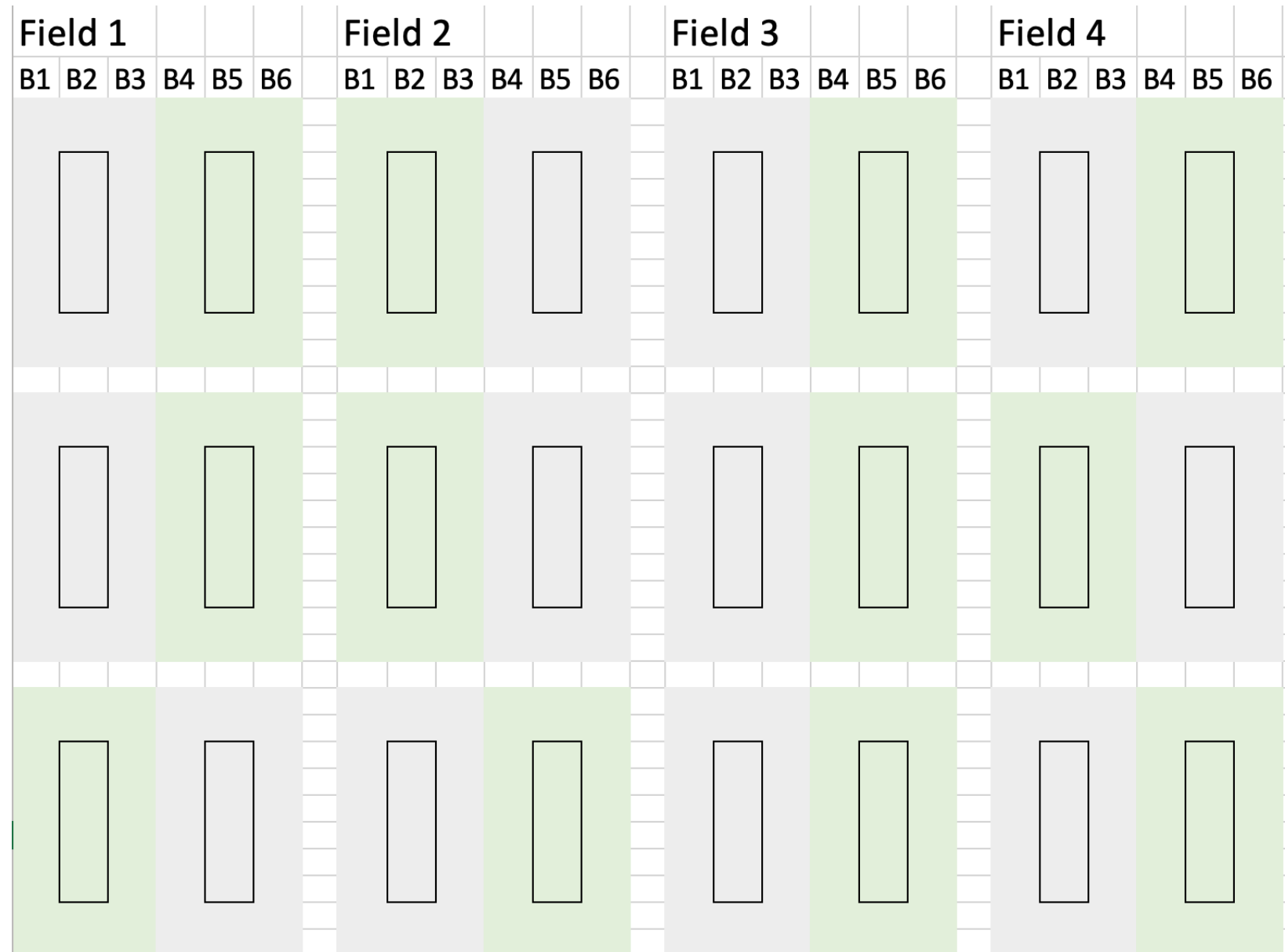


- Full water: Inoculation **decreased** yields by 34%.
- 50% deficit irrigation: Inoculation **increased** yields by 14%.

2021: Landscape-scale on-farm experiment

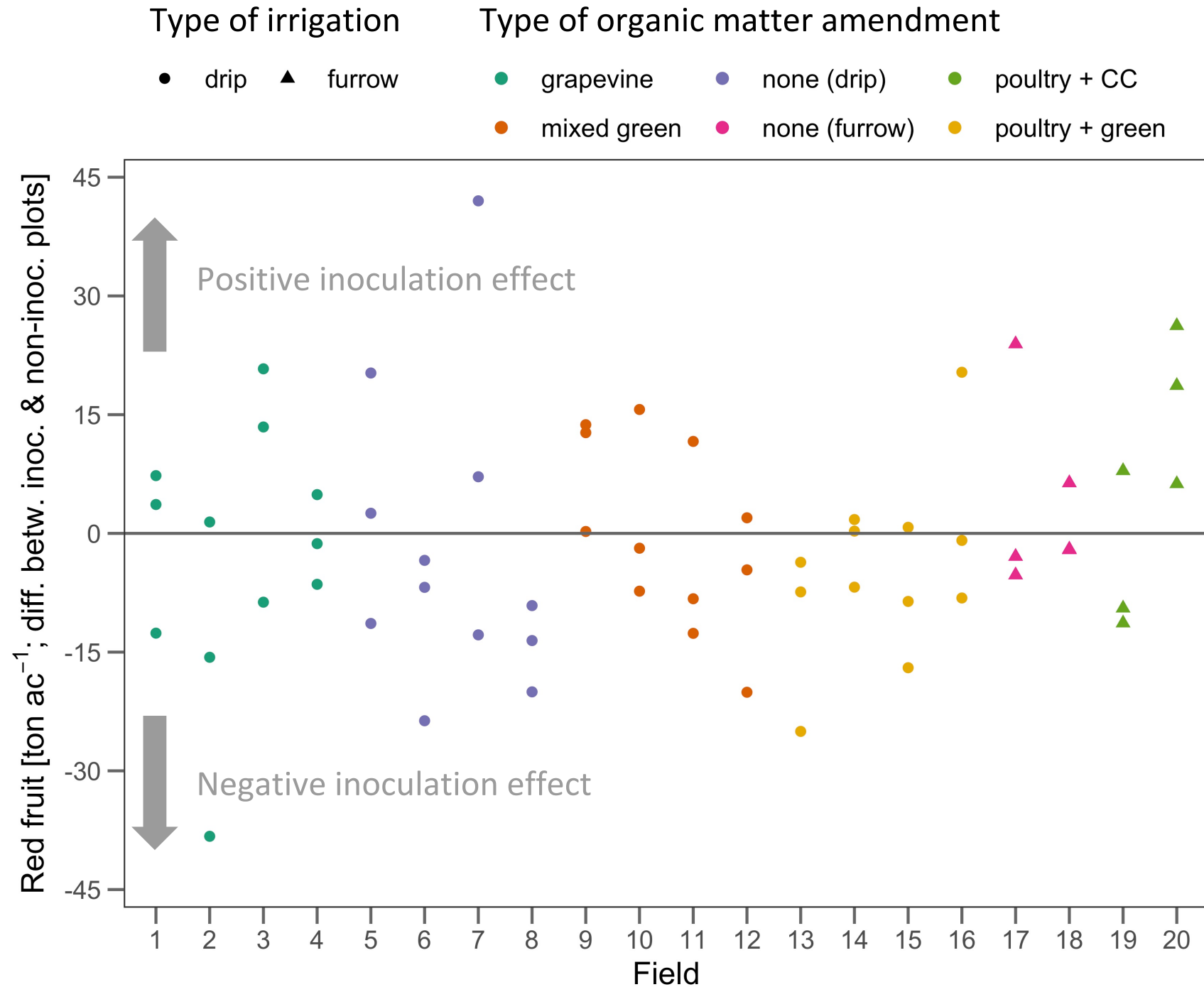
 = inoculated
 = non-inoculated

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



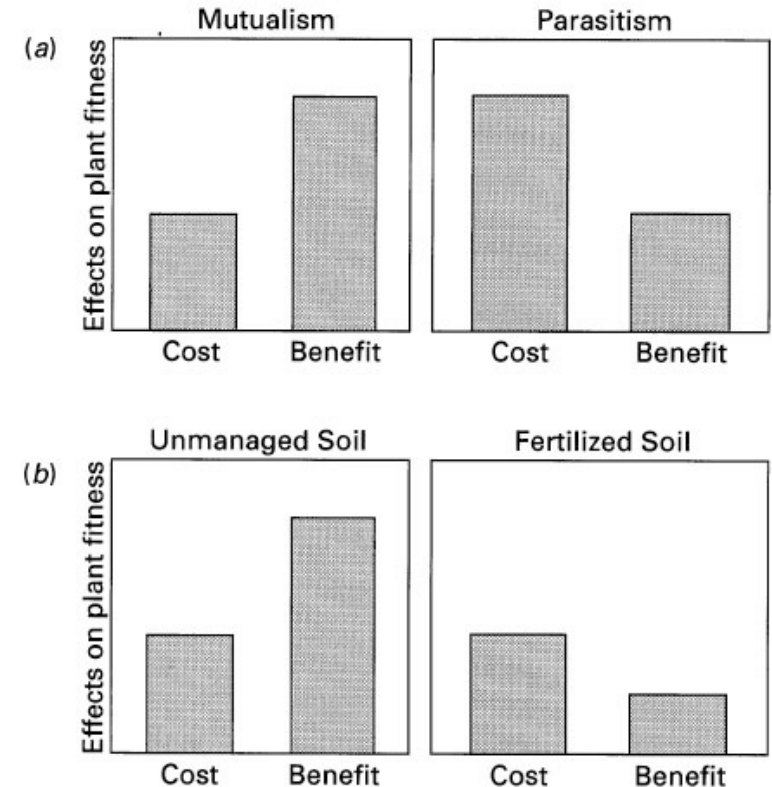
No inoculation impact on marketable yields

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



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.



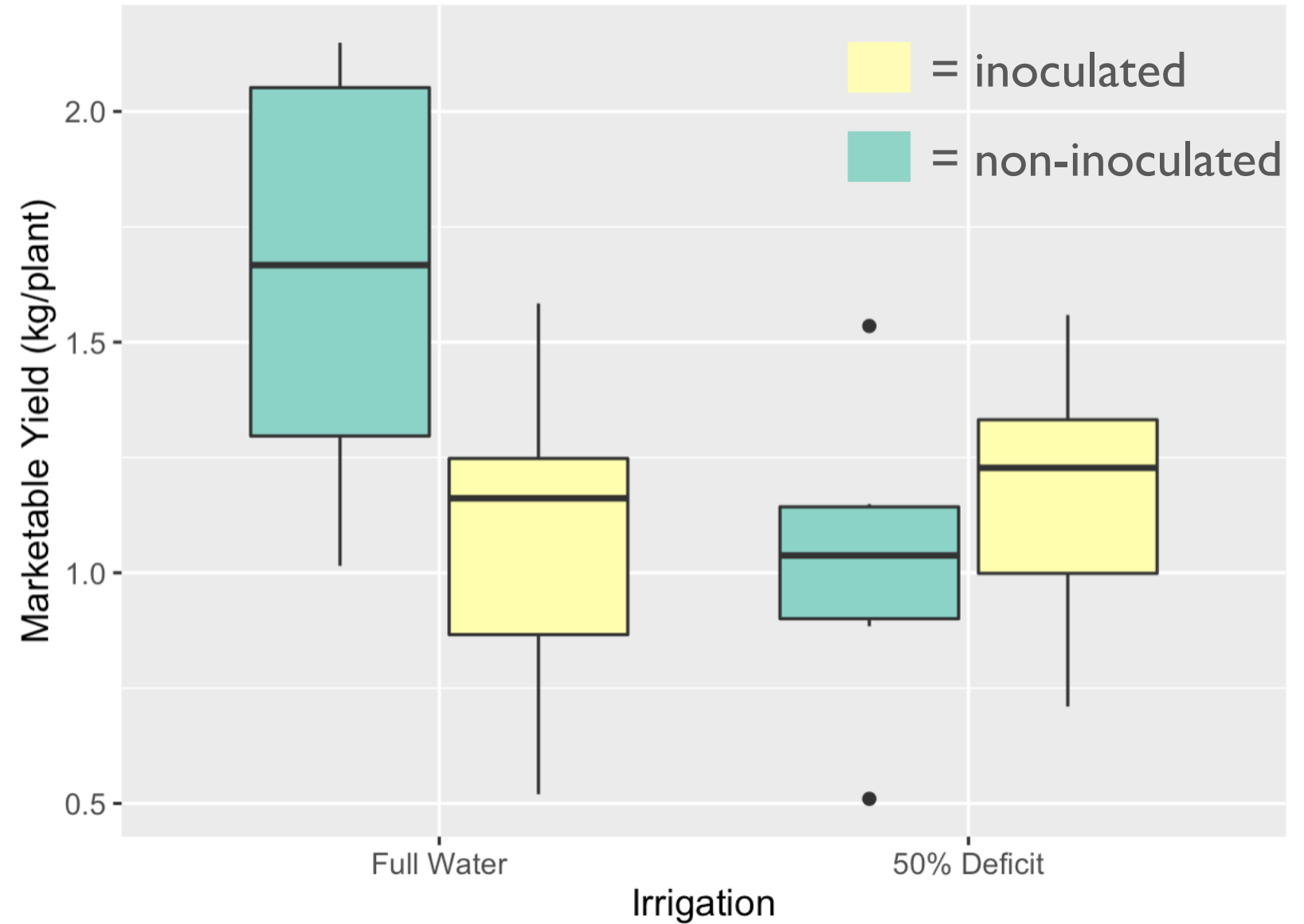
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What about water stress?

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



Why does dry farming work?

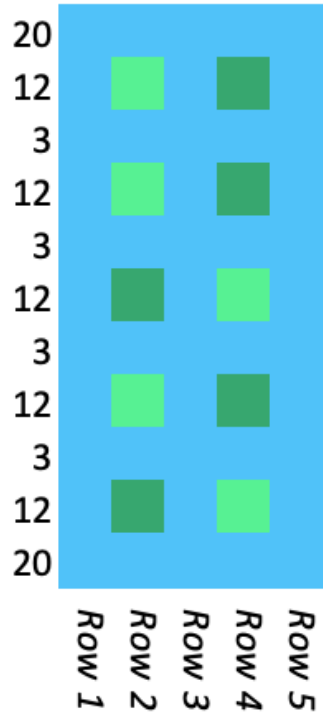
- Climate
- Increased soil water (holding capacity)
 - Inherent aspects
 - Clay content
 - Management
 - Cover crop
 - Dust mulch
 - Nutrient delivery



How do dry farm systems respond to inoculation?



Number of
Plants



- - buffer plants
- - experimental plot: inoculated
- - experimental plot: non-inoculated

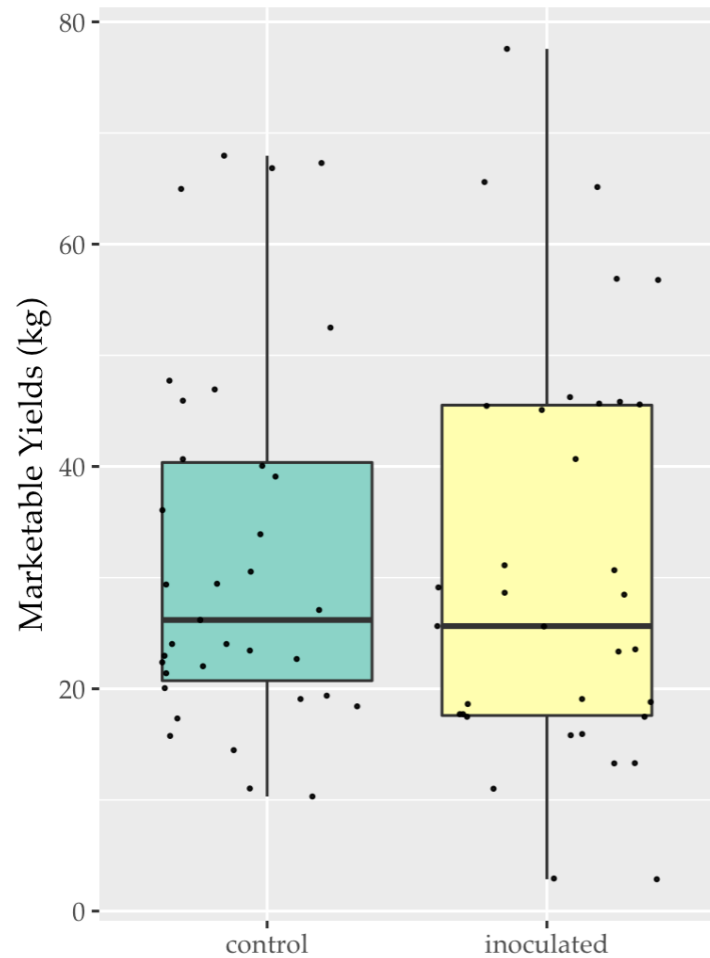
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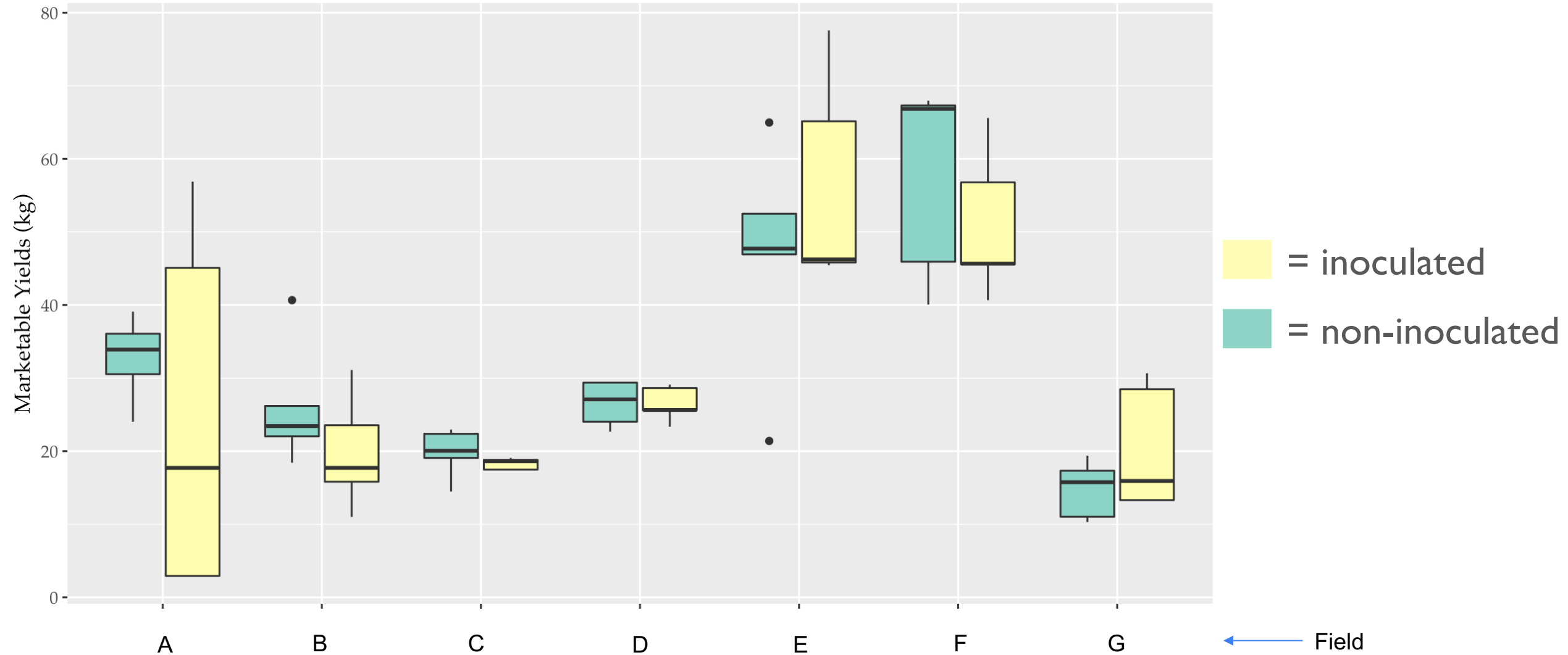
How do dry farm systems respond to inoculation?



- Preliminary results say ...not at all!



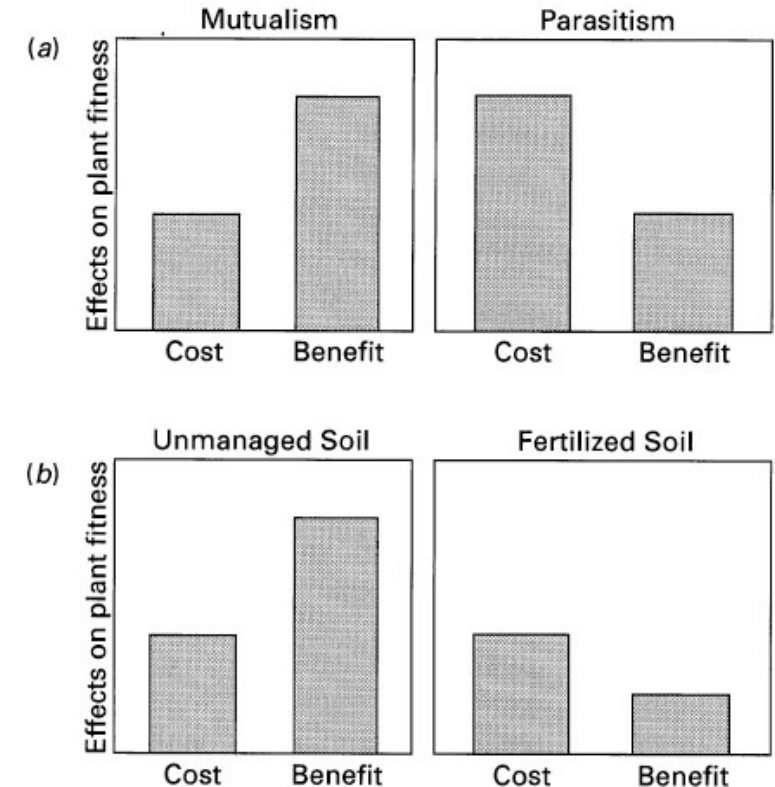
How do dry farm systems respond to inoculation?





Potential reasons for lack of inoculation impact

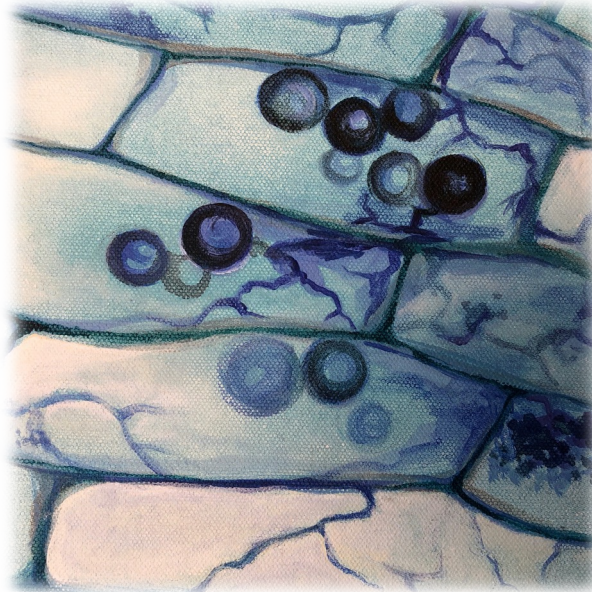
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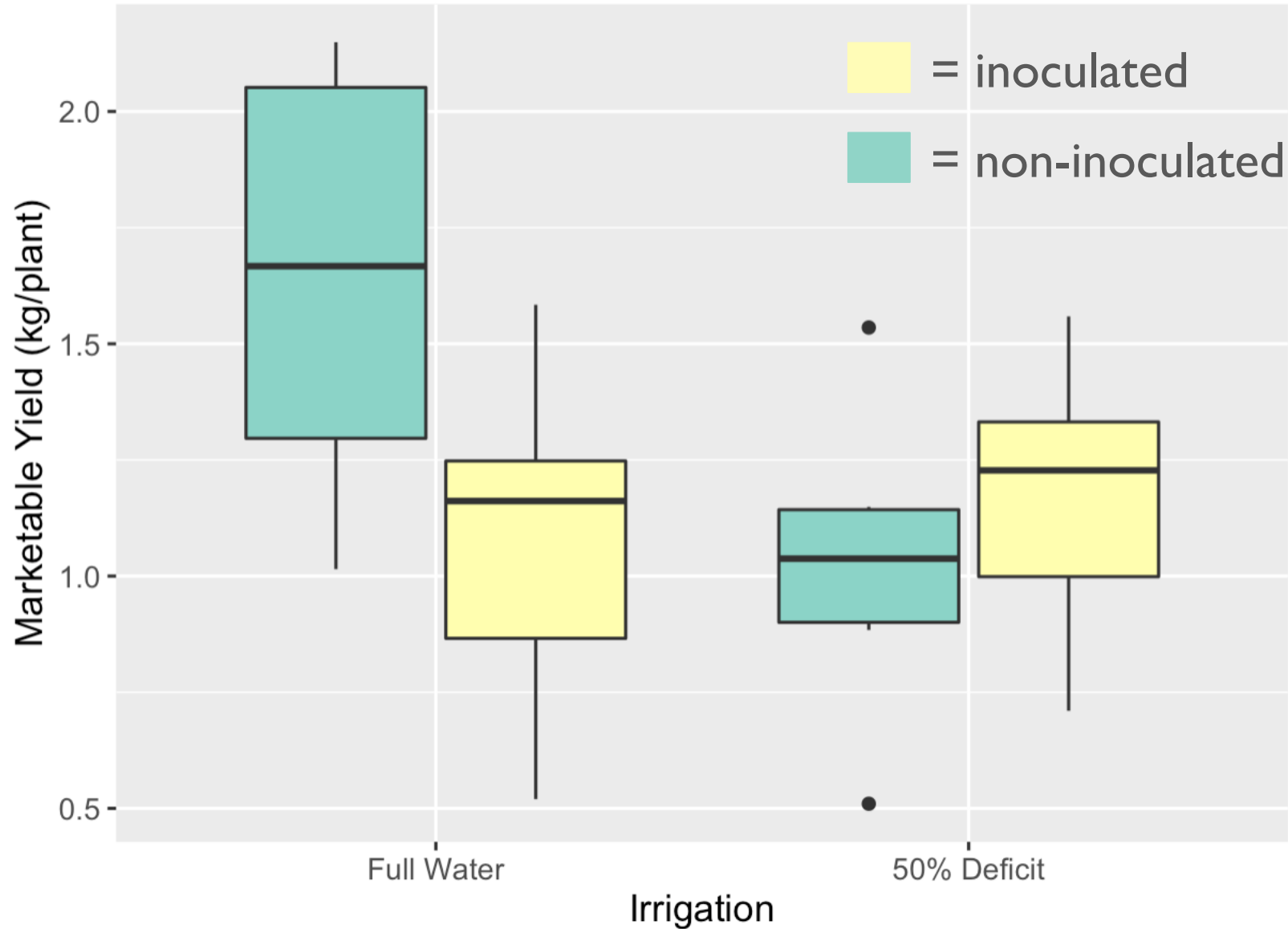
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VS



To inoculate or not to inoculate...



Summer 2020
results

Take-home messages

- AMF inoculation of processing tomato plants had no (positive) effect on yields and fruit quality.
- AMF inoculation of fresh market tomato plants under severe water stress has no effect on yields.
- When it is hard to reduce tillage, 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.