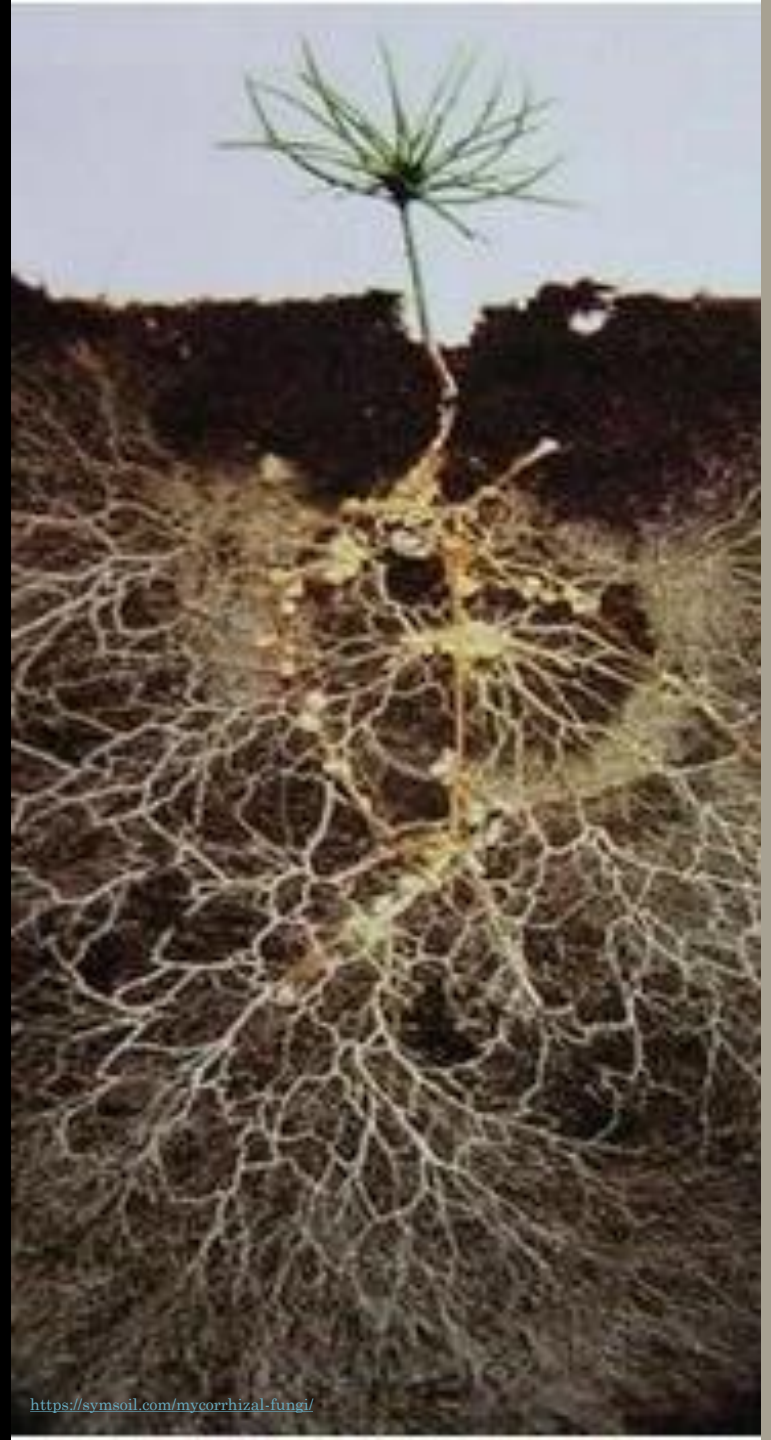
Effects of Mycorrhizal Colonization on Plant Health and Energy Content in Agricultural Setting

Magnolia Garbarino



https://symsoil.com/mycorrhizal-fungi/

Introduction

Mycorrhizal Fungi

Ectomycorrhizae
Do not penetrate root cells

Endomycorrhizae
Intracellular symbioses

Introduction

Arbuscular mycorrhizal fungi (AMF)

Symbiosis (mycorrhiza)

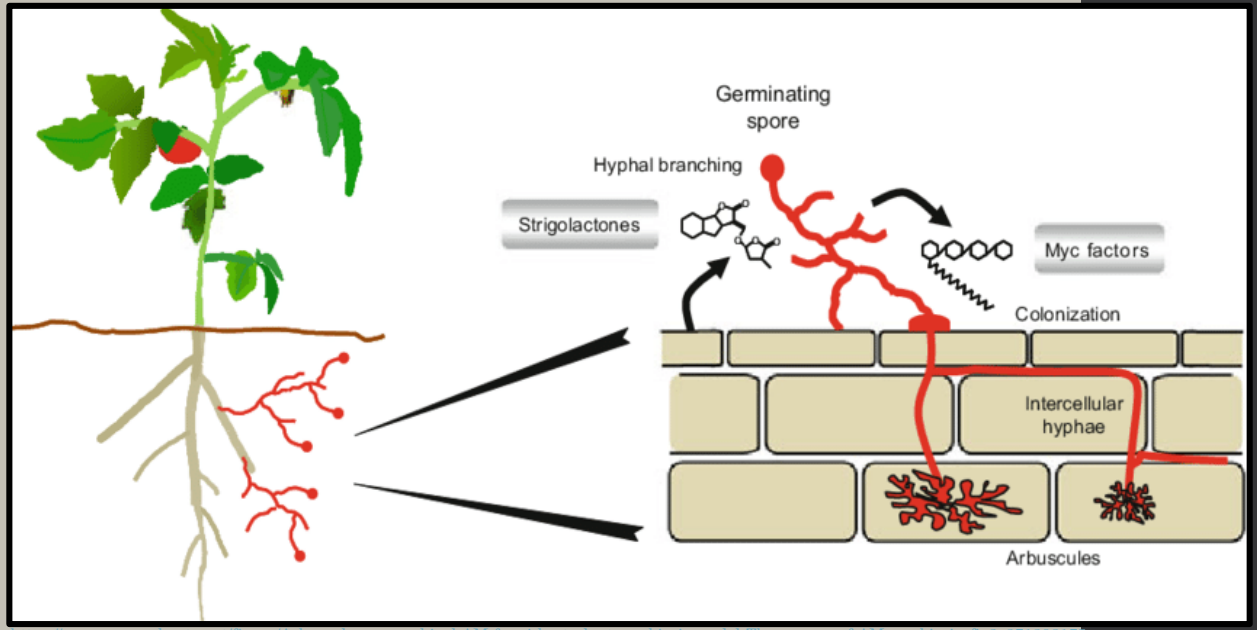
- 80% of vascular plants (1)
- Obligate symbionts (2)
- Mutual relationship
  - Carbon cycle

https://plantae.org/mycorrhizal-fungi-shaped-the-evolution-of-terrestrial-plants/

Introduction

Stages of Growth

1. Sporulation (Reproduction)
2. Hyphal growth (Development)
3. Host identification
4. Colonization



https://www.researchgate.net/figure/Arbuscular-mycorrhizal-AM-fungi-host-plant-symbiosis-model-The-process-of-AM-symbiosis_fig2_271208175

Introduction

Host identification

- Limited knowledge on mechanisms of identification

- Chemotaxis
  - Branching factor (BF) (3)
  - Myc factor (4)
  - Nod factor
  - Flavonoids (5)
    - Limitations (6)
  - Strigolactones (7)
  - Apocarotenoids (8)
  - Jasmonic Acid

Introduction

Stages of Growth

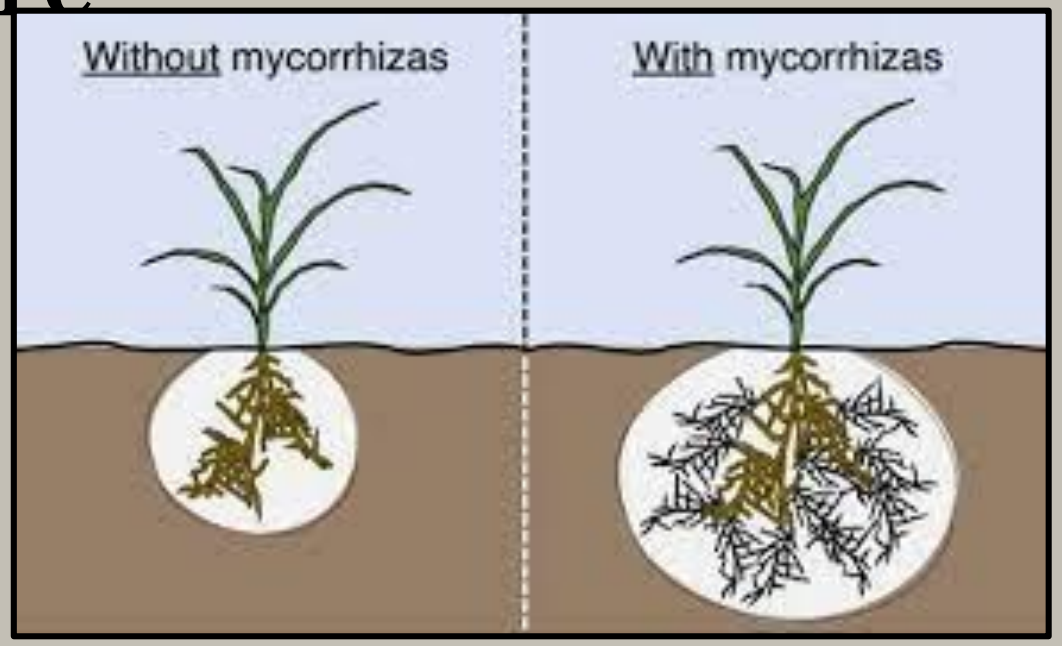
1. Sporulation
2. Hyphal growth
3. Host identification
4. Colonization

- Arbuscules
  - Paris Type
  - Arum Type
- Vesicles
- Appresoria
- Types of hyphae

Introduction

Mycorrhizae in agriculture

- Resilience to stressors (9)
  - Immune system
- Crop yield (10)
- Necessary fertilizer (11)
  - Potential biofertilizer (12)
- Conventional vs. organic agriculture



https://www.echocommunity.org/resources/2494c049-7310-4773-ad49-fe2699331125

Literature Review (Tawaraya et al. 2012)

- Limited phosphorus (P) resources
- AMF enhance P uptake

- **Purpose:** research the effects of AMF inoculation on *Allium fistulosum*
  - Less P fertilizer
  - Marketable yield

https://doraagri.com/mycorrhiza/

Literature Review (Tawaraya et al. 2012)

Methodology

Soil sterilized, necessary nutrients added, pH adjusted

AMF inoculum mixed into soil of ~½ *A. fistulosum* samples

Seedlings grown in greenhouse for 58 days, transferred to field

P fertilizer applied to plots (four concentrations ranging from 300 – 1,500 mg P_2O_5 kg soil^{-1})

Harvested 167 after sowing. Shoot length, diameter, dry mass, P concentration, AMF % colonization measured

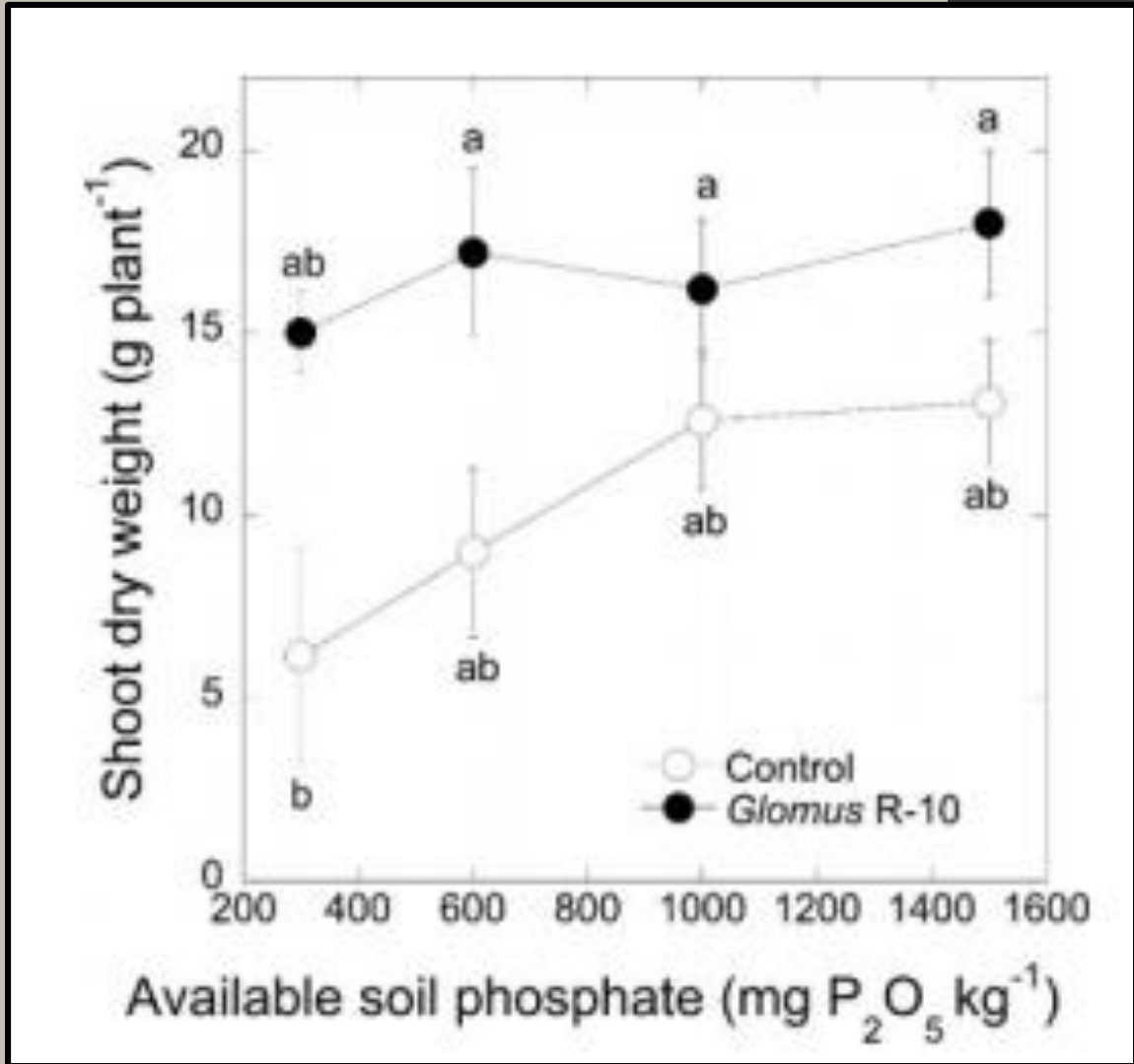
https://en.wikipedia.org/wiki/Allium_fistulosum

Literature Review (Tawaraya et al. 2012)

Results

- All measurements in non-inoculated plants increased with P treatments

Inoculated Plants	Non-inoculated Plants
No significant differences with P treatments	All factors greater among inoculated plants at some P_2O_5 concentrations



Literature Review (Tawaraya et al. 2012)

Table 1 Mycorrhizal colonization, shoot height, diameter of leaf sheath, and shoot P content grown at four soil P levels with or without inoculation

Inoculation	Soil P level (mg P_2O_5 kg^{-1})	Mycorrhizal colonization (%)	Shoot height (cm)	Diameter of leaf sheath (cm)	Shoot P content (mg P $plant^{-1}$)
Control	300	52±4 abc[a]	52.8±5.1 b	1.7±0.3 b	18±8 b
Control	600	47±5 abc	60.0±2.8 ab	2.0±0.2 ab	30±8 b
Control	1,000	27±7 bc	64.5±3.6 a	2.4±0.1 ab	40±7 ab
Control	1,500	18±9 c	70.5±7.6 a	2.5±0.1 a	41±4 ab
Glomus R-10	300	77±8 a	76.6±2.2 a	2.4±0.1 a	54±3 a
Glomus R-10	600	65±10 ab	77.1±2.9 a	2.5±0.1 a	63±8 a
Glomus R-10	1,000	66±5 ab	74.2±1.8 a	2.6±0.1 a	59±4 a
Glomus R-10	1,500	60±14 ab	78.2±2.5 a	2.7±0.0 a	67±4 a

[a] Means (±standard error, n=4) followed by different letters in the column are significantly (P=0.05) different as determined by the Tukey's HSD test

Literature Review (Minton et al. 2016)

Purpose: Measure effects of AMF

- Two *Solanum* species' defensive systems
- Growth of herbivores feeding on plants

Manduca sexta

https://i5k.nal.usda.gov/Manduca_sexta

Literature Review (Minton et al. 2016)

Methods

Solanum samples planted, some inoculated with AMF

→

Treated with Jasmonic Acid

→

Peroxidase (POD), polyphenol oxidases (PPO), protease inhibitors (PI) measured

↓

Experiment repeated, *M. Sexta* caterpillars allowed to feed on leaves. Mass measured

https://en.wikipedia.org/wiki/Solanum_ptychanthum

Literature Review (Minton et al. 2016)

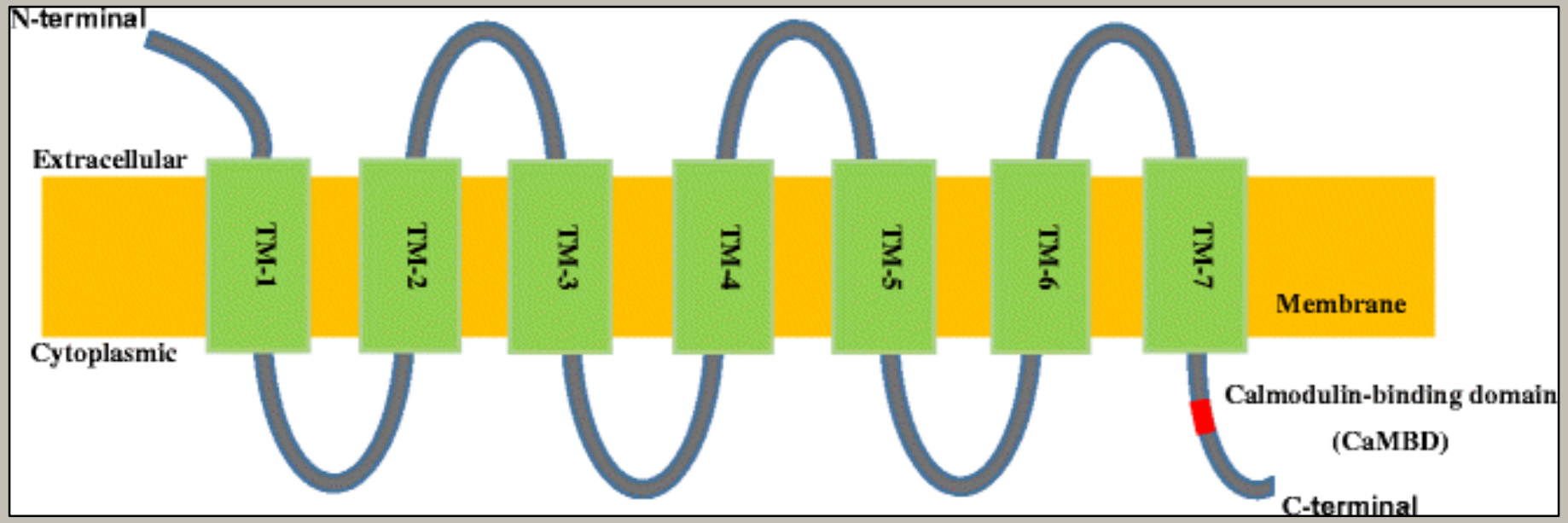
Results

- JA increased POD, but not PI
  - AMF colonization had no effect
- AMF/JA interactions significant for PPO and POD
- JA decreased *M. sexta* mass, but AMF had no effect

Solanum ptycanthum								
	POD		PPO		PI		Herbivore mass	
	χ^2	*P*	χ^2	*P*	χ^2	*P*	χ^2	*P*
JA	**3.88**	**0.049**	–	–	1.56	0.211	**10.96**	**< 0.001**
AMF	0.18	0.672	–	–	0.11	0.738	1.95	0.163
AMF × JA	1.56	0.212	–	–	1.90	0.168	2.57	0.109
Solanum dulcamara								
	POD		PPO		PI		Herbivore mass	
	χ^2	*P*	χ^2	*P*	χ^2	*P*	χ^2	*P*
JA	0.68	0.410	–	–	3.05	0.081	3.64	0.057
AMF	**7.56**	**0.006**	–	–	**4.83**	**0.028**	2.51	0.113
AMF × JA	2.98	0.085	**7.28**	**0.007**	1.96	0.161	2.54	0.111

Literature Review (Jacott et al. 2020)

Purpose: Investigate susceptibility factor *Mildew resistance locus o* (MLO) influence on emergence of AMF colonization



https://link.springer.com/article/10.1007/s10658-018-1454-3

Literature Review (Jacott et al. 2020)

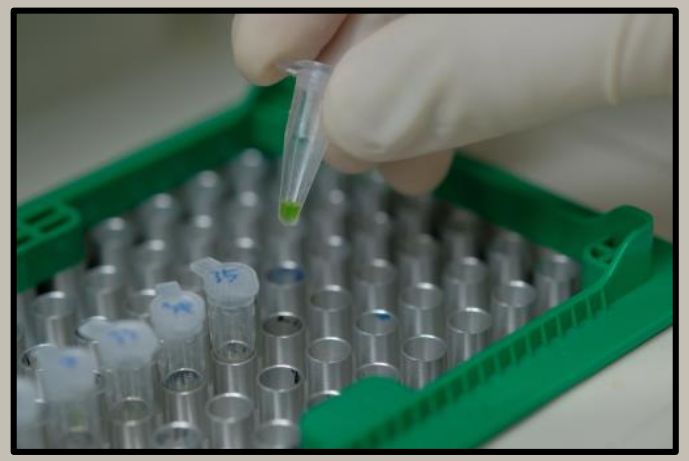
Methodolgy

MLO mutants identified and analyzed using PCR

Barley, wheat, and *Medicago truncatula* samples inoculated with AMF and MLO

Mycorrhizal colonization and mildew fungal structures measured

RT-qPCR used to analyze RNA from root tissue

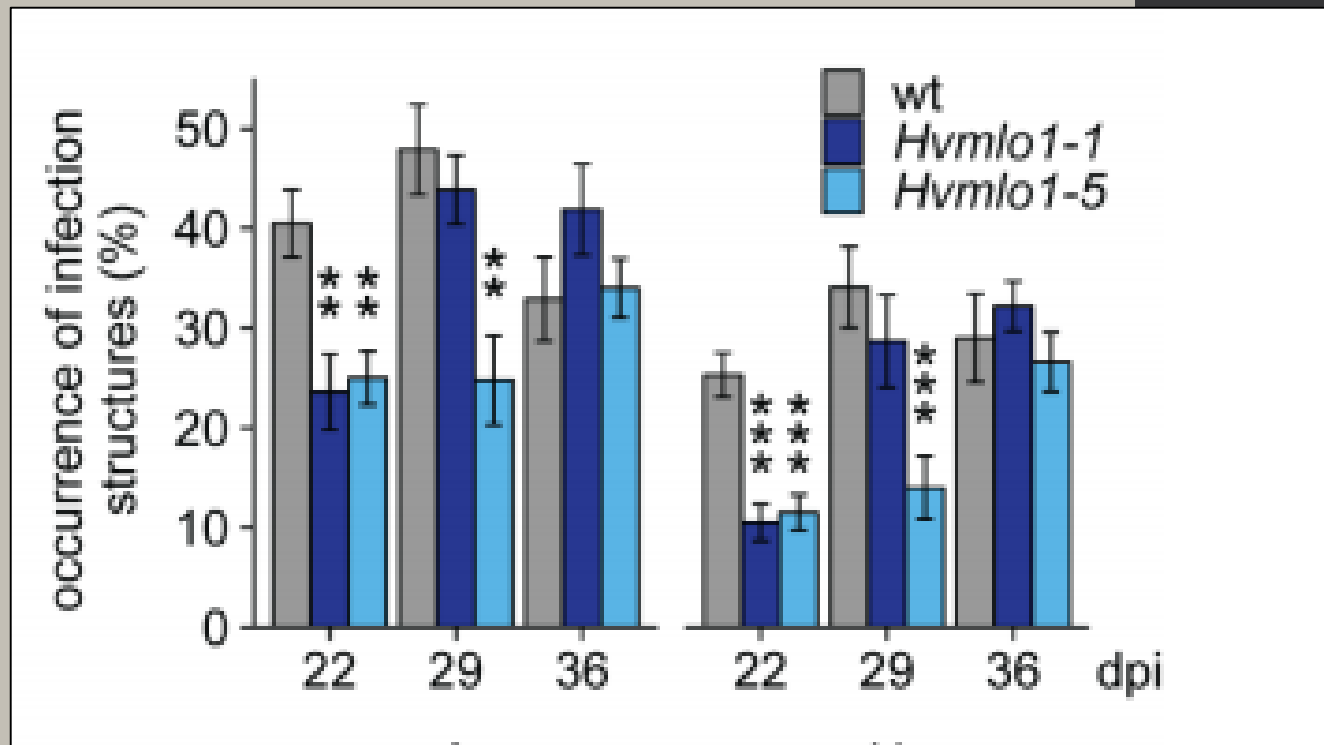


https://www.sigmaaldrich.com/technical-documents/protocols/biology/standard-pcr.html

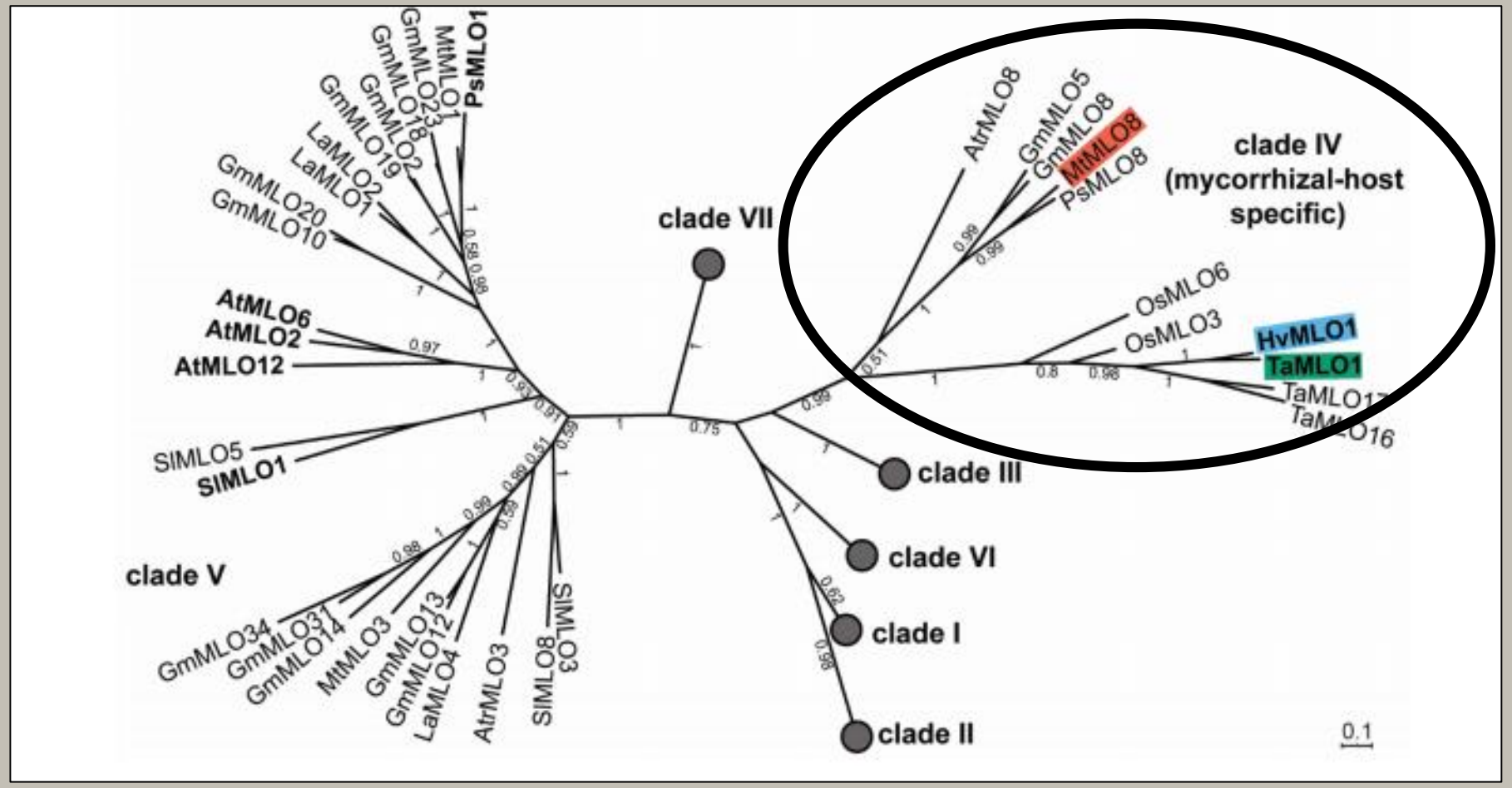
Literature Review (Jacott et al.)

Results

- MLO treated samples = less mycorrhizal colonization, evened out after ~1 month
- Genetic analysis suggests MLO necessary for colonization
- Possible evolutionary benefit in stimulating colonization



Literature Review (Jacott et al.)



Gap in Research

What effects can arbuscular mycorrhizal fungi have on plants' **nutrient density?**

https://www.foodsmart.com/blog/what-is-nutrient-density-and-does-it-matter

Problem Statement

How can **arbuscular mycorrhizal fungi** aid in the growth, development, nutrient acquisition, and **overall health** of plants grown in a **greenhouse** setting?

https://www.hobbyfarms.com/greenhouse-temperature-tools-perfect/

Hypothesis

AMF-treated plants will experience **far greater** yield, size, nutrient density, and general health than non-inoculated plants.

https://theconversation.com/when-plants-and-their-microbes-are-not-in-sync-the-results-can-be-disastrous-143802

Materials

- 120 [plant] seeds
- 600-1200g mycorrhizal inoculum
- Low P soil, sterilized (basaltic mixture OR peat moss/vermiculite)
- 40 6-12 inch flowerpots
- Low P, slow-release fertilizer

[Insert image of specific plant once chosen]

https://www.prairiemoon.com/prairie-moon-nursery-tool-shed-mycorrhizal-inoculum.html

Commercial powdered mycorrhizal inoculum

Methodology

Sterilize seeds with bleach (5-10 min)

Allow plants to germinate for [x days]

Fill 40 pots with sterilized soil; plant 3 seeds in each pot

Inoculate 30 samples with mycorrhizae (1 vol inoculum : 20 vol medium) post-germination; 10 control. Apply fertilizer

After 6 weeks, conduct analysis on roots to ensure colonization

Allow to grow for [x weeks]

Methodology

Measurements

- Wet and dry mass
- Leaf and fruit count
- Height
- Phosphorus and carbon levels
- Energy content

[Insert image of specific plant once chosen]

Past Results - Zhu et al. (2016)

Salinity [g kg^{-1}]	AMF status	Calorific value [kJ g^{-1}]
0	Non-AMF	17.36 ± 0.39^{b}
	R. irregularis	18.67 ± 0.44^{a}
	G. versiforme	18.21 ± 0.37^{a}
1.5	Non-AMF	16.61 ± 0.27^{c}
	R. irregularis	17.49 ± 0.34^{b}
	G. versiforme	17.28 ± 0.48^{b}
Significance		
Salinity		0.000^{**}
AMF		0.000^{**}
Salinity× AMF		0.464

Mycorrhizal colonization = **increased energy content**

Increased salinity = **decreased energy content**

Anticipated Results

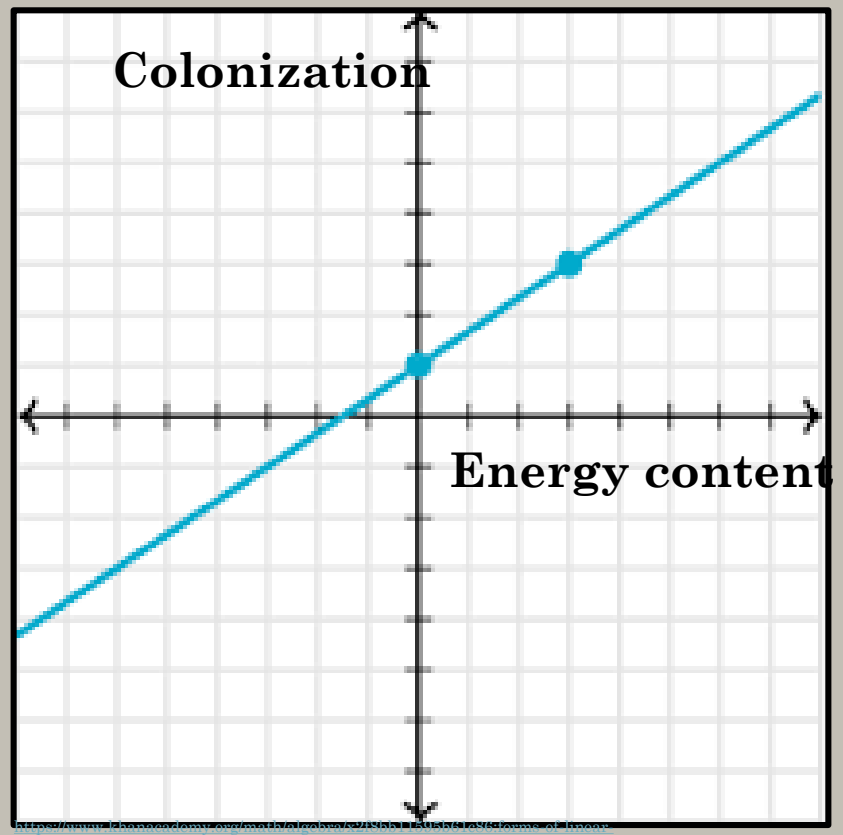
Colonization Results In:

- Increased height
- Greater fresh and dry weight
- Larger fruit count
- Greater P and C content

https://botanicalgarden.berkeley.edu/home-page-3/attachment/7-dealing-with-pests

Anticipated Results

Energy content **50% greater** with colonization



https://www.khanacademy.org/math/algebra/x2f8bb11595b61c86:lines-of-best-fit/x2f8bb11595b61c86:graphing-slope-intercept-equations/a/graphing-slope-intercept-form

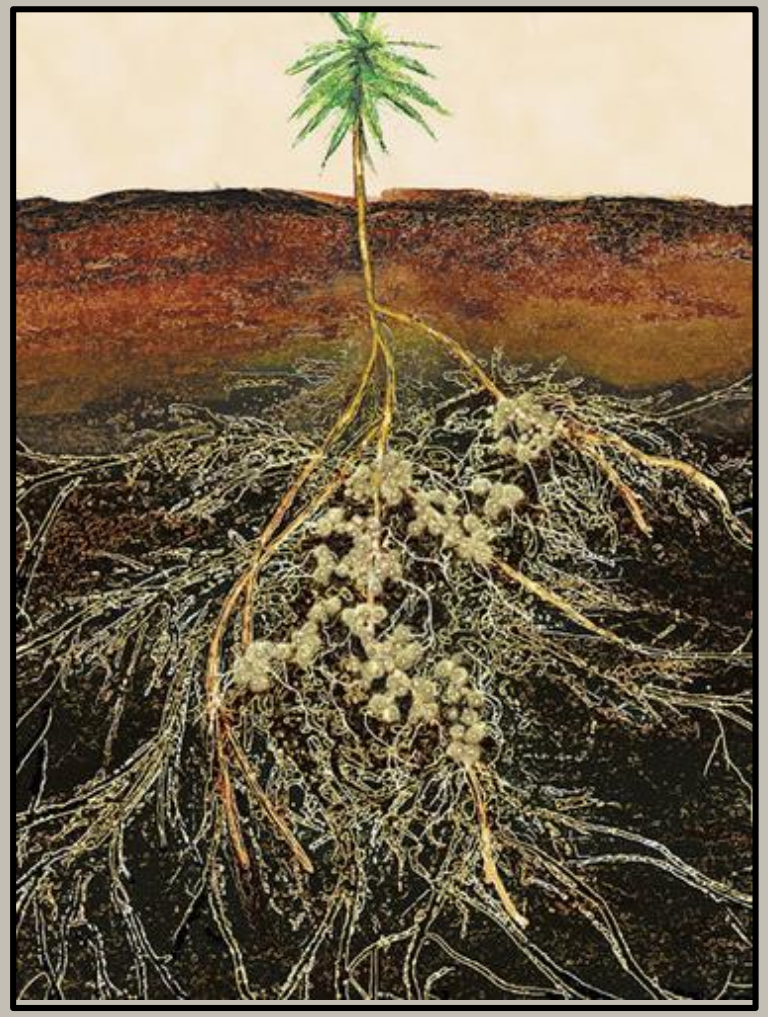
Discussion

https://www.easytogrowbulbs.com/blogs/plant-care/importance-of-healthy-roots

Connection to Literature

- Increased macro/micronutrient content in roots (13)
- Increased carbon content – photosynthetic ability (14)
  - Greater energy content (15)
- Increased solar energy acquisition (16)

Discussion



https://www.finegardening.com/article/mycorrhizae-help-feed-your-plants

Connection to Literature - Colonization and Plant Development

- Fruit count and plant health (17)
- Colonized plant reproduction (18)
- Immune/defense systems (19)
- Interplant interactions (20)

Discussion

Implications

- Use in agriculture
  - Organic and Conventional (17)
- Cost efficacy (12)
  - Potential in developing nations

https://greentumble.com/pros-and-cons-of-using-agricultural-fertilizers/

Discussion

https://mijarceurope.net/2020/06/12/growing-vegetables-fields-or-greenhouses/

Limitations

- Highly **regulated** setting
  - May **differ** in field
- **Other indicators** of health
  - Chlorophyll content
- **Single** fungal morphotype

Future Research

Quantifying effects of mycorrhizal colonization on field-grown [plant]

Potential efficacy of mycorrhizal inoculum as pesticide

[Plant] growth and development under adverse conditions (salinity, high phosphorus, etc.)

[Insert image of specific plant once chosen]