Soil solarization effects on plant growth variables of field-grown tree saplings

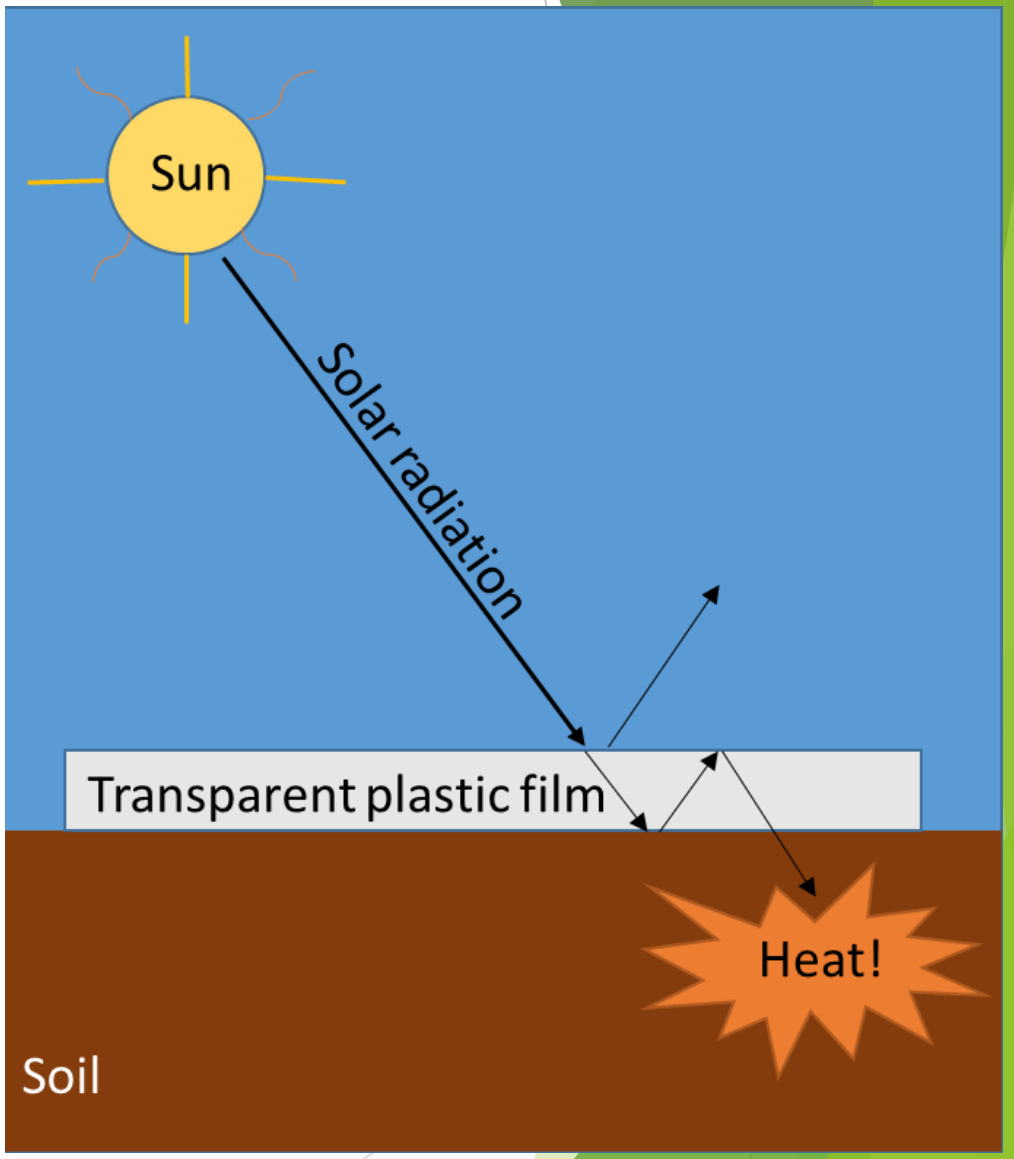
Simon Fraher, Joyce Eberhart, Jennifer Parke, PhD

Department of BioResource Research, Oregon State University, Corvallis, Oregon
Department of Crop and Soil Science, Oregon State University, Corvallis, Oregon

Introduction

What is solarization?

- Control soil environment
  - Chemical, biological, and physical changes
  - Direct thermal lethality on soil pests, pathogens
- First in Israel, now in over 60 countries
  - Many developing countries
  - Organic agriculture
- Most effective at surface
  - Temperature gradient established in soil
- Soil stores thermal energy



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Type of Plastic Matters

- Opaque blocks like a mulch
  - Hot surface, like a stovetop
- Clear kills
  - Heat penetrates soil, more like an oven
  - Light can allow for photosynthesis

http://2.bp.blogspot.com/-QQpTp5VYeqo/TcW3v1UeVEI/AAAAAAAAAW8/_RQSuOLBfH8/s1600/DSCF1327.JPG

Clear vs. AC Plastic

- Clear vs. anti-condensing (AC) plastic
  - AC plastic appears clear
  - Clear plastic appears opaque

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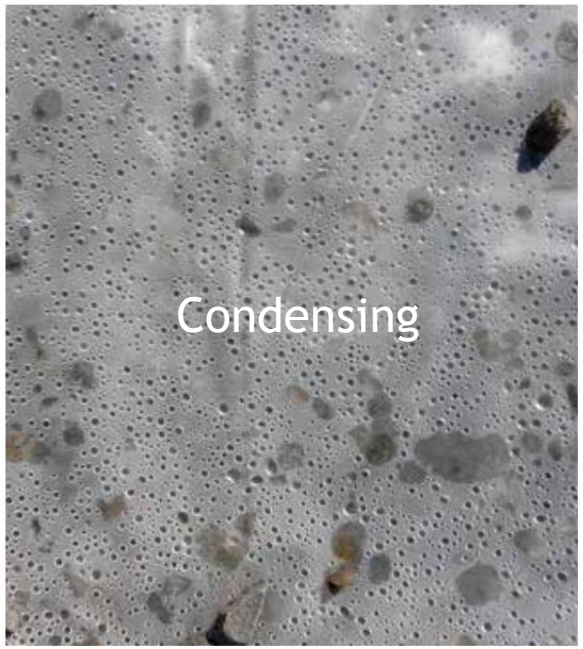

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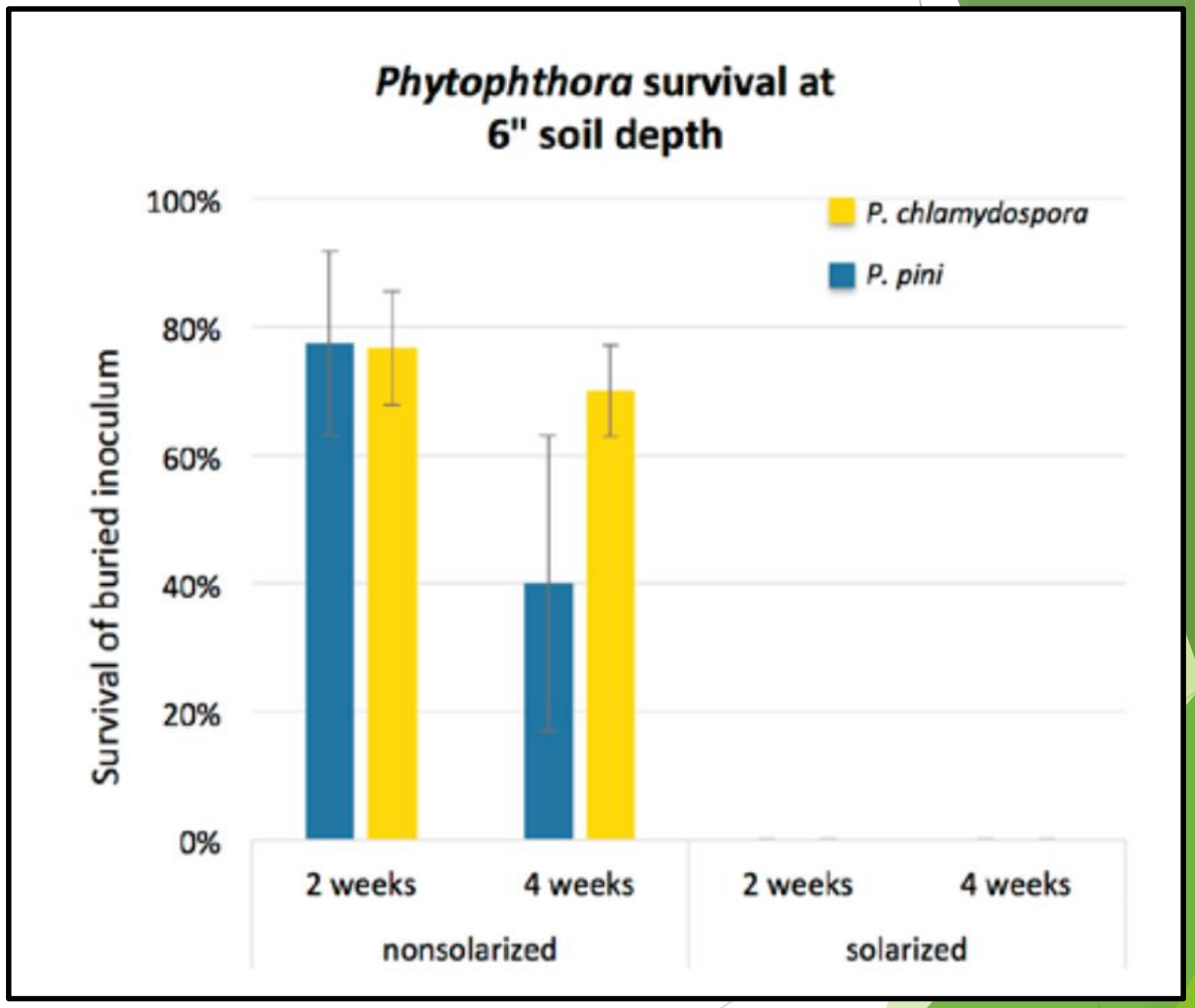
Results of Solarization

- Pathogen control
  - Like pasteurization
    - NOT sterilization
- Temperature kills
  - 140˚F for X weeks
    - Depends on climate, latitude
  - Diurnal fluctuations



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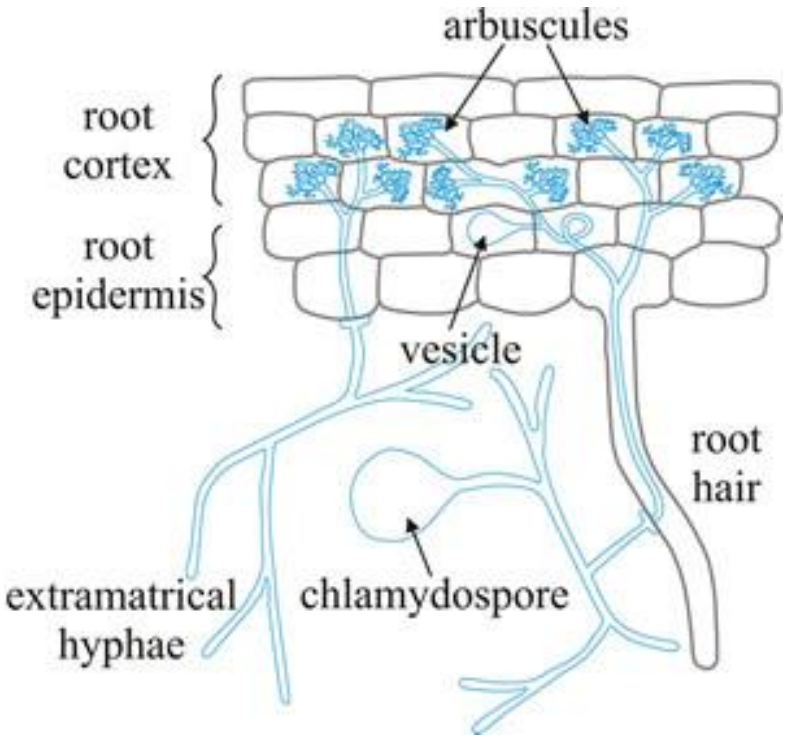
Many fungi are beneficial

- Ectomycorrhizae
- Endomycorrhizae
  - Arbuscular mycorrhizal fungi (AMF)



http://www.davidmoore.org.uk/assets/mostly_mycology/diane_howarth/images/arbuscular_mycorrhiza.png

http://tropicalfungi.org/wp-content/uploads/Freshly-harvested-boletoid-ectomycorrhizae-from-Pakaraimaea-dipterocarpacea.jpg

Traditional Weed and Pathogen Controls

- Fumigation
  - Dangerous
  - Legality
    - Methyl bromide banned 2005
- Pesticides/Herbicides
  - Public perception
  - Organic
- Hand-picking weeds
  - Labor = 70% of farm costs
- Steaming
  - Costly energy usage

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Costs

- Herbicides: $900 - $3400 per acre annually
  - Weeds
- Hand weeding: $900 - $3400 per acre annually
  - Weeds
- Fumigation: $1100 – $2000 per acre annually
  - Pathogens, some weeds
- Soil solarization: $330 - $491 per acre annually
  - Weeds AND pathogens
- Some of these may negatively affect AMF colonization

Nonsolarized

Solarized

J. Frank Schmidt Nursery (JFS)

- Ornamental tree nursery in Boring, OR
- Early adopters
  - Acres under solarized treatment
- Pilot study
  - Assess cost, viability
- Pathogens and weeds
  - Major problem, take a proactive approach
  - Hand-weeding

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Steps in Field Application

- Till, add amendments
- Damp soil is darker, stores heat
- Apply spring/summer
- Bury edges to seal
  - This project done by hand
- Wait 6 - 8 weeks
- Remove plastic and plant

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Considerations

- Competition with growing season
  - Better than getting shut own
- Waste plastic
  - Can recycle in Willamette Valley
- What if it kills beneficial stuff?
  - This is a special treatment
  - Can re-inoculate
  - Nutrients

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Objective:

- Solarization
  - Known to be effective in controlling pathogens
- What effect does it have on subsequent plantings?
  - Specifically biomass, length, and mycorrhizal colonization

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Methodology

(45°25'31.1"N 122°19'20.6"W)

Sam Doane, JFS 2014

Sam Doane, JFS 2014

Field Methods

- 12 rows, standard practices
  - Fertilize, till, mound
  - Nonsolar mounded after plastic removed and treated with glyphosate
- 2 possible treatments (6 rows each)
  - Solarization
  - Nonsolarized control (no plastic)
- Allow 6 - 8 weeks pass
  - 7/22/14 - 9/11/14
    - 7wk, 2d

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Field Methods

- Solarization plastic removed
  - Balled and recycled
- Three species planted from seed
  - Hawthorn – *Crataegus monogyna*
  - Mazzard Cherry – *Prunus avium*
  - Red Oak – *Quercus rubra*
- Harvest methods
  - Early season 6/23/15
  - Late season 9/10/15

Red oak (*Quercus rubra*) seedlings

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Plant Preparation

- Shoots
  - Plants washed, measured, and cut
  - Shoot length: lowest bud to the apical meristem
    - To the nearest 0.5 cm
- Roots
  - Rinsed, gently shaken dry
  - Put in moist bags to keep separate
  - Set aside for AMF/ECM
- Drying oven 48hr at 50°C

Lab Methods

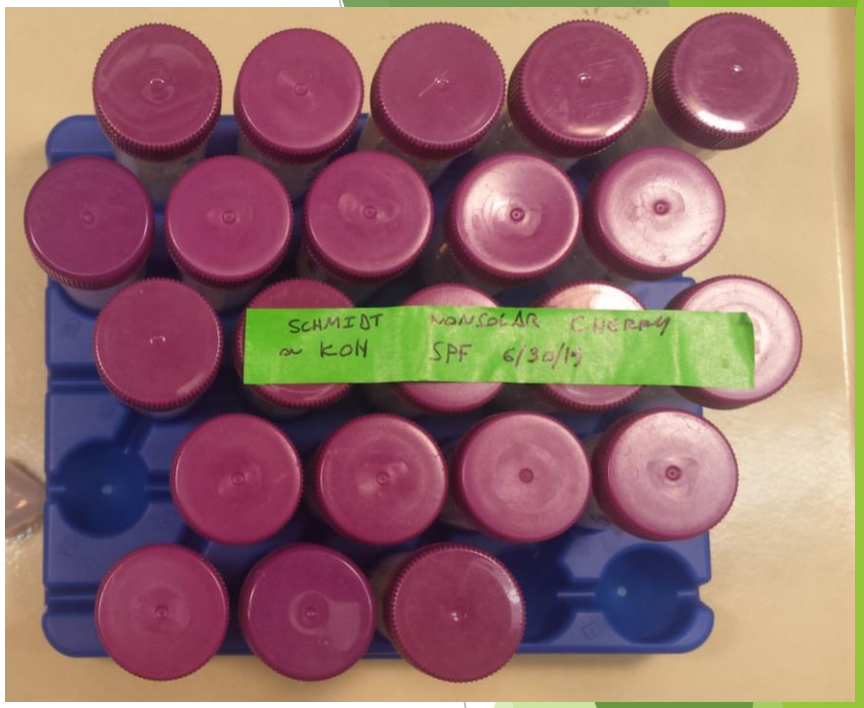
- AMF colonization assessment (cherry, hawthorn)
- Ectomycorrhizae (red oak)
  - Microscopy – no stain
- Both assessments done only on early harvests

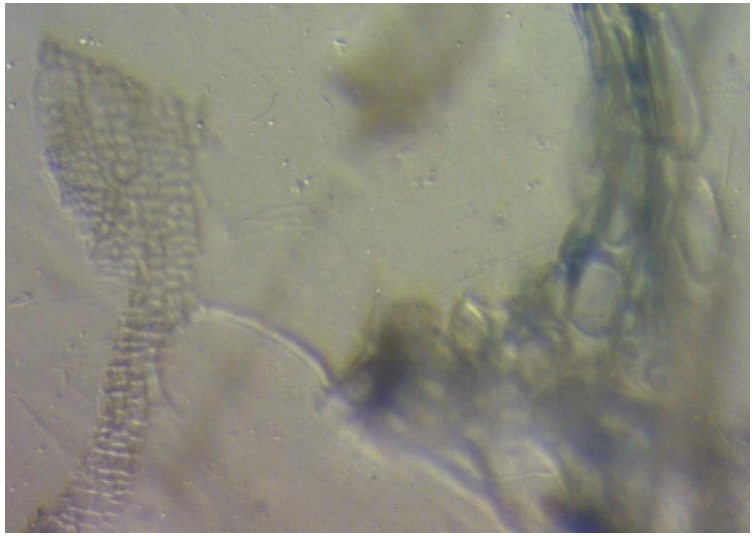
Mycorrhizae on nonsolarized oak

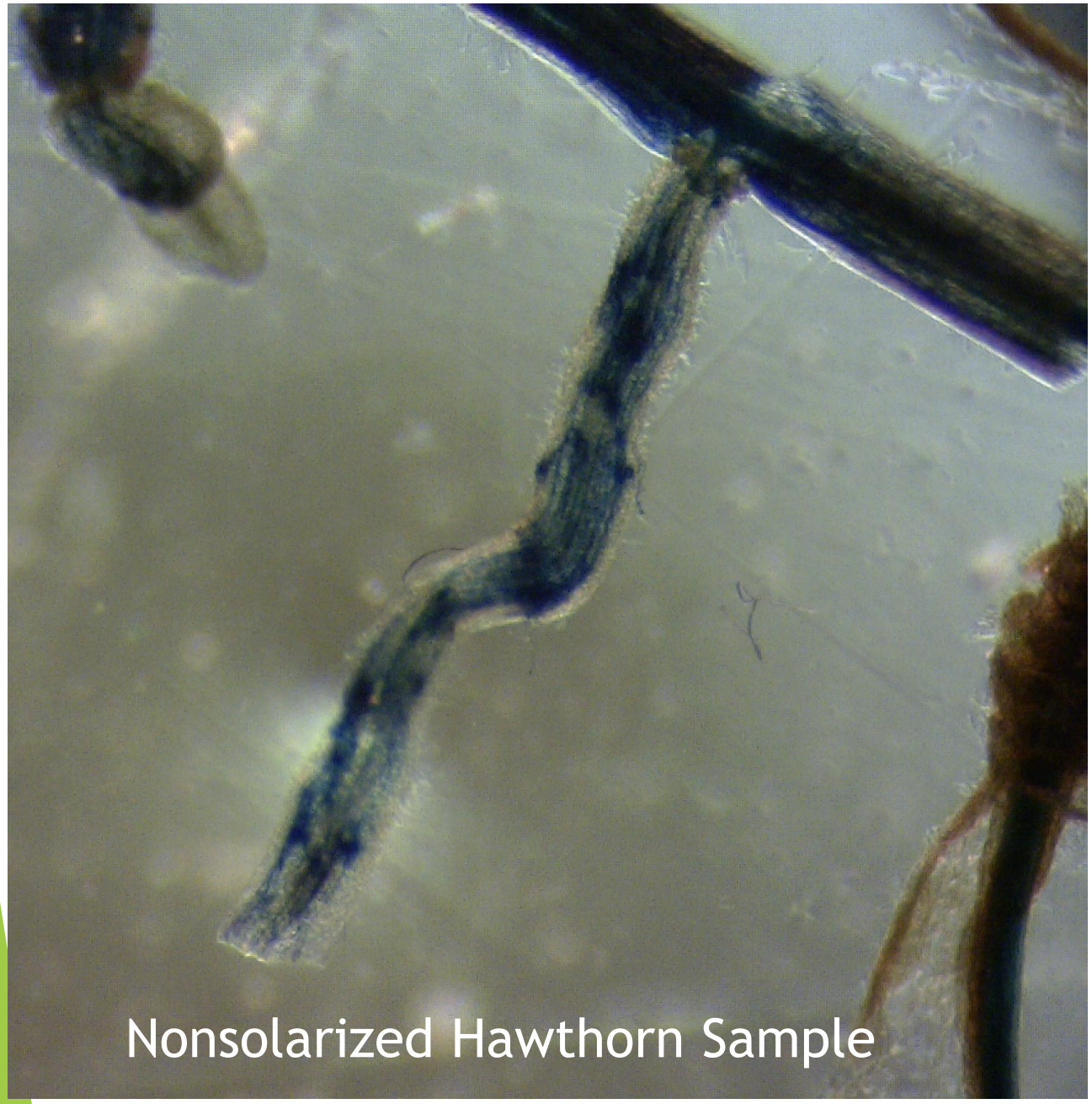
Joyce Eberhart

Clearing and Staining

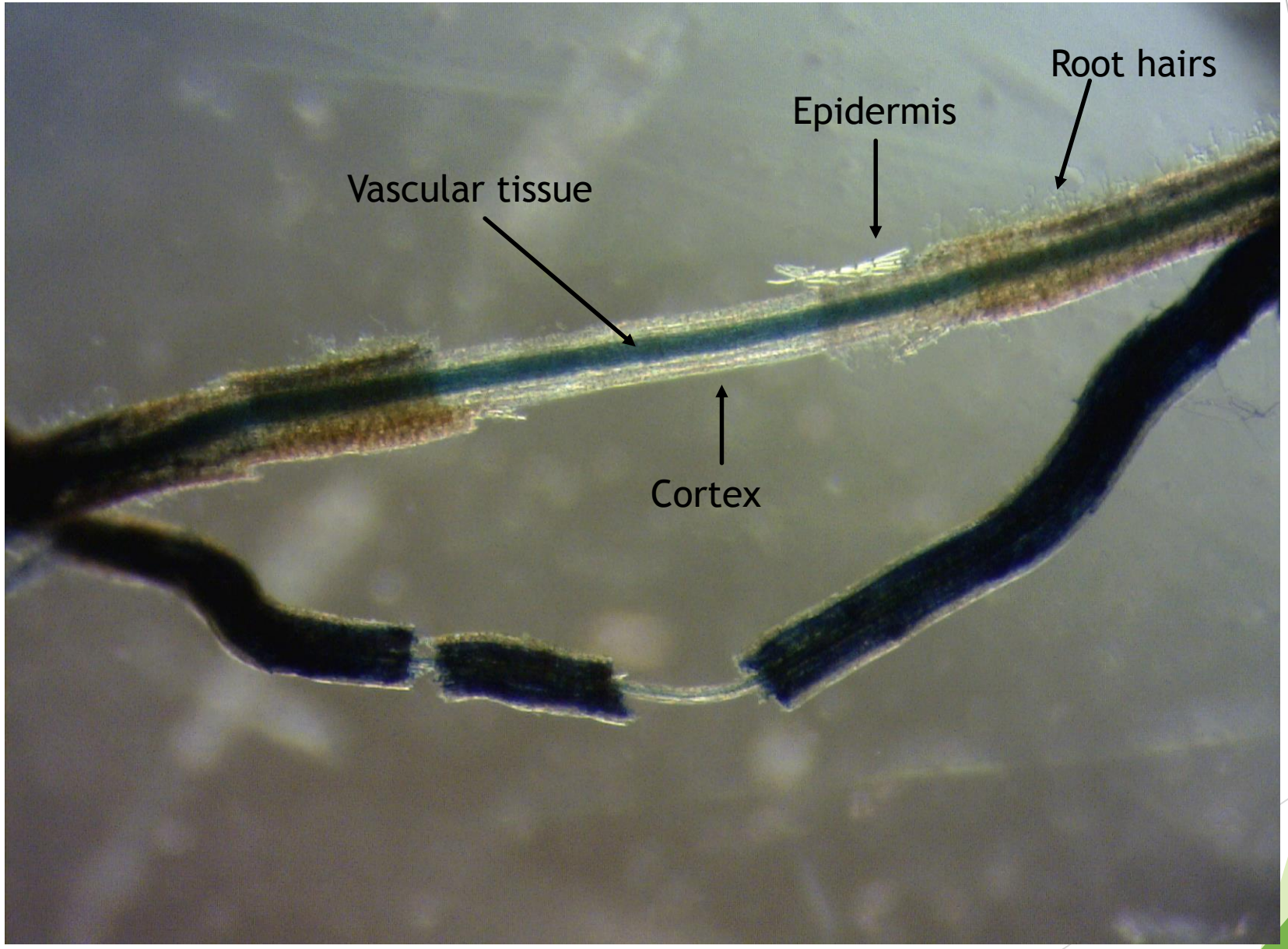
- Modified protocol: Phillips and Hayman 1970
- KOH + heat = pigment removed from roots
  - (Alkali soluble compounds come out)
- Rinse with tap water
- HCl + heat = more “stuff” removed
- Add stain + lactoglycerol





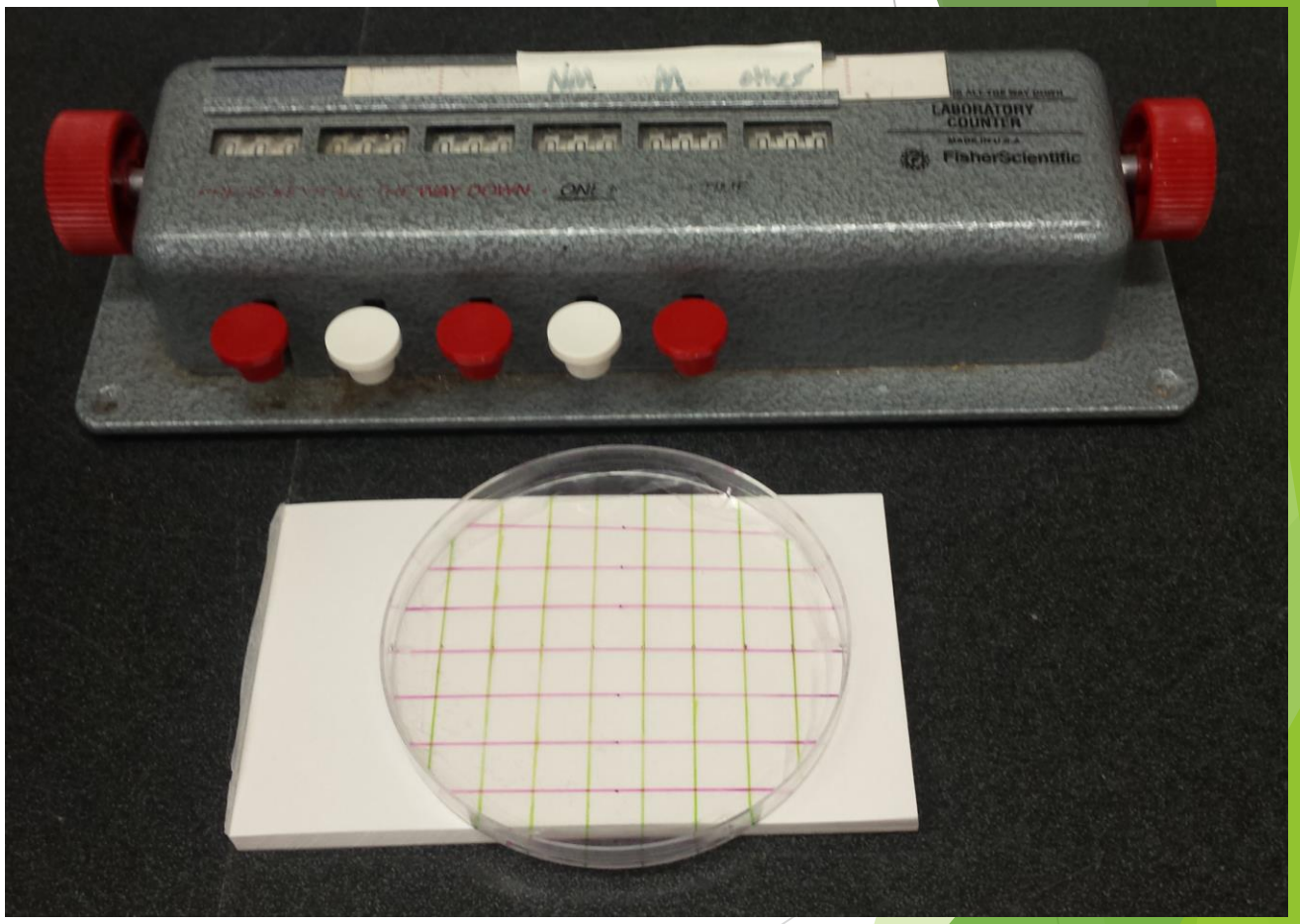

Nonsolarized Hawthorn Sample


Solarized Cherry Sample


Root hairs
Epidermis
Vascular tissue
Cortex

Grid-Line Intersect

- Giovanetti and Mosse, 1980
- 1cm grid
- Count to 100
  - Percent of root intercepts with AMF associations



T-test

- All data were run through 1-way t-tests to form the following graphs
- Significance determined by P < 0.05

Mazzard Cherry 6/23/15

Shoot Length

Source of Variation	SS	df	MS	F	P-value
Between Groups	2067.25	1.00	2067.25	21.25	<0.001
Within Groups	4669.70	48.00	97.29		
Total	6736.95	49.00			

Shoot Dry Mass

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.00	1.00	0.00	0.00	0.99
Within Groups	236.61	98.00	2.41		
Total	236.61	99.00			

Root Dry Mass

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.00	1.00	0.00	0.00	1.00
Within Groups	43.85	98.00	0.45		
Total	43.85	99.00			

Red Oak 6/23/15

Shoot Length

Source of Variation	SS	df	MS	F	P-value
Between Groups	28.13	1.00	28.13	0.91	0.34
Within Groups	1484.00	48.00	30.92		
Total	1512.13	49.00			

Shoot Dry Mass

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.24	1.00	0.24	0.21	0.65
Within Groups	110.90	97.00	1.14		
Total	111.14	98.00			

Root Dry Mass

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.23	1.00	0.23	0.97	0.33
Within Groups	22.98	97.00	0.24		
Total	23.21	98.00			

Hawthorn 6/23/15

Shoot Length

Source of Variation	SS	df	MS	F	P-value
Source of Variation	1415.12	1.00	1415.12	59.57	<0.001
Within Groups	1140.36	48.00	23.76		
Total	2555.48	49.00			

Shoot Dry Mass

Source of Variation	SS	df	MS	F	P-value
Between Groups	13.30	1.00	13.30	37.83	<0.001
Within Groups	34.45	98.00	0.35		
Total	47.74	99.00			

Root Dry Mass

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.40	1.00	0.40	5.69	0.02
Within Groups	6.84	98.00	0.07		
Total	7.23	99.00			

Mazzard Cherry 9/10/15

Shoot Length

Source of Variation	SS	df	MS	F	P-value
Between Groups	1726.40	1.00	1726.40	1.57	0.21
Within Groups	107547.85	98.00	1097.43		
Total	109274.25	99.00			

Shoot Dry Mass

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.36	1.00	0.36	0.00	0.97
Within Groups	21681.00	97.00	223.52		
Total	21681.36	98.00			

Root Dry Mass

Source of Variation	SS	df	MS	F	P-value
Between Groups	NA	NA	NA	NA	NA
Within Groups	NA	NA	NA		
Total	NA	NA			

Red Oak 9/10/15

Shoot Length

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	930.25	1.00	930.25	2.55	0.11
Within Groups	35714.61	98.00	364.43		
Total	36644.86	99.00			

Shoot Dry Mass

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	13.16	1.00	13.16	0.12	0.73
Within Groups	10858.47	98.00	110.80		
Total	10871.63	99.00			

Root Dry Mass

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	1.57	1.00	1.57	0.03	0.87
Within Groups	5801.63	98.00	59.20		
Total	5803.21	99.00			

Hawthorn 9/10/15

Shoot Length

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	10652.19	1.00	10652.19	25.81	<0.001
Within Groups	40041.10	97.00	412.79		
Total	50693.29	98.00			

Shoot Dry Mass

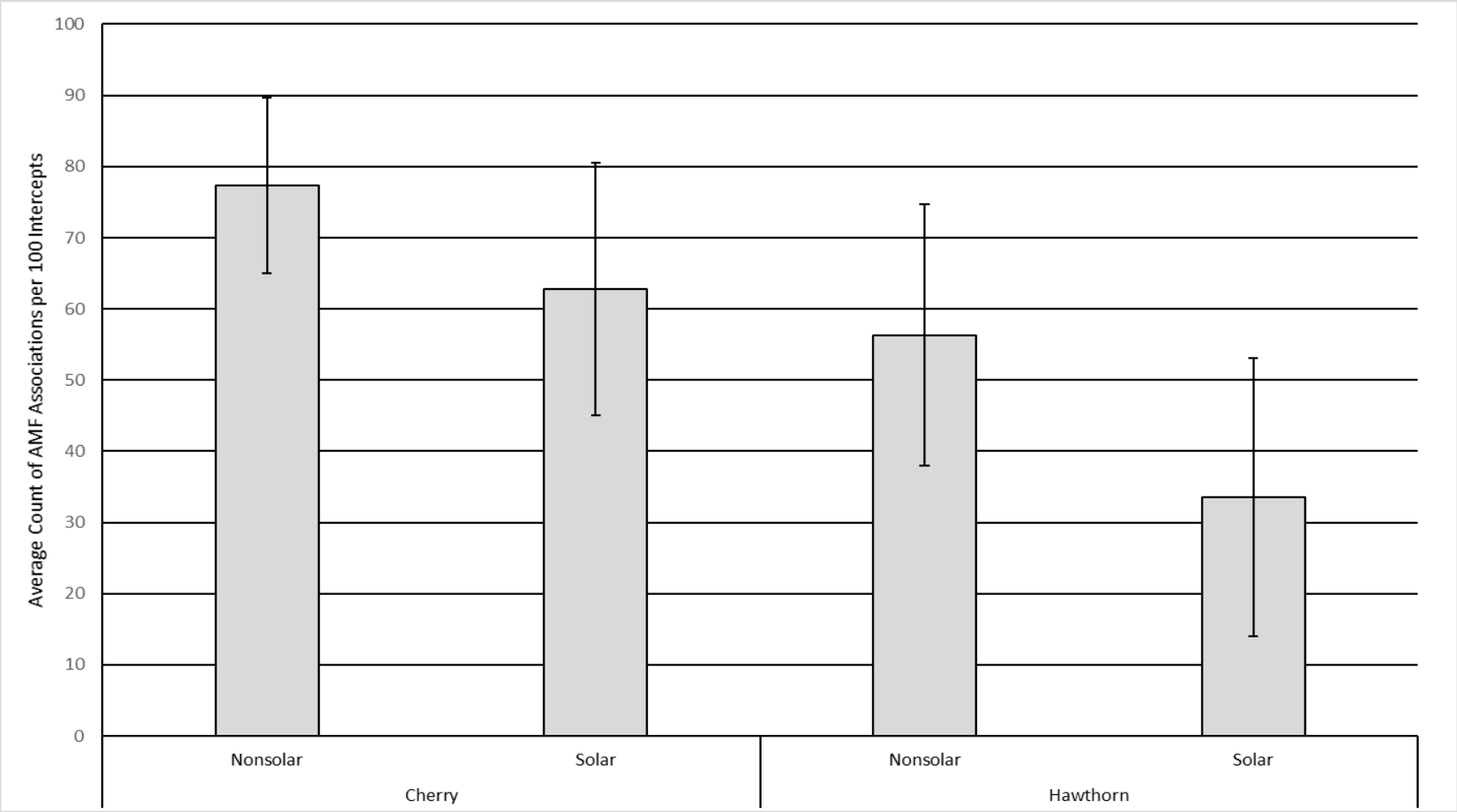
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	553.68	1.00	553.68	16.40	<0.001
Within Groups	3308.26	98.00	33.76		
Total	3861.94	99.00			

Root Dry Mass

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Between Groups	37.51	1.00	37.51	6.44	0.01
Within Groups	570.57	98.00	5.82		
Total	608.08	99.00			

Results

Mean mycorrhizal associations per 100 intercepts, hawthorn and cherry, 6-23-15



All differences between nonsolar and solar treatments showed significance ($P < 0.05$). Error bars represent standard deviations.

Ectomycorrhizae

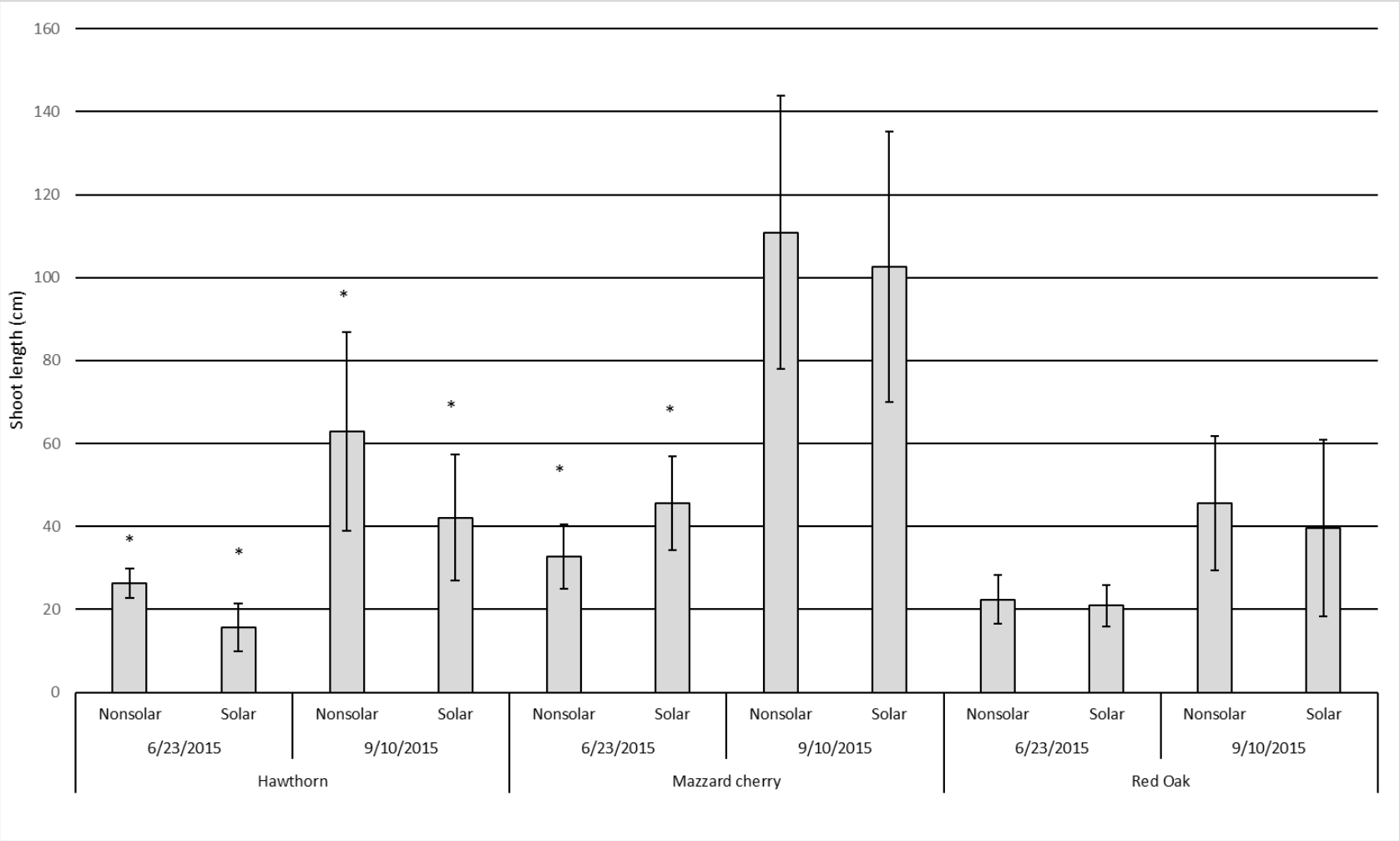
- Very few instances observed
- Not enough data to graph
  - Certainly consider further experiment

Joyce Eberhart

Non-solarized#20 oak root

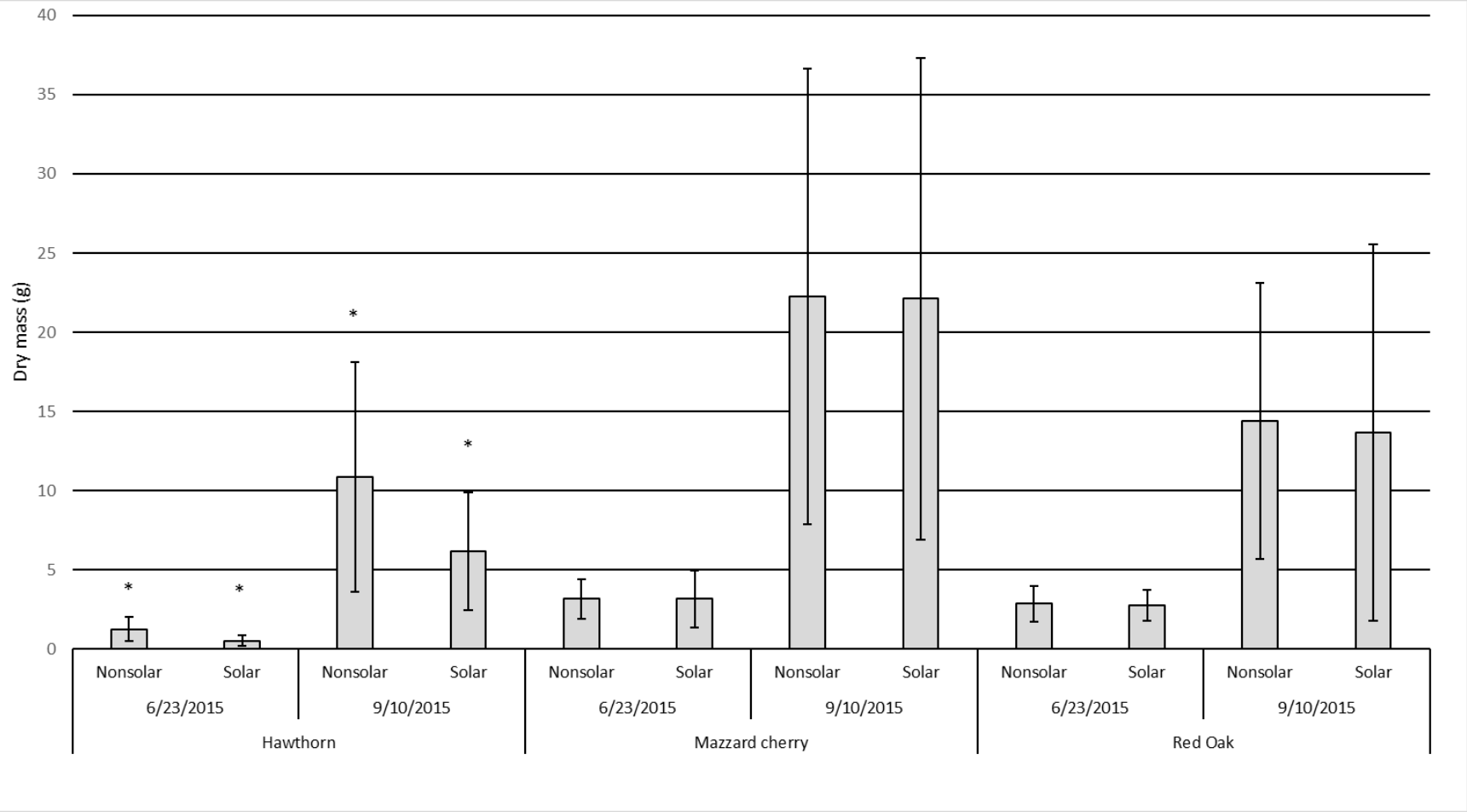
Joyce Eberhart

Mean shoot length



Starred bars (*) showed significant differences between nonsolar and solar treatments (P < 0.05). Error bars represent standard deviations.

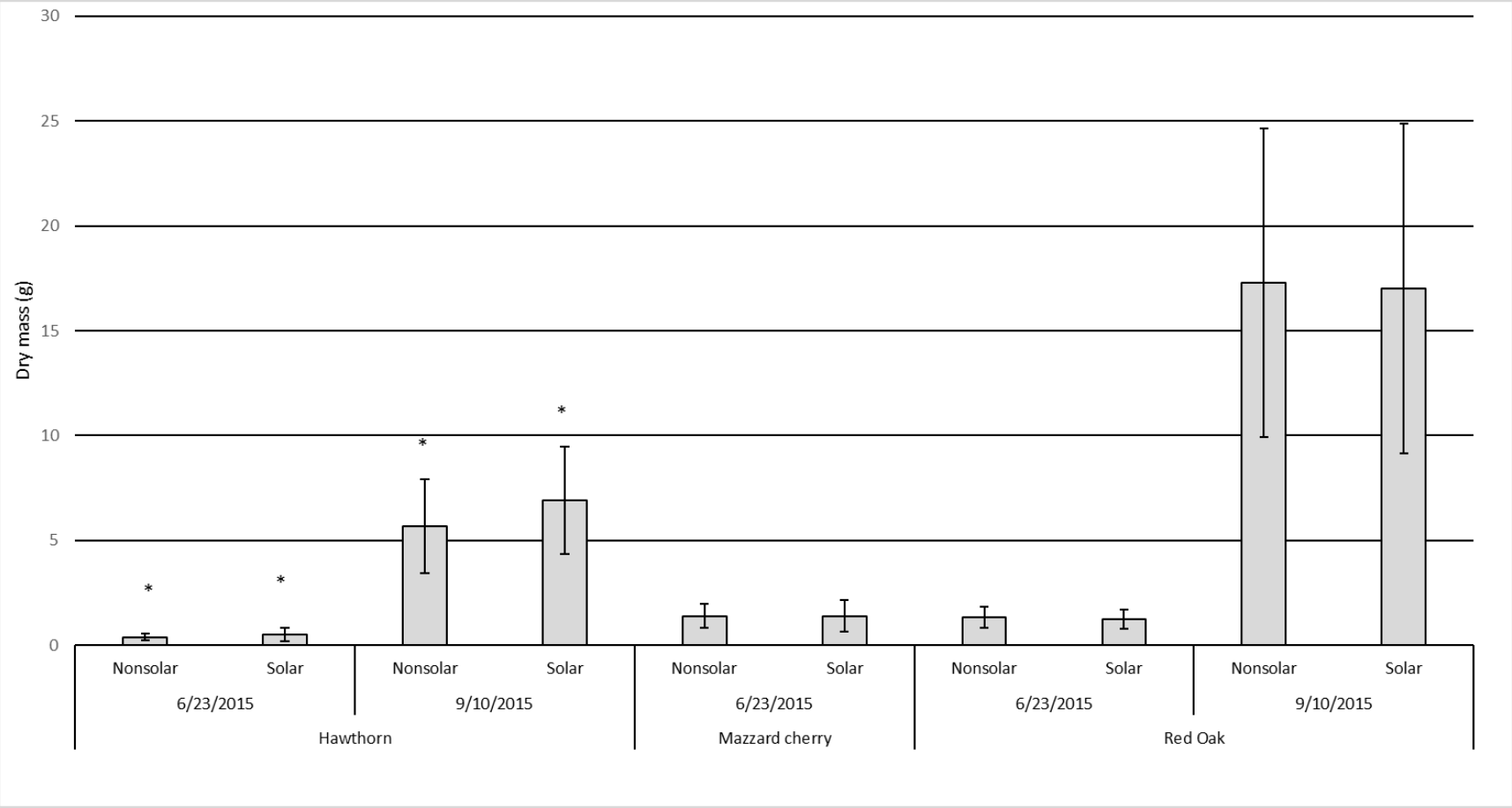
Mean shoot biomass



Starred bars (*) showed significant differences between nonsolar and solar treatments ($P < 0.05$). Error bars represent standard deviations.

Mean root biomass

There were no data collected for Mazzard cherry roots on 9/10/15.

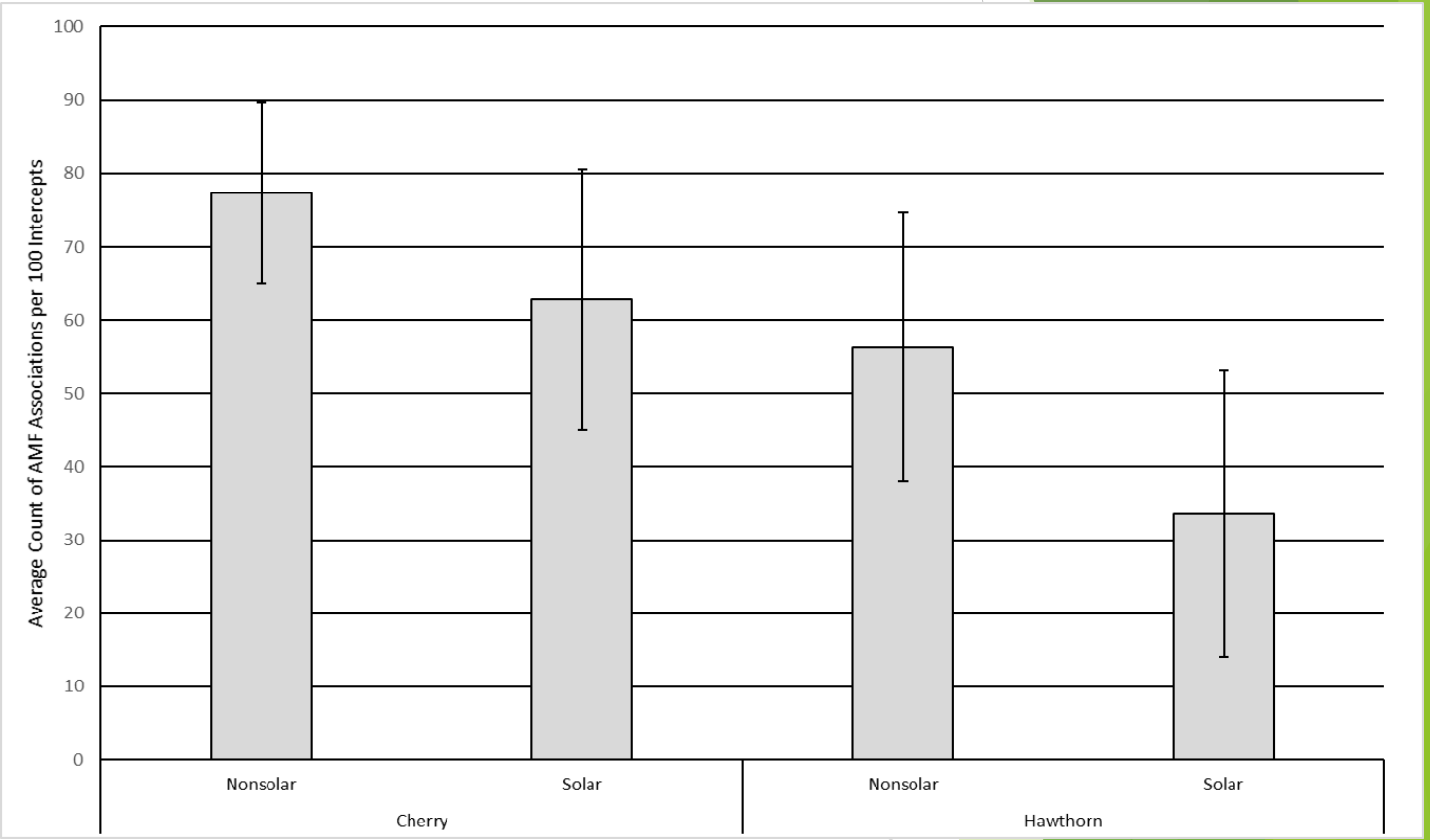


Starred bars (*) showed significant differences between nonsolar and solar treatments ($P < 0.05$). Error bars represent standard deviations.

Discussion

Mycorrhizal colonization

- Solarization does reduce AMF colonization
  - Not necessarily a bad thing – solarization IS working
- For species more reliant on AMF, solarization may not be recommended
  - Especially a species where disease is not a major issue
- ECM – needs more robust data set



Conclusions

- Species respond differently to solarization
  - AMF reduced by solarization in hawthorn and Mazzard cherry
- Hawthorn negatively affected by solarizing, except in root biomass
  - Solarization (maybe) not recommended for this species
  - May rely more on AMF than other species
- Mazzard cherry had slightly better shoot growth when solarized
  - For the early season – when it matters most
- Red oak showed no differences in trials
  - For the documented variables
  - Look next at disease

Future Research

- Finding better materials
- Solarization timing – was 7 weeks enough?
  - Could less time achieve same result?
  - Especially of interest in Willamette Valley
- AMF or Disease:
  - Which matters more, and to what plants
- Looking at various crops and assessing viability of solarization

Acknowledgements

- Sam Doane, JFS Nursery
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- Alonso Salazar
- Caleb Trammell

Questions?