Mycorrhizal Fungi in the Orchard

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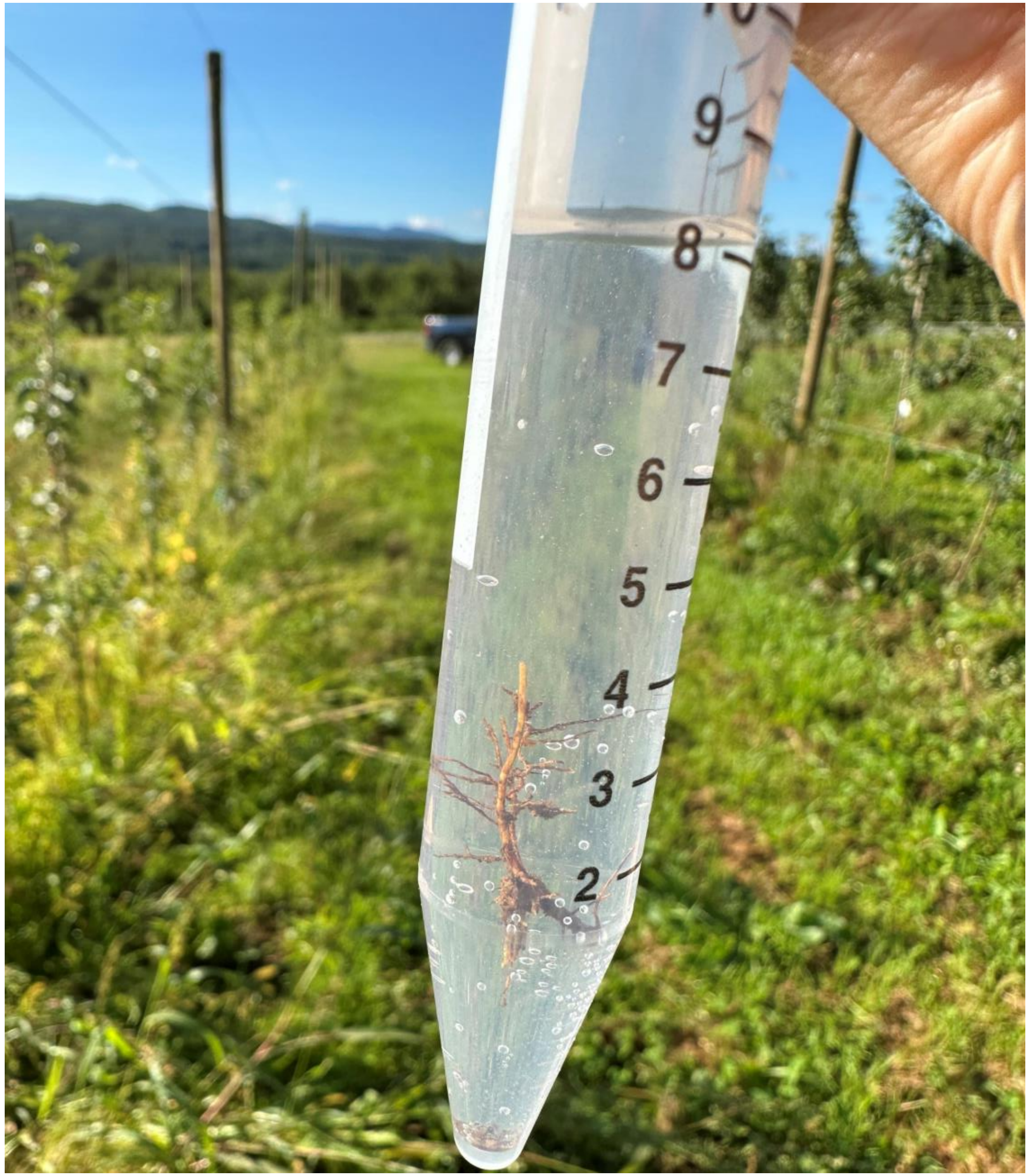


Soil organisms

There are all kinds of critters in the soil

Arbuscular Mycorrhizal Fungi (AMF)

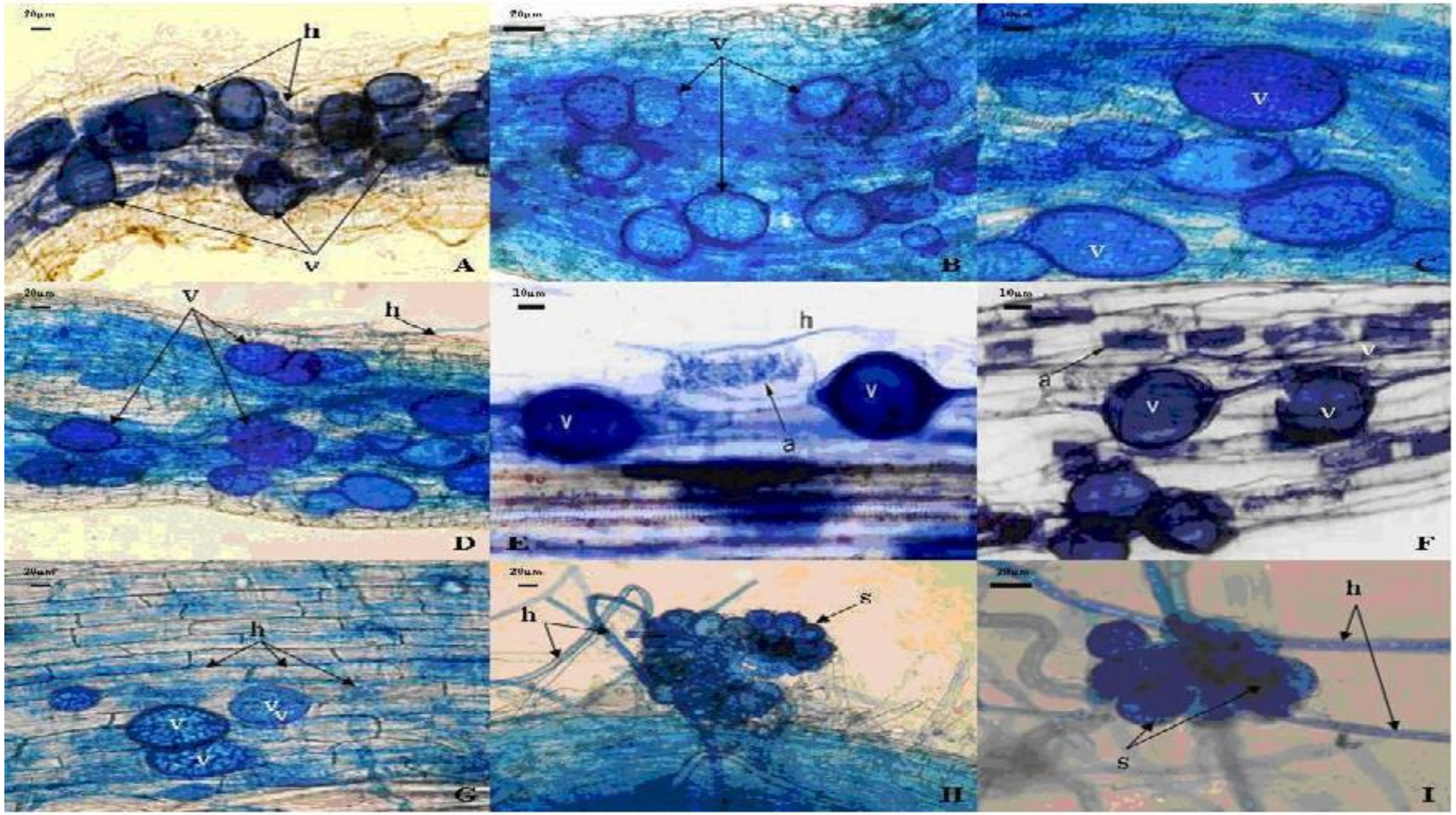


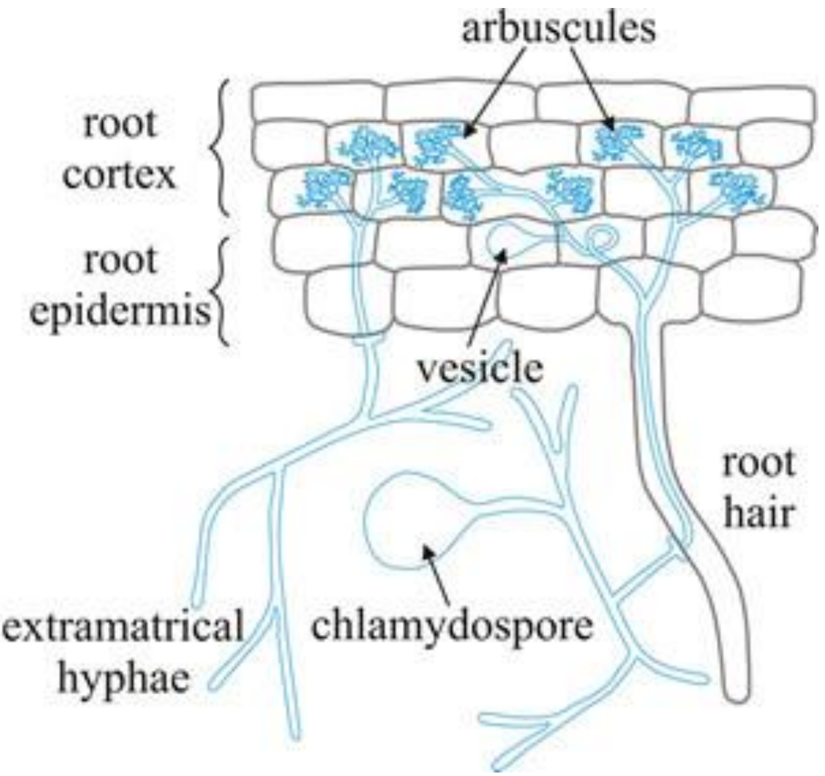
Figure 3. Fungal structures including vesicles (v), hyphae (h), arbuscules (a) and spores (s) observed in clover roots after staining

- 240 species
- Associate with >200,000 plant species (~80%)

Symbiosis

- Plants give fungi carbohydrates
- Fungi increase root surface area, providing nutrients and water to the plant

AMF Benefits



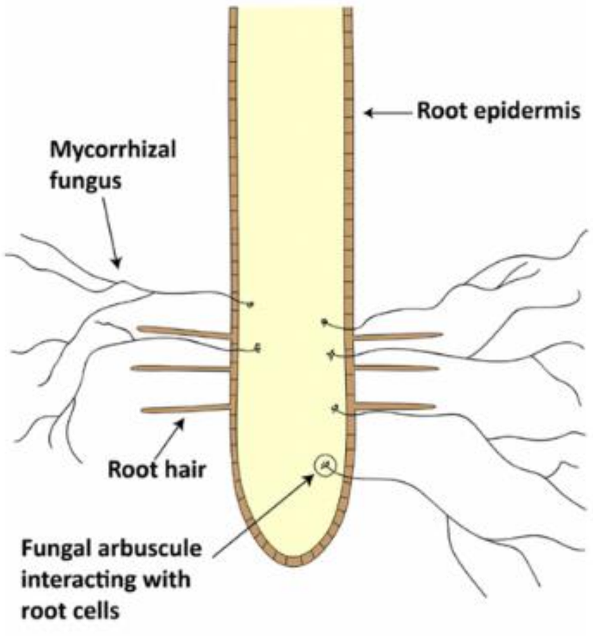
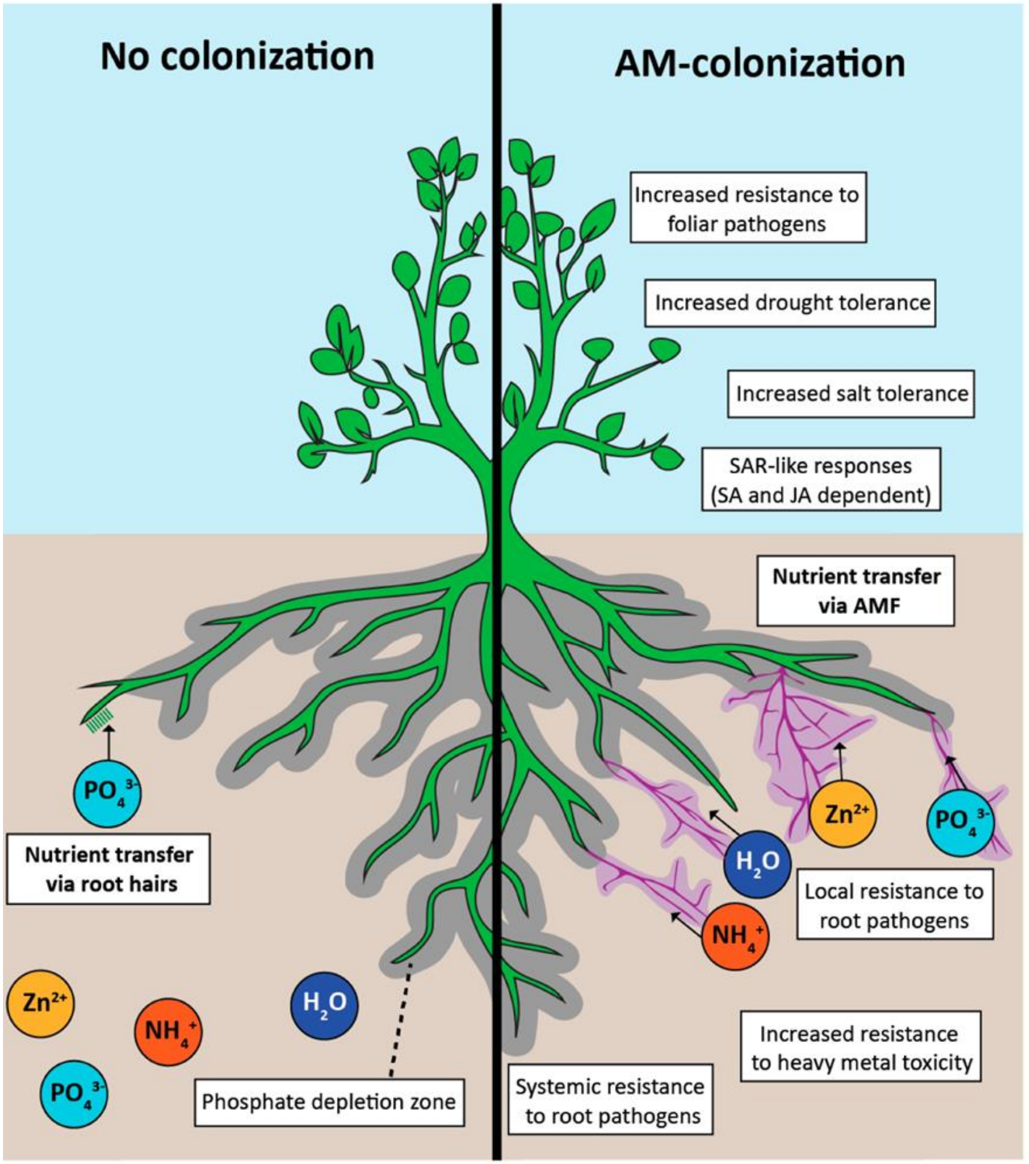


Figure 1. Graphic of a plant root with mycorrhizae fungus hyphae.



Jacott, Murray, and Ridout. 2017. Trade-Offs in Arbuscular Mycorrhizal Symbiosis: Disease Resistance, Growth Responses and Perspectives for Crop Breeding.

Tree Growth

Multiple studies in apple have found AMF have the potential to increase tree growth

Table 2. Mean comparison of simple effects of rootstocks and AMF inoculation on root colonization, growth, and biomass of apple rootstocks 21 weeks after inoculation

Treatments	Root colonization (%)	Shoot height (cm)	Stem diameter (mm)	Leaf area (cm^2)	Fresh weight ($g\ plant^{-1}$)		Dry weight ($g\ plant^{-1}$)	
					Shoot	Root	Shoot	Root
AMF Species								
Control	5.55^{c}	47.22^{c}	5.56^{c}	32.36^{d}	27.63^{b}	18.34^{c}	13.39^{c}	10.20^{c}
G. versiforme	72.77^{a}	57.55^{a}	7.23^{a}	37.25^{a}	34.20^{a}	29.06^{a}	17.64^{a}	15.06^{a}
R. intraradices	67.55^{b}	54.55^{b}	6.63^{b}	35.62^{b}	32.94^{a}	26.76^{b}	16.67^{ab}	13.05^{b}
C. etunicatum	67.44^{b}	52.77^{b}	6.83^{b}	34.38^{c}	33.05^{a}	25.57^{b}	15.61^{b}	12.80^{b}
ANOVA	**	**	**	**	**	**	**	**

Hosseini and Gharaghani, 2015. (greenhouse, potted, high-pH unsterilized field soil)

Nutrient Use Efficiency

A few studies have found some increases in leaf nutrients in trees inoculated with AMF, though this is not always consistent.

Table 4. Mean comparison of simple effects of rootstocks and AMF inoculation on leaf mineral concentration (of dry weight) of apple rootstocks 21 weeks after inoculation

Treatments	N (%)	P (%)	K (%)	Mg (%)	Ca (%)	Zn (µg g^{-1})	Cu (µg g^{-1})	Mn (µg g^{-1})	Fe (µg g^{-1})
AMF Species									
Control	1.93^{b}	0.22^{c}	1.33^{a}	0.34^{c}	1.21^{b}	15.78^{b}	11.57^{a}	55.77^{a}	124.11^{c}
G. versiforme	2.13^{a}	0.36^{a}	1.34^{a}	0.42^{a}	1.39^{a}	17.53^{a}	11.54^{a}	54.66^{a}	131.22^{a}
R. intraradices	2.11^{a}	0.32^{b}	1.34^{a}	0.41^{a}	1.37^{a}	16.93^{a}	11.68^{a}	54.55^{a}	129.33^{b}
C. etunicatum	2.10^{a}	0.31^{b}	1.34^{a}	0.36^{b}	1.36^{a}	17.20^{a}	11.61^{a}	54.11^{a}	130.00^{c}
ANOVA	**	**	ns	**	**	**	ns	ns	**

Hosseini and Gharaghani, 2015. (greenhouse, potted, high-pH unsterilized field soil)

Nutrient Use Efficiency

A few studies have found some increases in leaf nutrients in trees inoculated with AMF, though this is not always consistent.

Table 1. Leaf mineral concentrations and DRIS[z] indices of apple rootstock cultivars inoculated with different VAM isolates.

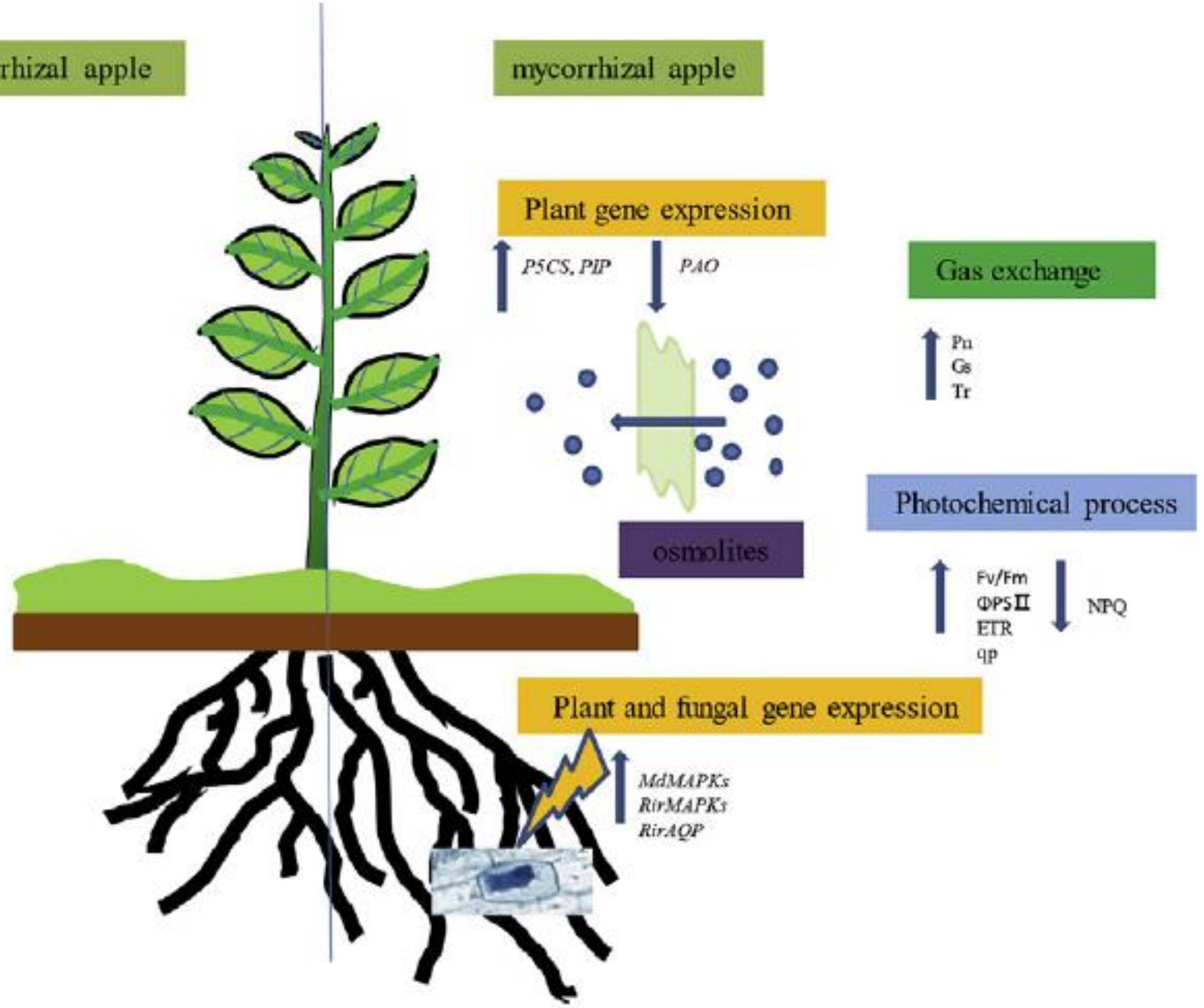
Inoculation treatments	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
			mg·g^{-1}						µg·g^{-1}		
G. versiforme(OR)	13.0[y]a	1.90 a	23.1 a	10.6 a	3.37 a	1.67 a	55.4 a	16.0 a	142.9 a	48.6 a	41.4 a
G. aggregatum	12.7 a	2.30 a	21.6 a	10.8 a	3.18 a	1.54 a	57.1 a	18.0 a	142.4 a	48.0 a	43.6 a
G. intraradix	12.4 a	2.01 a	21.8 a	10.6 a	3.23 a	1.65 a	56.6 a	15.7 a	137.8 a	50.2 a	46.2 a
G. versiforme(CAL)	14.3 a	1.96 a	22.7 a	10.2 a	3.37 a	1.72 a	55.8 a	17.2 a	138.8 a	47.2 a	40.6 a
Control	18.9 b	1.24 b	23.1 a	10.8 a	3.84 b	2.04 b	60.5 a	15.2 a	180.4 b	50.3 a	43.7 a
			DRIS index[x]				Total DRIS index				

Morin et al. 1994 (Greenhouse, potted, high P nursery soil, sterilized)

Drought Tolerance

Mycorrhizal colonization enhanced apple drought tolerance by:

- improving gas exchange capacity
- increasing chlorophyll fluorescence parameters
- creating a greater osmotic adjustment capacity
- increasing scavenging of reactive oxygen species (ROS)
- and using MAPK signals for interactions between AMF and their apple plant hosts. (Huang et al., 2020). (greenhouse, sterilized mix in pots)



Disease Resistance

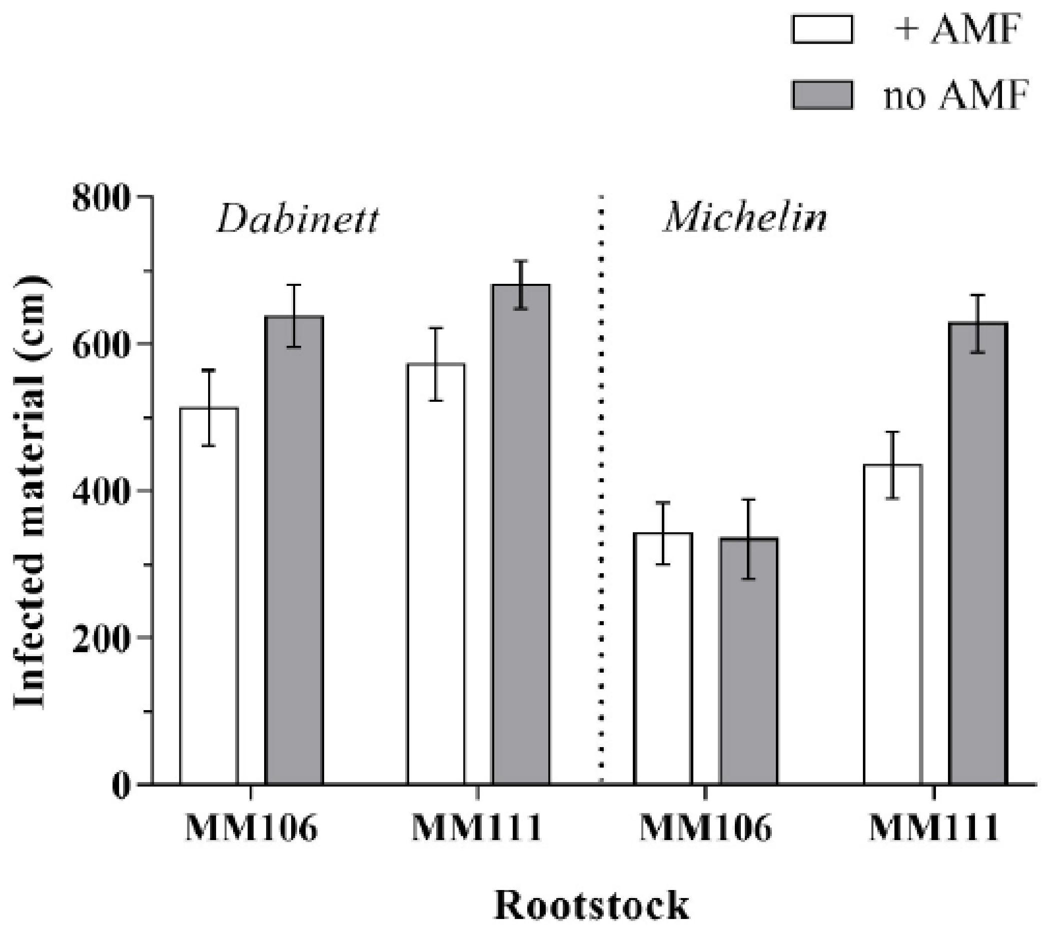


FIGURE 3 | Total apple tree (*Malus pumila*) material infected by the fungal pathogen *Neonectria ditissima*. Trees were grown with and without inoculation with arbuscular mycorrhizal fungi (AMF). Error bars represent ± SE per treatment (n = 20). Total pathogen infected material was significantly affected by AMF inoculation (P = 0.001), scion type (P < 0.001) and rootstock type (P < 0.001).

- Berdeni et al. (2018) found mycorrhizal applications decreased the prevalence of nectria apple canker in apple trees by 18%. (potted plants, in low AMF media)

But....

How does this all translate to the field in commercial orchards?

?

Our NESARE Study

To determine the economic potential of inoculating northeast apple orchards with AMF at planting

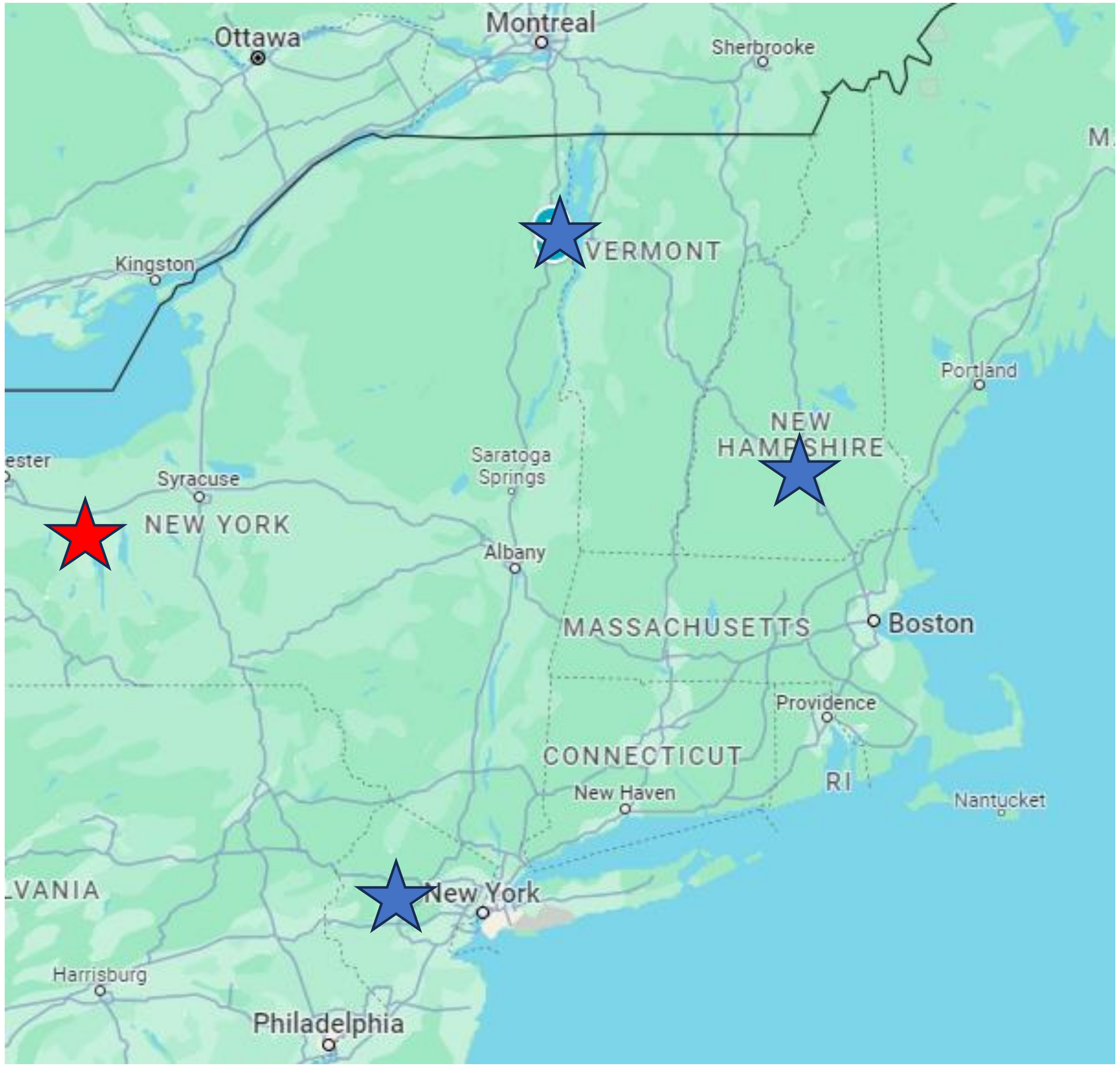
3 commercial replant field sites (NY, NH, and NJ)

4 commercial fungi blends

2 fertility management scenarios

- High/low P and N (NY and NJ)
- Neutral/low pH (NH)

Greenhouse studies in Geneva to give us more control, comparing different combos of scions and rootstocks



Our team is evaluating:

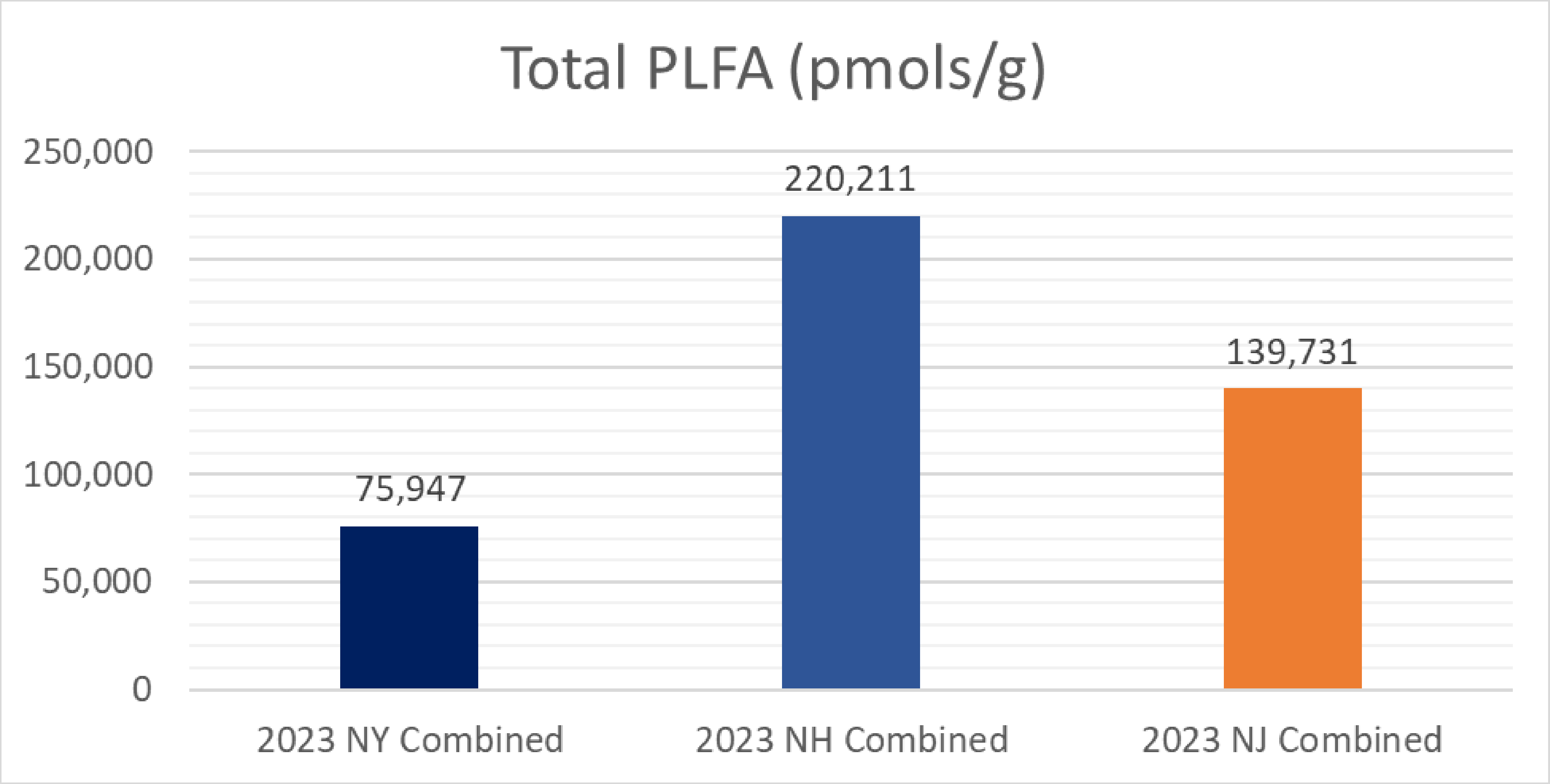
- AMF Root Colonization
- Tree growth and survival
- Leaf nutrient levels
- Tree water use efficiency
- Effects on the microbial community
- Economics

Species	Symvado	Mykos Gold	MycoBloom	Promate
Claroideoglomus claroideum	x		x	
Funneliformus mosseae	x		x	
Cetraspora pellucida			x	
Claroideoglomus lamellosum			x	
Acaulospora spinosa			x	
Racocetra fulgida			x	
Entrophospora infrequens			x	
Rhizophagus irregularis	x	x		x
Claroideoglomus etunicatum	x			
Total Species per Product	**4**	**1**	**7**	**1**

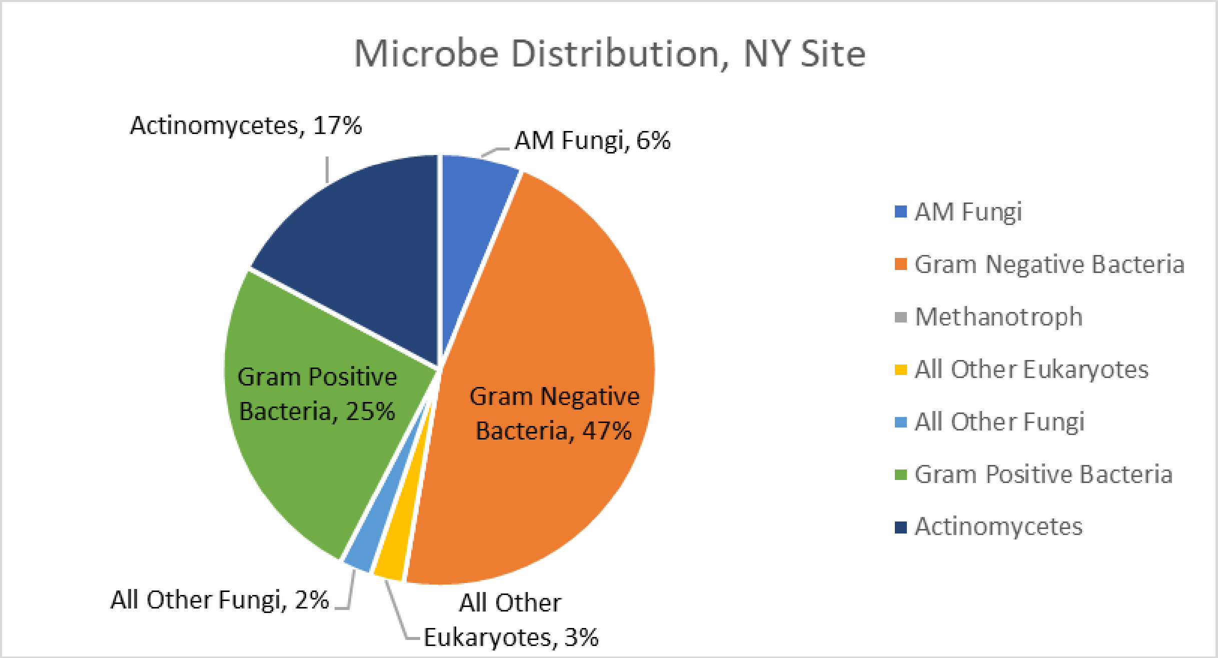
Product Comparison					
Product	**Propagules per Tree***	**Rate Per Tree**	**# Trees per Acre**	**Cost per Acre**	**Other Listed Ingredients**
Symvado	1320	1 pouch	1210	435.60	
Mykos Gold	900	3 grams	1210	45.42	
MycoBloom	2160 spores per tree	3 Tablespoons	1210	1269.56	
Promate	2400	2 pouches	1210	1393.92	N,P,K,Ca, Mg, S, Humic acid

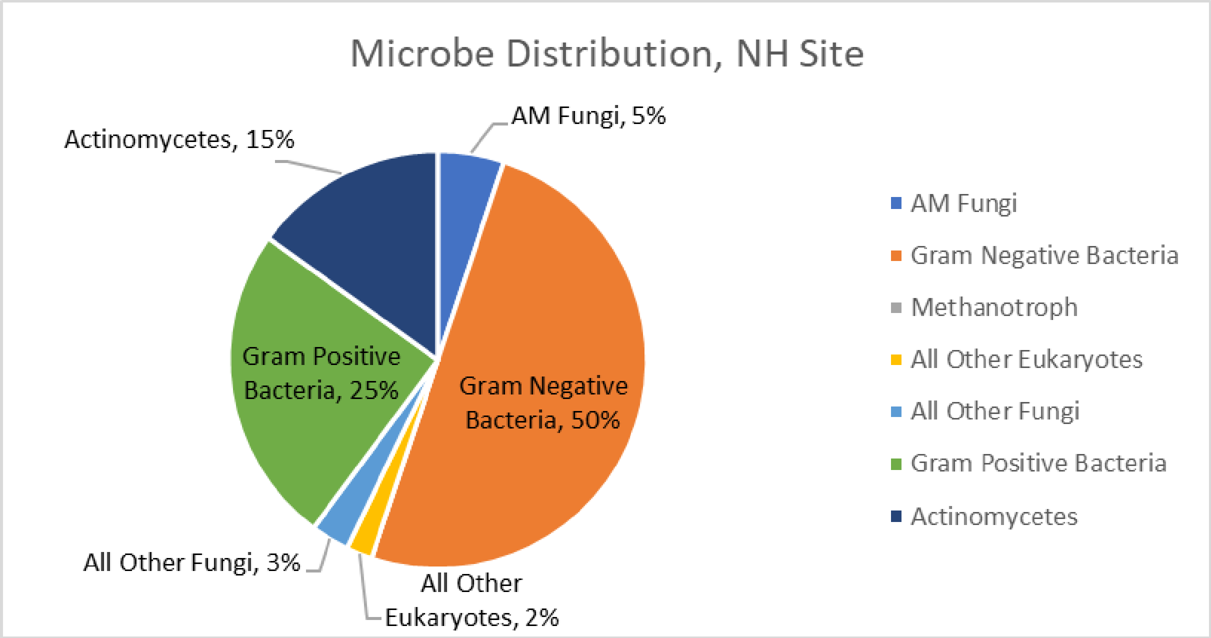
Test orchards planted in 2023

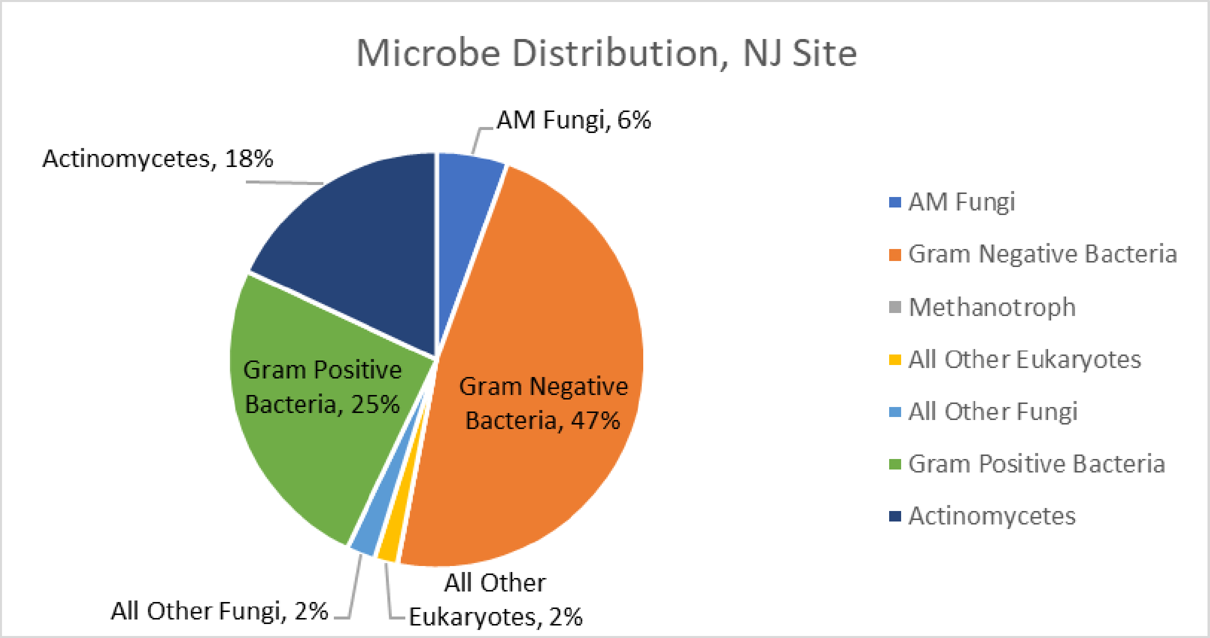
Pre-Plant Soil Diversity



Pre-Plant Soil Diversity



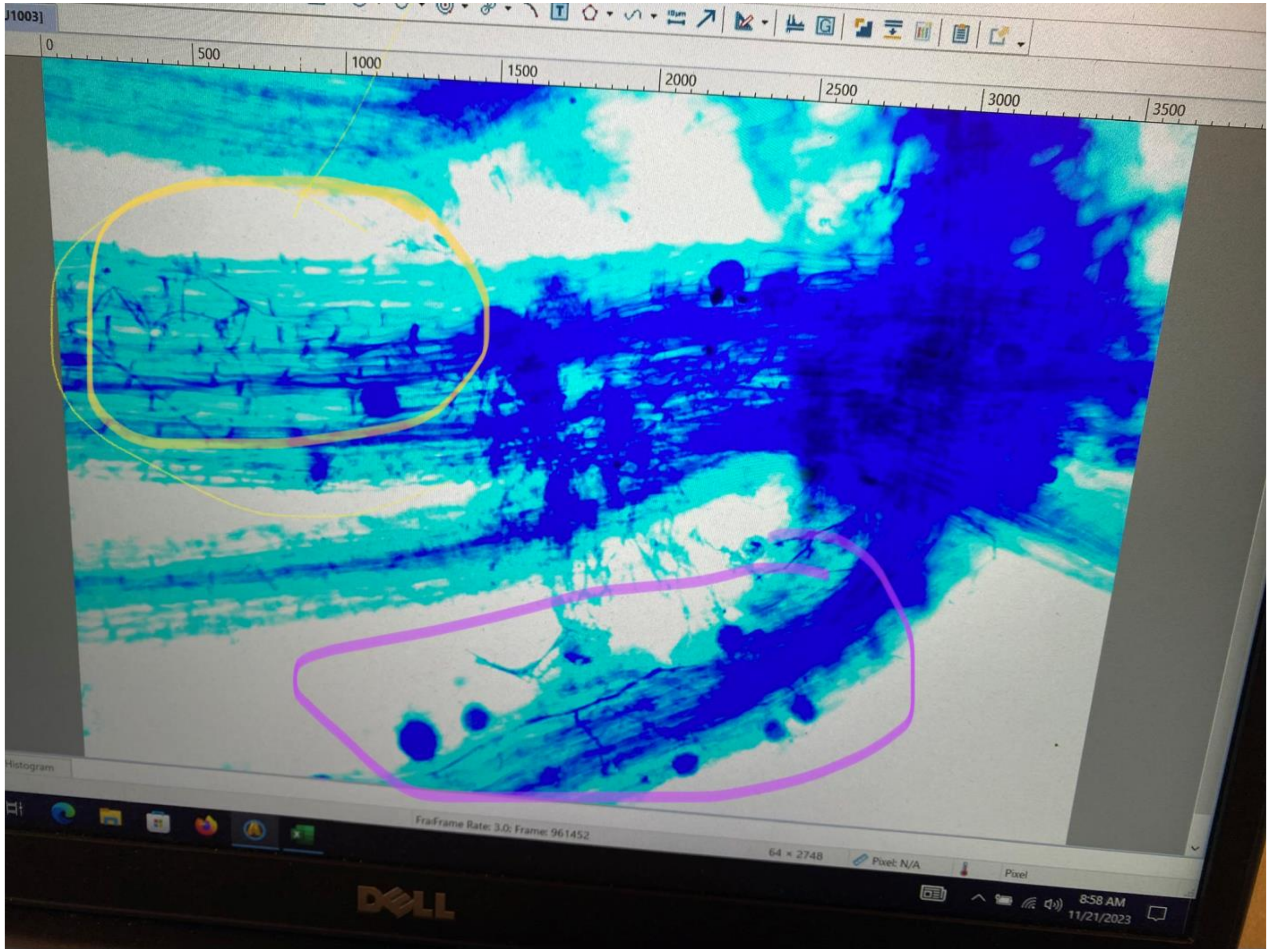




Tree Growth: June-Oct 2023

2023 Field Trial Trunk Circumference Growth (cm)				
		NY	**NJ**	**NH**
Fungi	Symvado	0.6 B	0.9	1.4
	MycoBloom	0.7 AB	0.9	1.5
	Mykos Gold	0.6 B	0.9	1.5
	Promate	0.9 A	1.0	1.5
	Control	0.7 AB	1.0	1.4
	P-value	**0.00382**	0.6076	0.87525
Fertility	Low	0.7	1.0	1.5
	High	0.7	0.9	1.4
	P-value	0.1382	0.2512	0.7481
Fungi x Fertility	**P-value**	0.6361	0.1098	0.4124

2023 Data Still Being Analyzed



Summer and Fall Water Use Efficiency Estimates

Root Colonization Assessments

In 2024, we will assess nutrient uptake with leaf analyses

Project continues through February 2026

2023 Greenhouse Studies

Objective: Examine the interaction between rootstock, scion, AMF treatment and applied stress on growth and performance

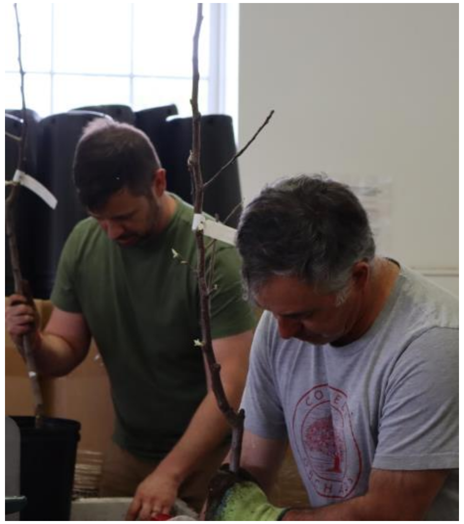
Design:

- Three stress treatments (Control, Drought, Low Phosphorus)
- Four AMF treatments (None, MycoApply, MykoBloom, MykosGold)
- Four rootstocks (B.9, M.9, G.41, G.935)
- Two scions (Aztec Fuji, Honeycrisp)
- Total trees = 480

Stomatal conductance and photosynthetic efficiency data throughout the experiment

Trunk diameter measurements

Water use efficiency testing, waiting on results from the lab, foliar testing in later years

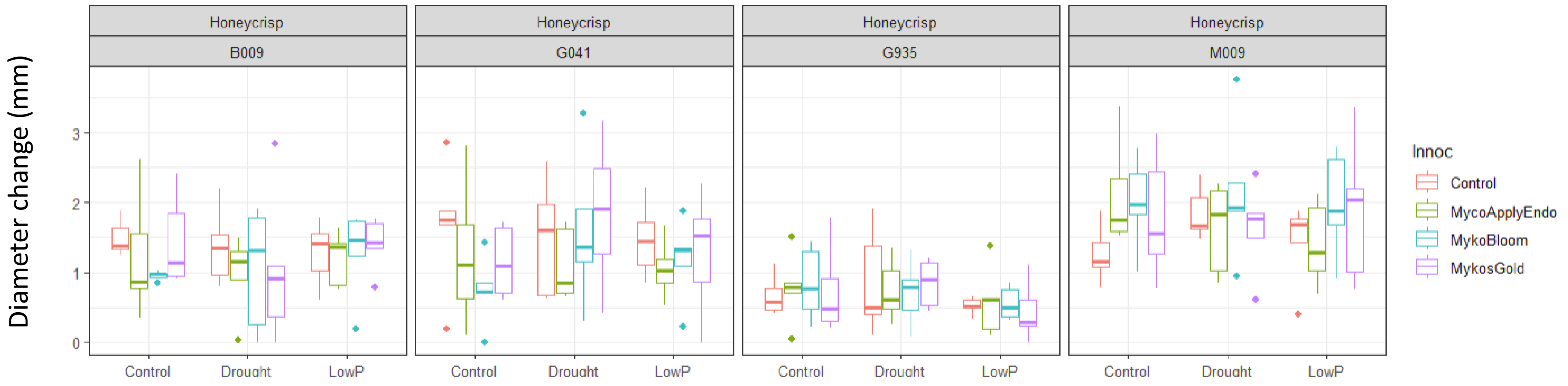


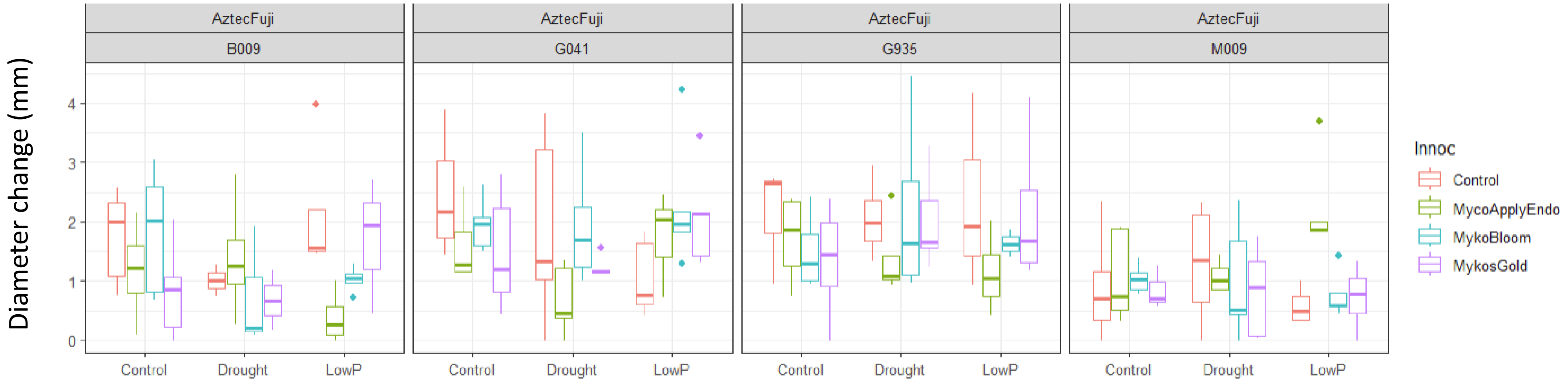

9
10
11
12

Trunk diameter change during the experiment

Data is messy and inconclusive. No significant effect of AMF treatment nor stress treatment detected.

Rootstock and Scion are significantly different





Stay in Touch

We will be hosting meetings on this topic this summer in Eastern and Western NY

More details to come!

Thank you!

Northeast SARE

Our research team:

Jason Londo, Megan Muehlbauer, Jeremy DeLisle, Mario Miranda-Sazo, Jenn Stanton, Liz Tee, Hannah Martens

Our cooperating orchards: Northern Orchard, Riamede Farm, Apple Hill Farm

Advisory member: Chris Whipple, Tedd Furber, Ely Giroux, Ben Keim, Steve Woods, Deborah Aller

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