Putting the Sun to Work: Soil Solarization for Management of Weeds and Soilborne Pathogens

Jennifer Parke

Oregon State University

Corvallis, OR

OSU Soil Solarizers

Dr. Maria Dragila,
Soil physicist
(not pictured)

Dr. Carol Mallory-Smith,
Weed scientist

Sam Doane,
Grower collaborator

OSU Soil Solarizers

Brian Hill, Nami Wada, Clara Weidman,
Graduate students

Putting the Sun to Work: Soil Solarization for Management of Weeds and Soilborne Pathogens

- Nursery industry and production cycle
- Why soil solarization?
- Weed management
- Crop growth and soil biology
- Other potential applications of soil solarization
- Practical tips for solarizing
- Online forecasting tool
- Questions and discussion

Tree Seedling Production

- Oregon nurseries and greenhouses sold **$996 million** worth of products in 2018

Oregon's Top Agricultural Commodities (ODA, 2019)

1

$996m

2

$652m

3

$590m

~$300m from **trees grown in the field**

Tree nurseries

Fruit, shade, and flowering trees (ornamentals) ~$300 m

Christmas trees ~$120 m

Conifers for reforestation ~$37 m

Challenges in Field Production Nurseries

Weeds

Spring weeds in seedling beds

Ornamental nurseries:

- Multiple crops; multiple weed issues
- Few registered herbicides
- High potential for crop damage
- Require hand weeding

  $900-$3,000/acre
- Labor shortage

Challenges in Field Production Nurseries

Weeds

Methyl bromide fumigation

Forest nurseries:

- Soil fumigation with methyl bromide is **standard practice**
- Ozone depleting
- Dangerous, expensive ($1000/acre)

Soilborne Plant Pathogens

- Many crops, many diseases
- Damping-off, root rots, wilt diseases, crown gall
- Expensive losses
- Buffer restrictions limit soil fumigation

Mazzard cherry seedlings
Healthy Diseased

Pythium ultimum damping-off
Fusarium oxysporum root and crown rot

Soilborne Plant Pathogens

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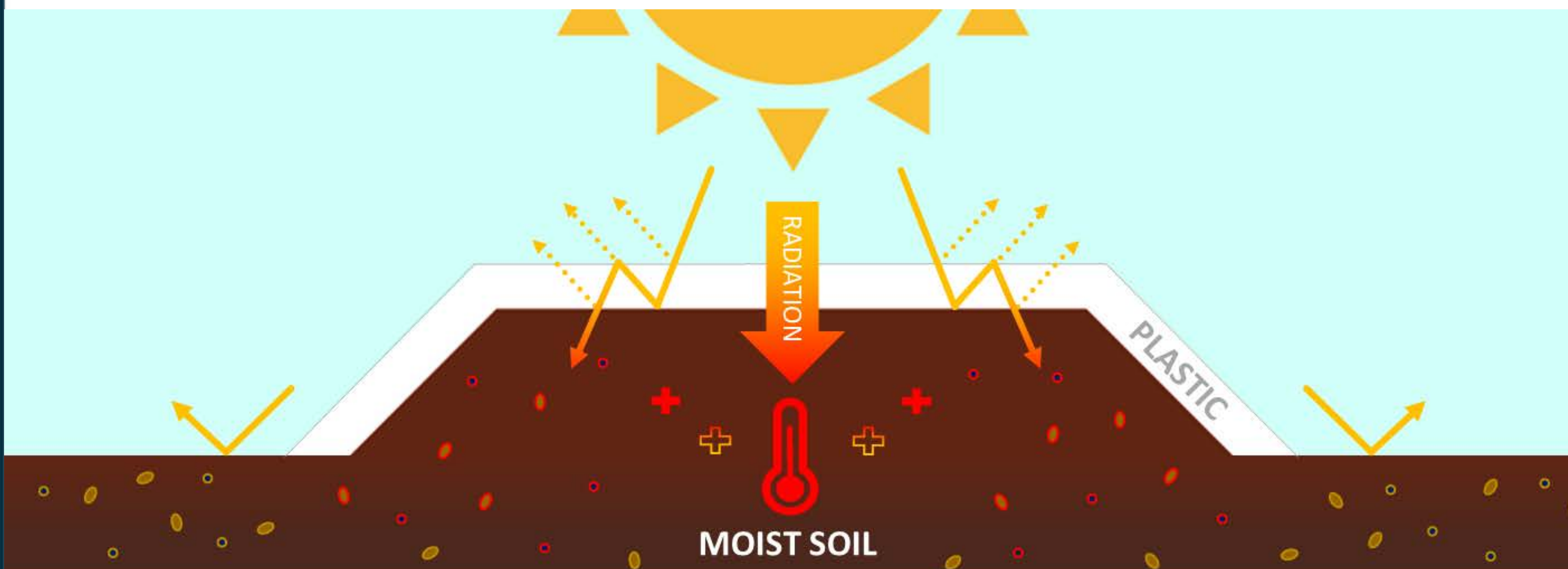
Pythium ultimum damping-off
Fusarium oxysporum root and crown rot

Need alternative strategies to manage weeds and soilborne diseases

Mazzard cherry seedlings
Healthy Diseased

Soil Solarization

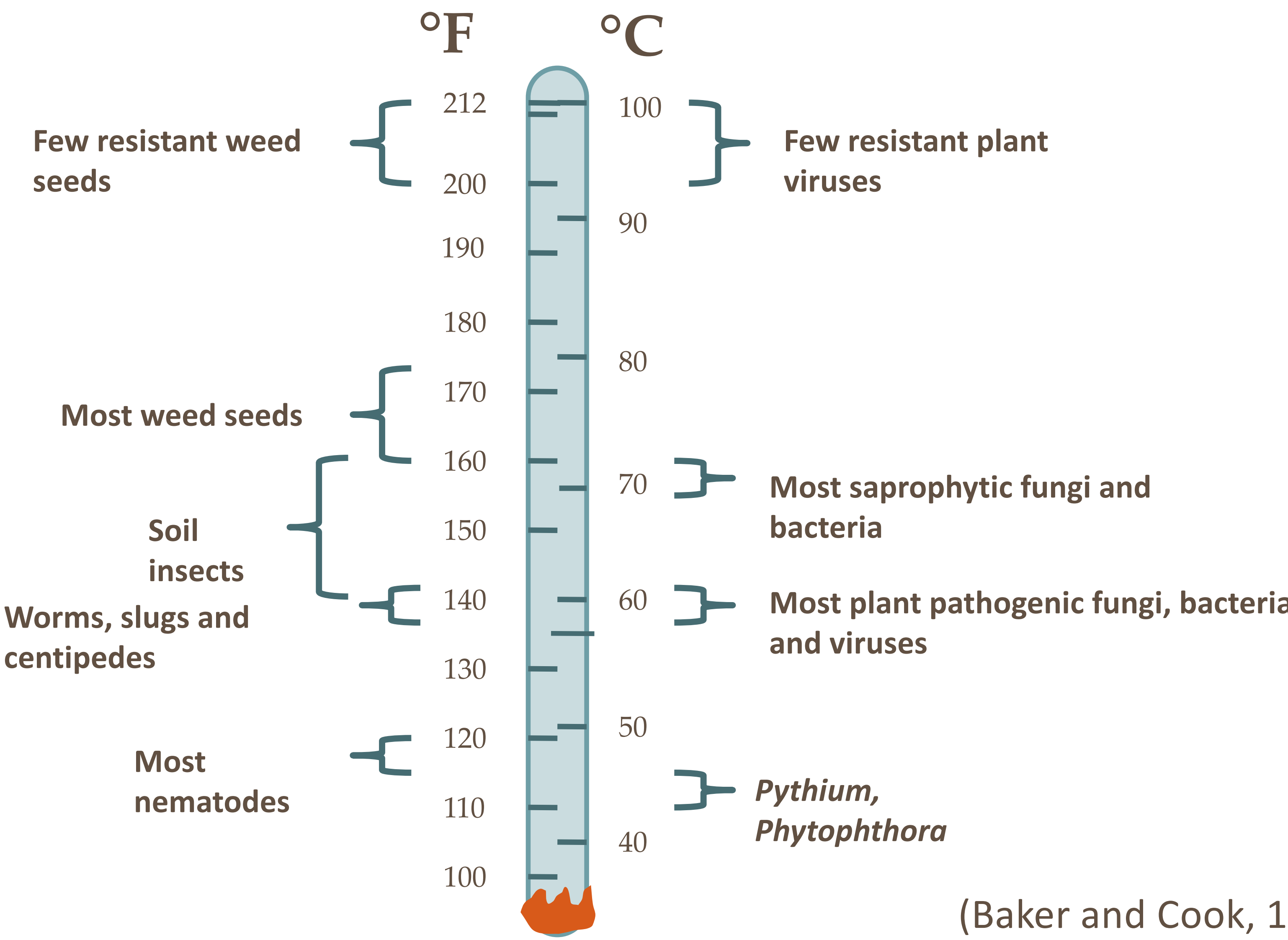
- Uses natural **sunlight** and plastic film, commonly a **clear polyethylene sheet**, to heat the soil
- Affects weed seeds and pathogens in the soil



Soil solarization

- Soil solarization works on the principle that high temperatures can kill certain weed seeds and plant pathogens without sterilizing the soil
- Pacific Northwest has a "**marginally suitable climate**" for soil solarization
- Recent advancements in horticultural films increased the feasibility of soil solarization in PNW by improving energy capture

Temperatures necessary to kill various groups of soil organisms – 30 min. of aerated steam



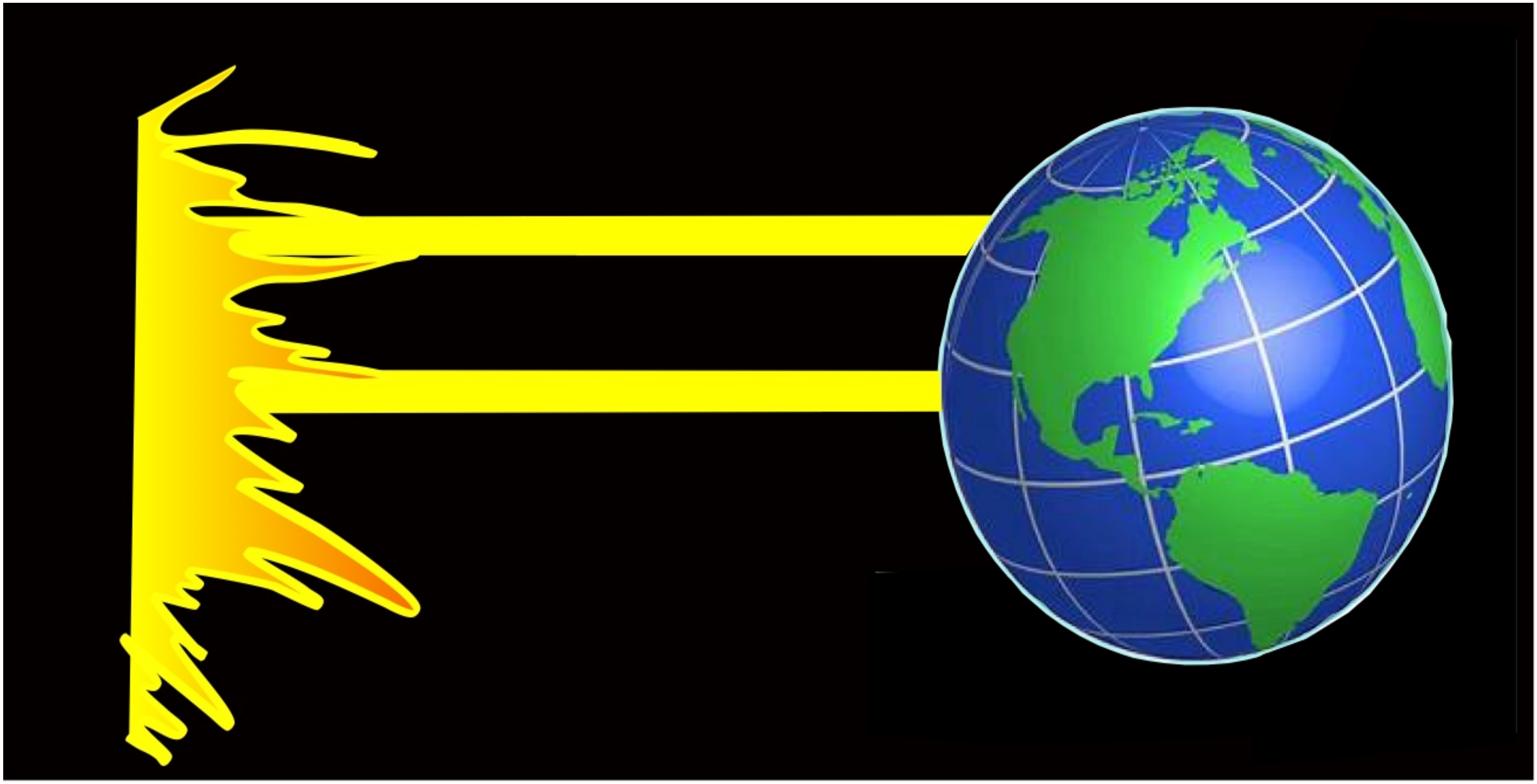
(Baker and Cook, 1974)

Soil Solarization in the PNW

Factors involved in successful solarization include:

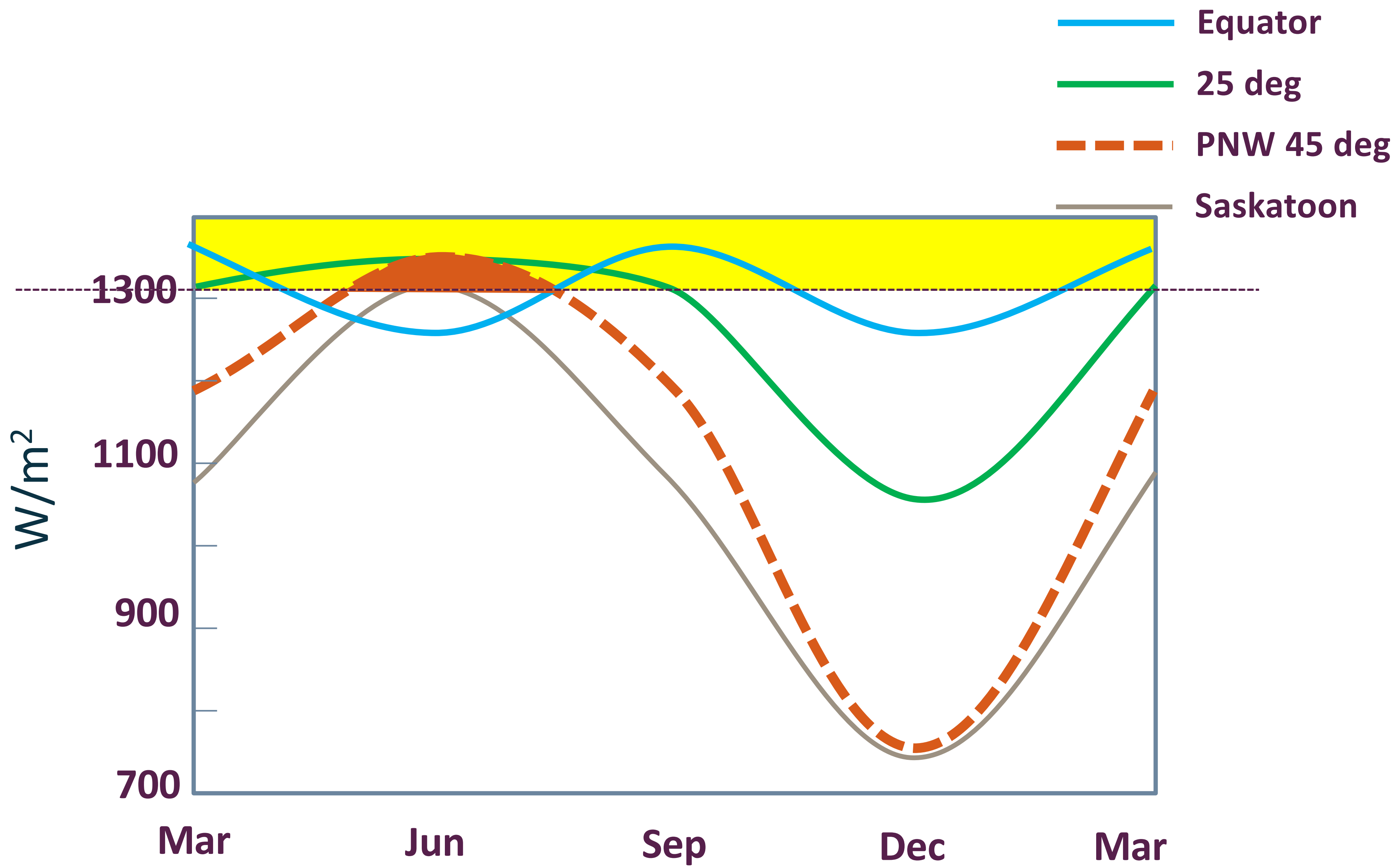
1. **Solar radiation**
2. **Types of plastic film**
3. **Timing and duration**
4. **Soil moisture**

Sunlight is spread over a larger area at higher latitude compared to at the equator



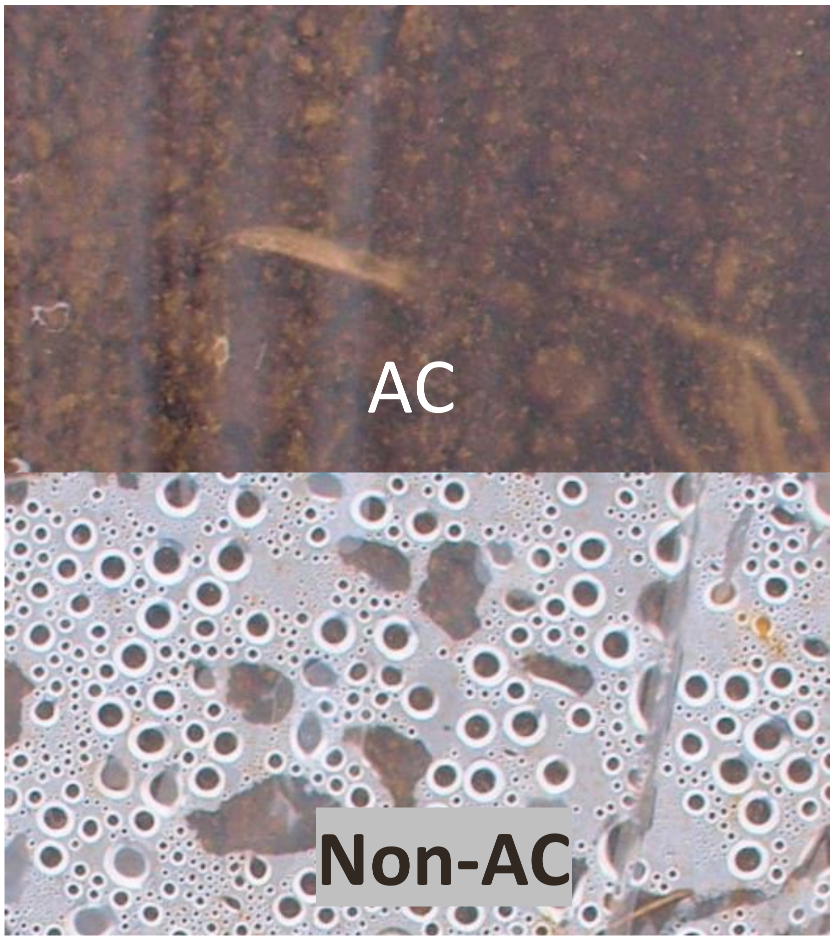
Therefore solar radiation is less intense at higher latitudes

Solar irradiation at different latitudes



Improved Horticultural Film

Anti-Condensation (AC)



Thermal Effect (IR)

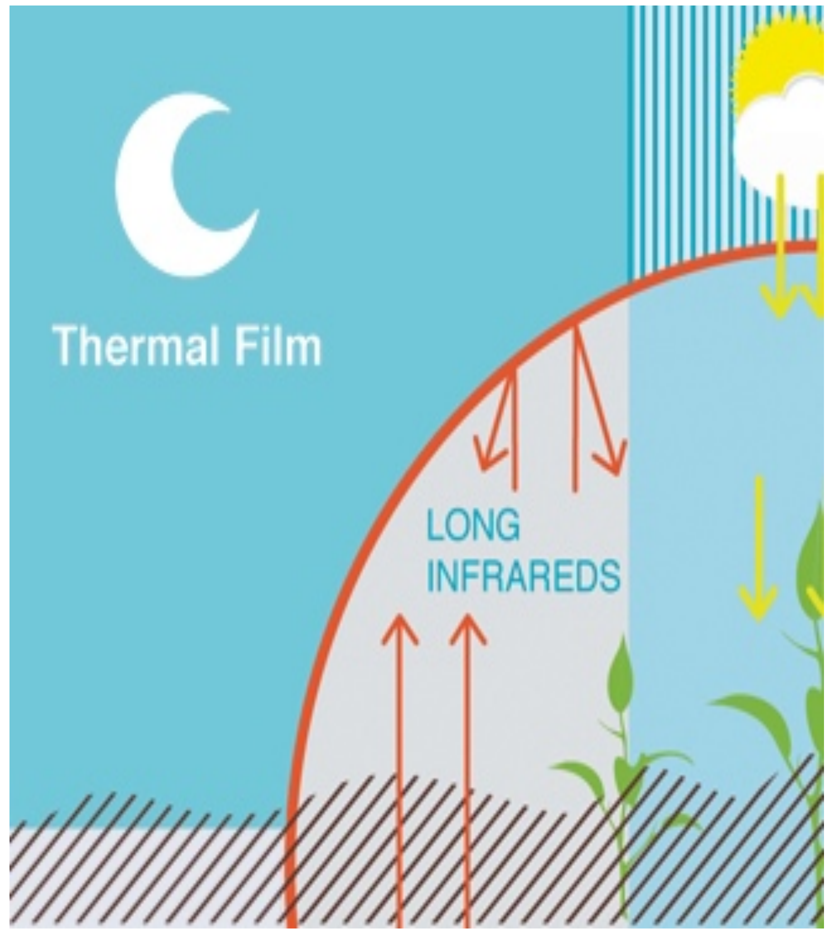
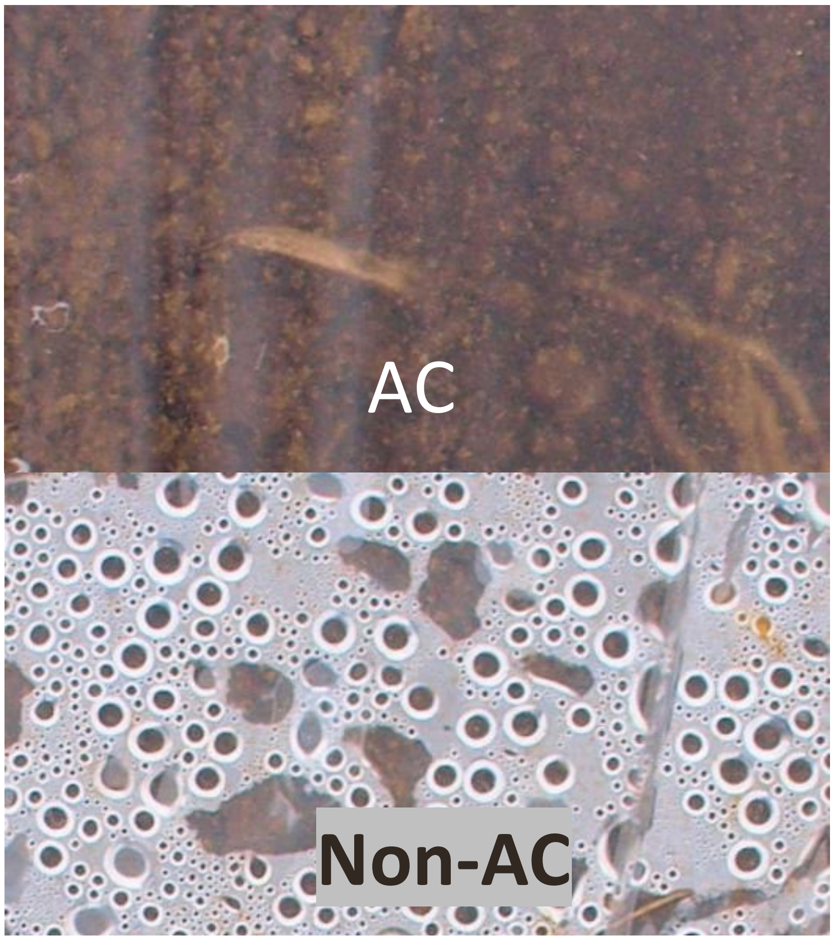


Diagram : Ginegar Plastic Products Ltd.

Improved Horticultural Film

Anti-Condensation (AC)



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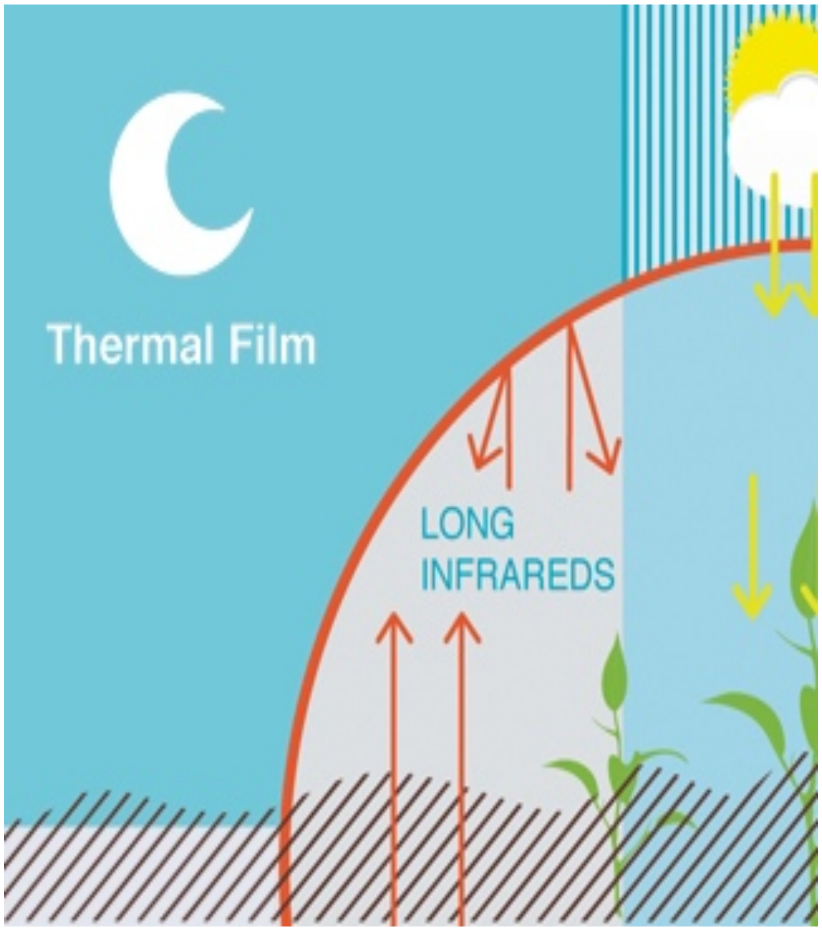


Diagram : Ginegar Plastic Products Ltd.

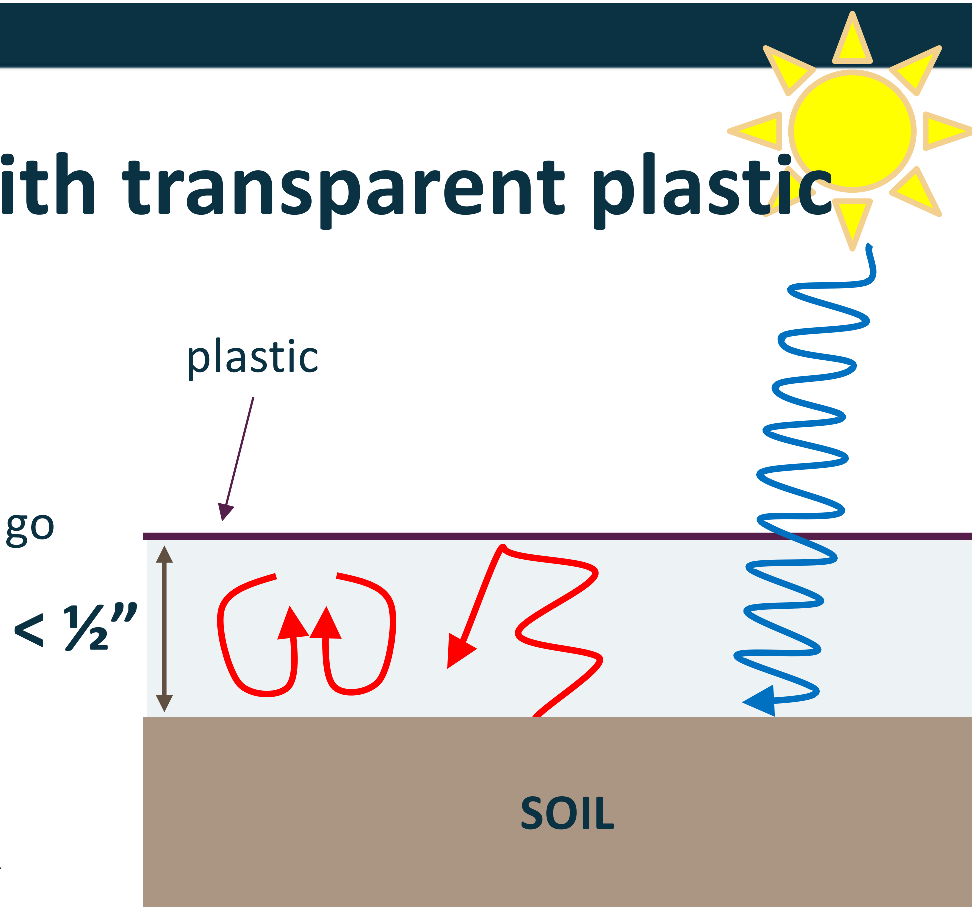
In the PNW
Horticultural Film is Recycled

http://www.agriplasinc.com/index.html

Trapping the heat with transparent plastic

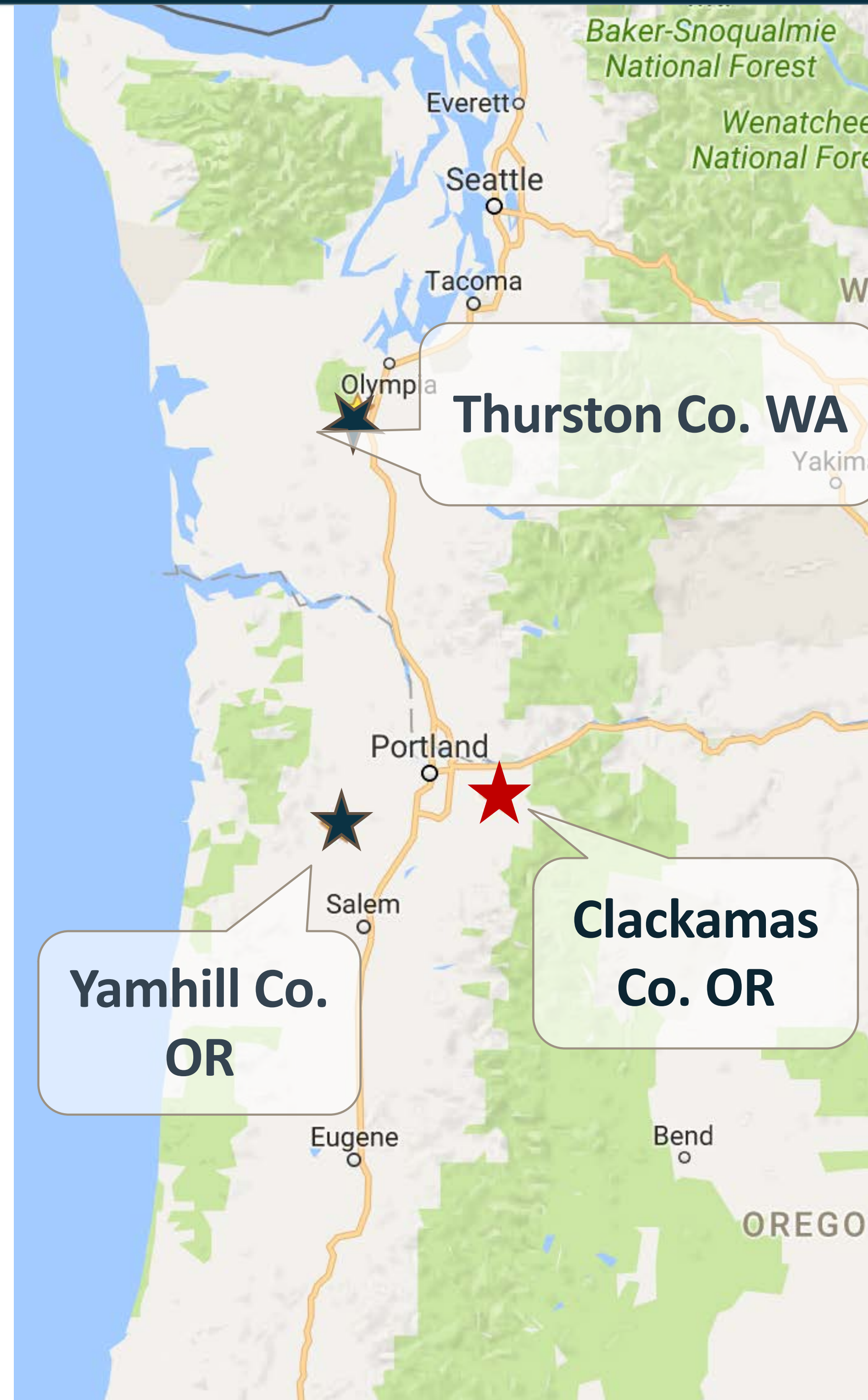
Goals:

- Let sunlight through
  - Transparent plastic allows sunlight to go through and heat soil directly.
  - Anti-condensation plastic lets more sunlight through
- Trap IR
  - IR treated plastic traps more of the IR losses
- Trap heat due to evaporation
  - Plastic prevents evaporation
- Trap heat leaving by convection
  - Plastic is placed as close to soil as possible.
  - Repair any tears in the plastic. Tuck in sides.



Objective

Determine if soil solarization is an effective way to manage weeds and soilborne pathogens in tree seedling nurseries in the Pacific Northwest



Production cycle Year 1

Cover crop
(Summer)

Till and "rough hill"
(September)

Final bed formation.
Seed planted in shallow furrows; covered with sawdust (October)

Production cycle Year 2

Seedling emergence (April)

Seedling growth (July)

Seedlings dug (November)

Field production cycle
Year 3

Seedling emergence (April)

Seedling growth (July)

Scions/grafts planted

Production cycle Year 1

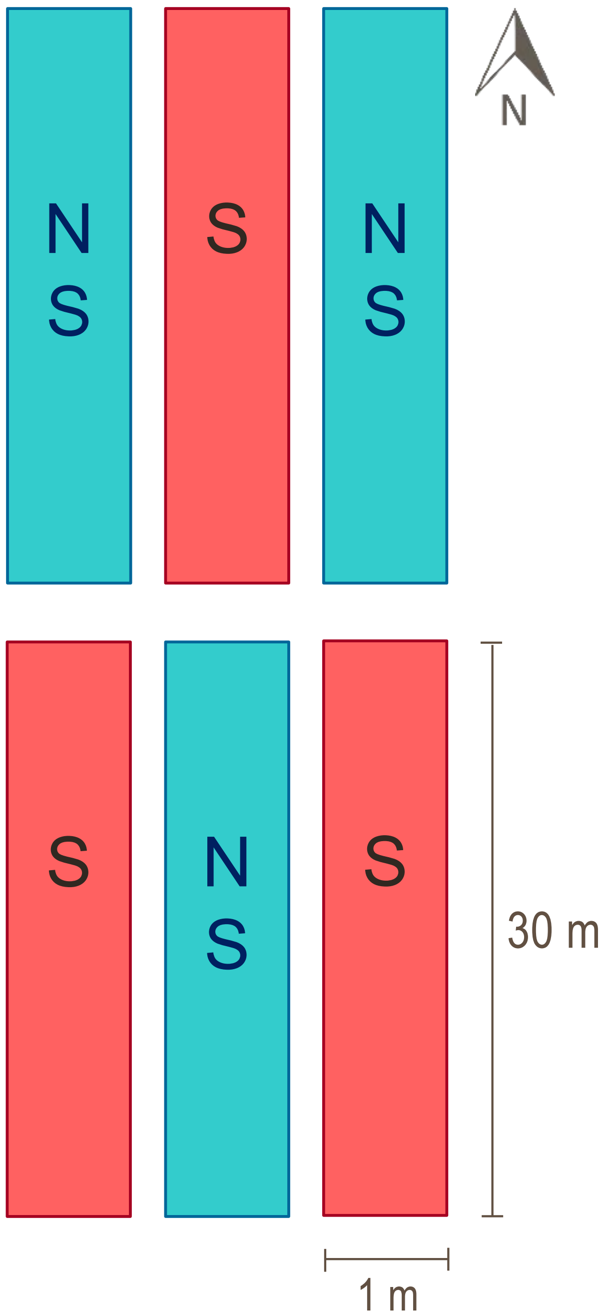
Cover crop
(Spring)

Till and “rough
(June)

Solarize 6 weeks
(July-August)

Final bed formation.
Seed planted in shallow
furrows; covered with
wdust (October)

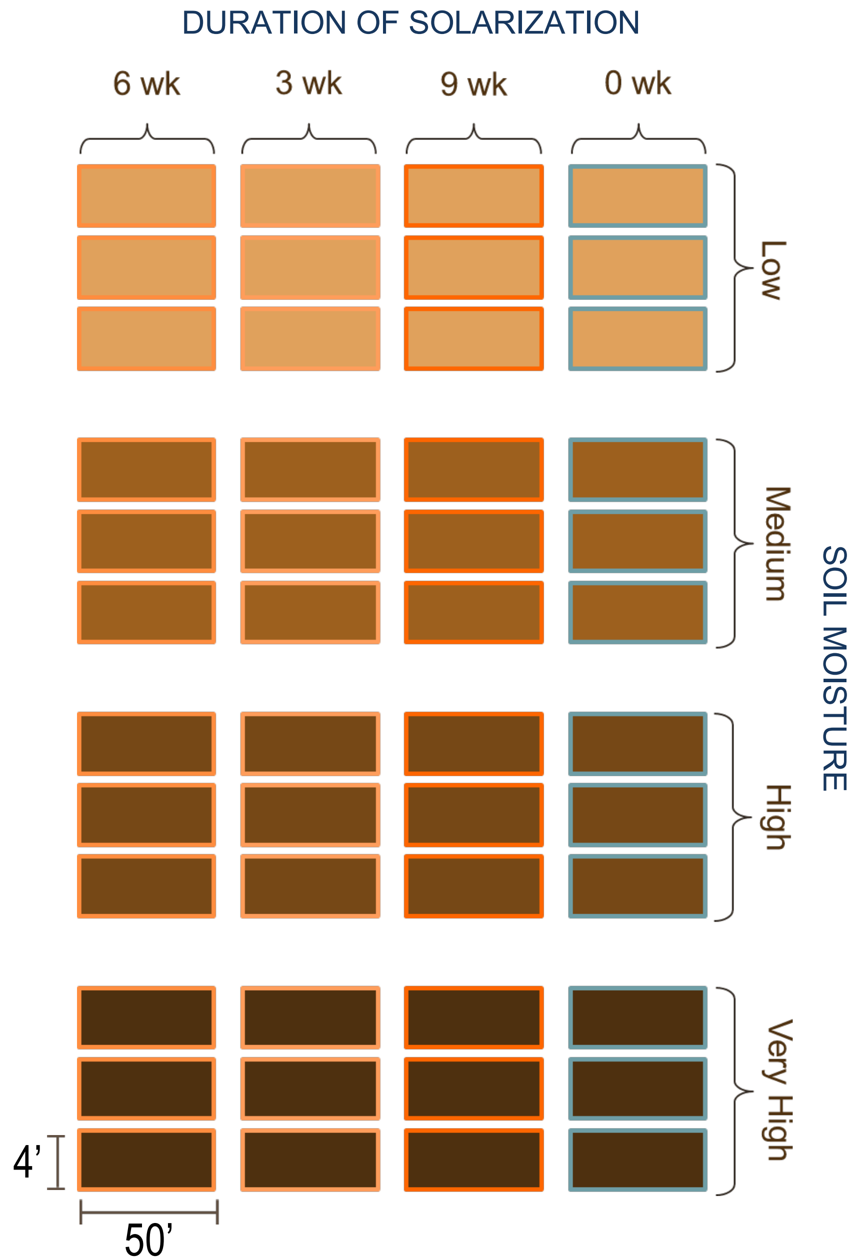
Expt. 1 : Efficacy Study



- Solarized vs Non-Solarized
  - 3 replications each
  - 3 nursery sites
  - 2 years
- 6-week Treatments
  - July – August, 2016 & 2017
- Evaluation:
  - Soil temperature and soil moisture
  - Weeds
  - Soilborne pathogens
  - Soil microbial communities
  - Soil nutrients
  - Crop response

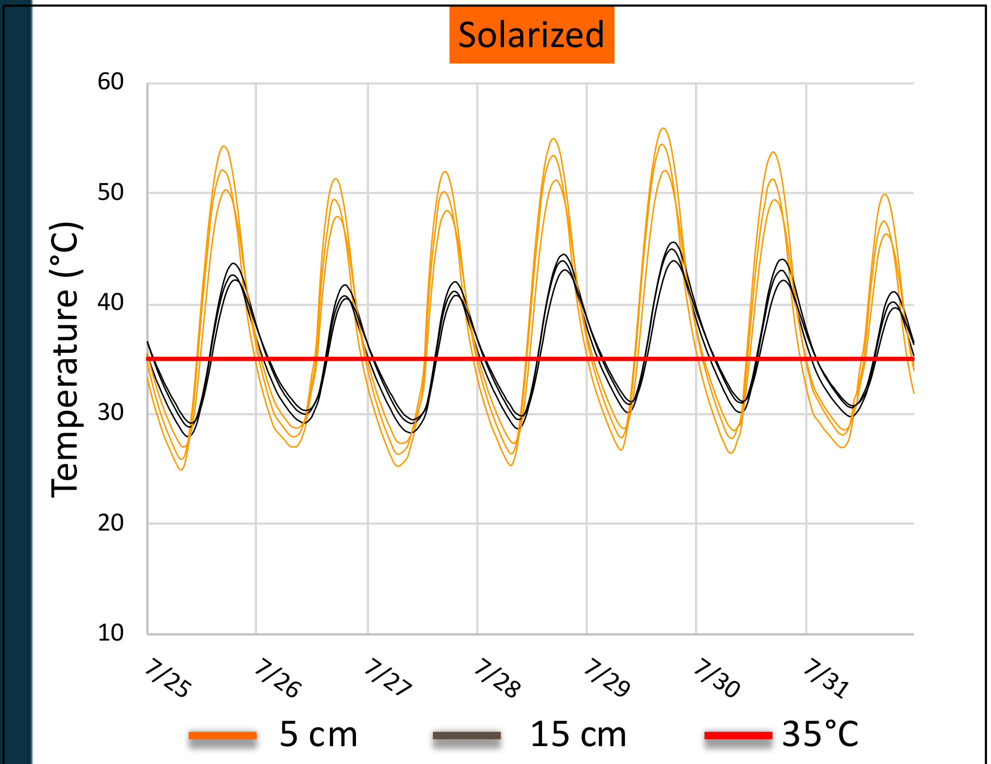
Expt. 2: Moisture x Duration

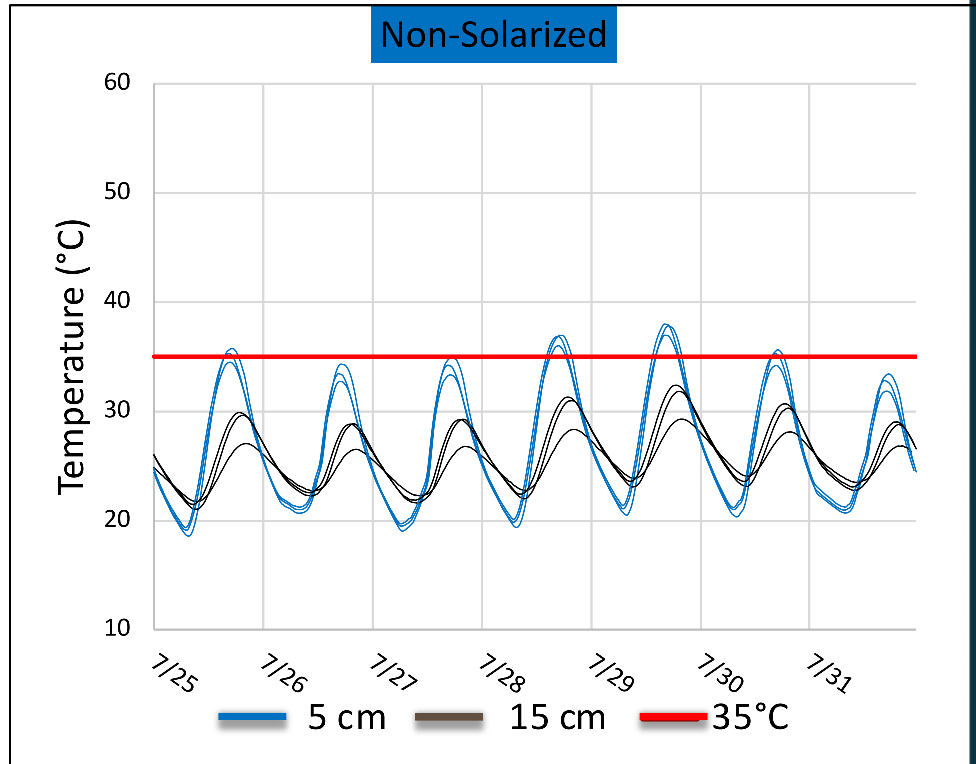
- 16 treatments:
  - **4 Solarization Durations** (0, 3, 6, 9 weeks)
  - **4 Soil Moisture Levels**
  - 3 replications each
- Treatment period
  - July to September 2016 & 2017
- Single location
  - Clackamas Co.



Clackamas Co., Oregon- Efficacy 7/7-8/18/17

Last Week of July Temperature Data

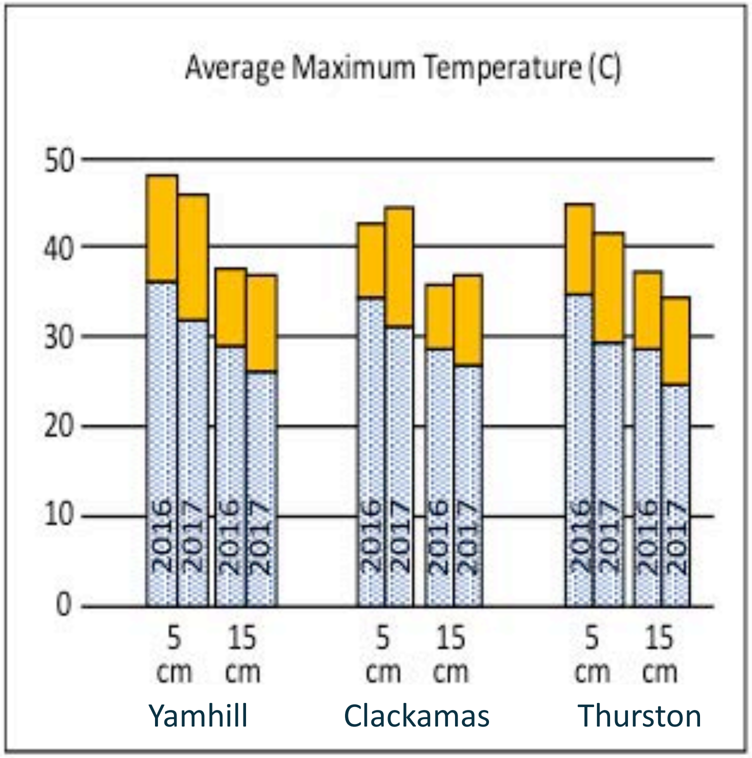


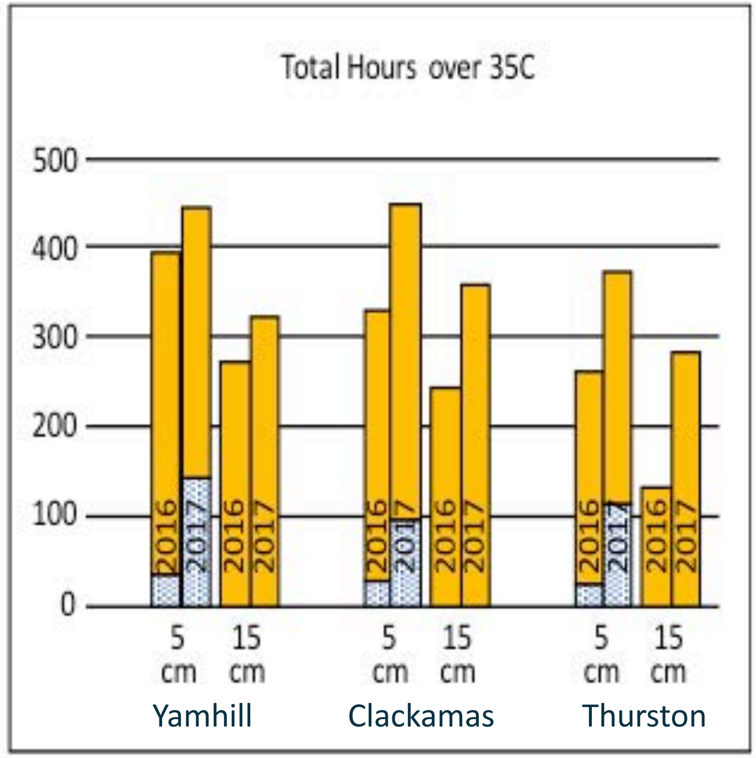


Season Long Temperature Summary

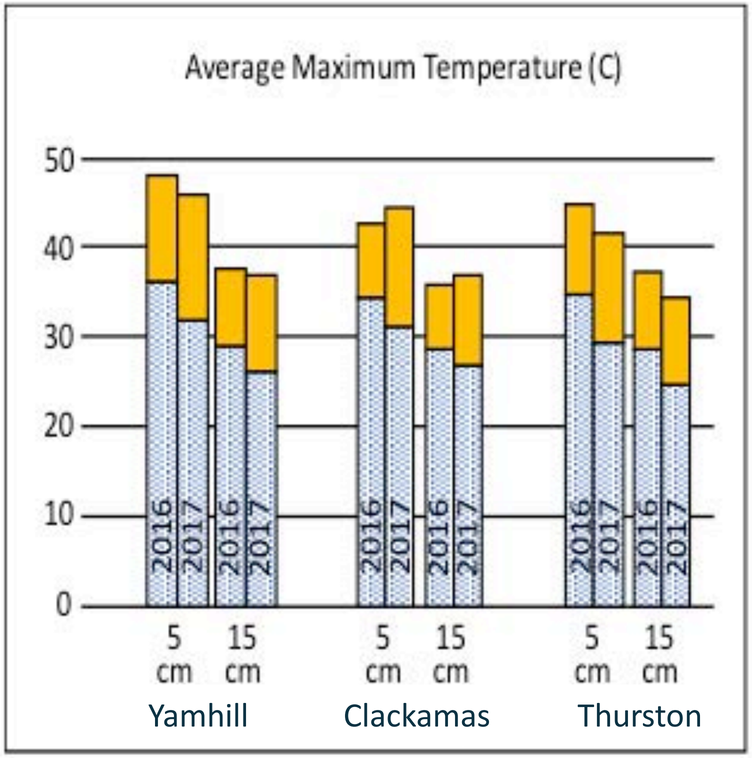
Solarized	Max Temp	Min Temp	Average Temp	Hours > 35	Hours >40	Hours >45	Hours >50	Hours >55
5 cm	54	19	29	361	224	137	42	1
15 cm	45	21	28	269	82	1	0	0
Non-Solarized	**Max Temp**	**Min Temp**	**Average Temp**	**Hours > 35**	**Hours >40**	**Hours >45**	**Hours >50**	**Hours >55**
5 cm	38	14	24	34	0	0	0	0
15 cm	31	17	23	0	0	0	0	0

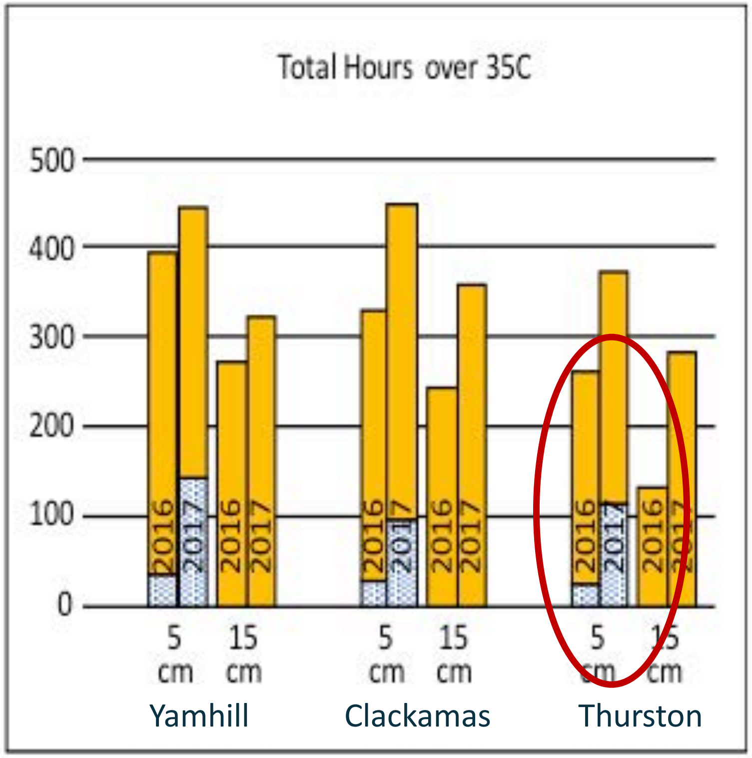
Average Maximum Temperature and Hours over 95˚ F
All Sites – 2016 & 2017





Average Maximum Temperature and Hours over 95° F All Sites – 2016 & 2017





Total hours > 95° F in Thurston Co. WA in 2016 were the lowest in our field trials. Solarization was less effective here than for other sites and years.

Method 1: **Weed Seed Packets**

Contains 4 weed species (50 seeds each)

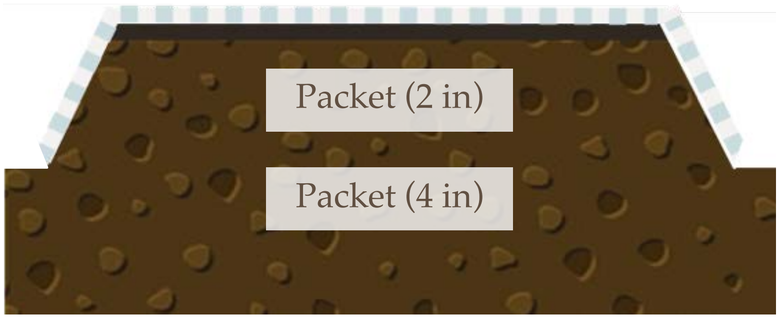

Annual bluegrass

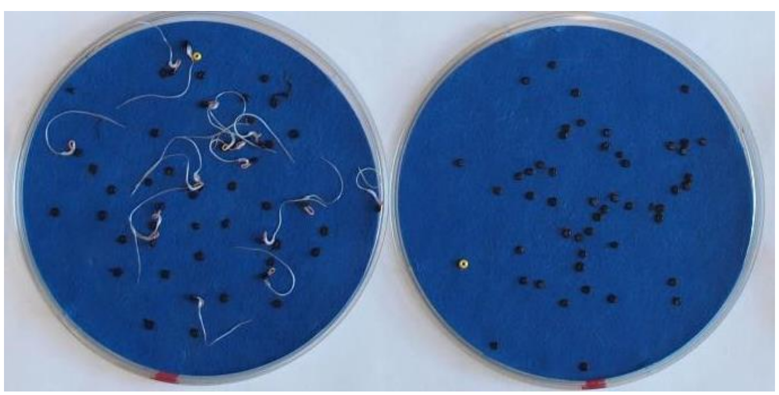

Pennsylvania smartweed


Redroot pigweed


Common purslane

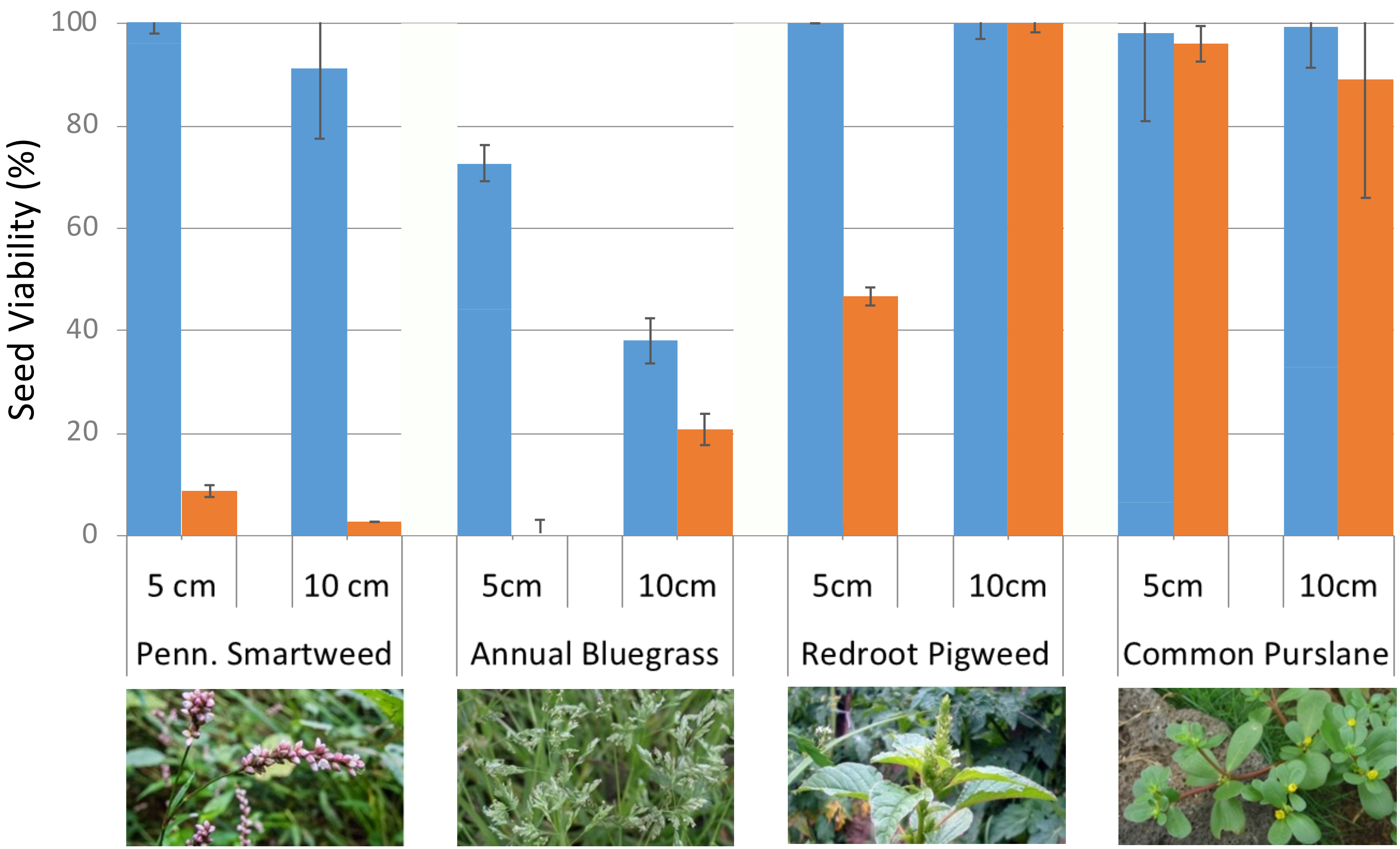
Method 1: **Weed Seed Packets** (cont.)





- Buried at **2 and 4 inch** depths in each plots
- At 6 weeks, seeds removed and tested for germination and viability.

Weed Packet Study – Yamhill 2017 Trial



Summary – Weed Seed Packets

- More effective at 2 than 4 inches
- At all sites and depths, solarization:
  - was most effective on **Pennsylvania smartweed**
  - was least effective on **common purslane**
  - increased dormancy in **redroot pigweed**
  - was more variable for **annual bluegrass**

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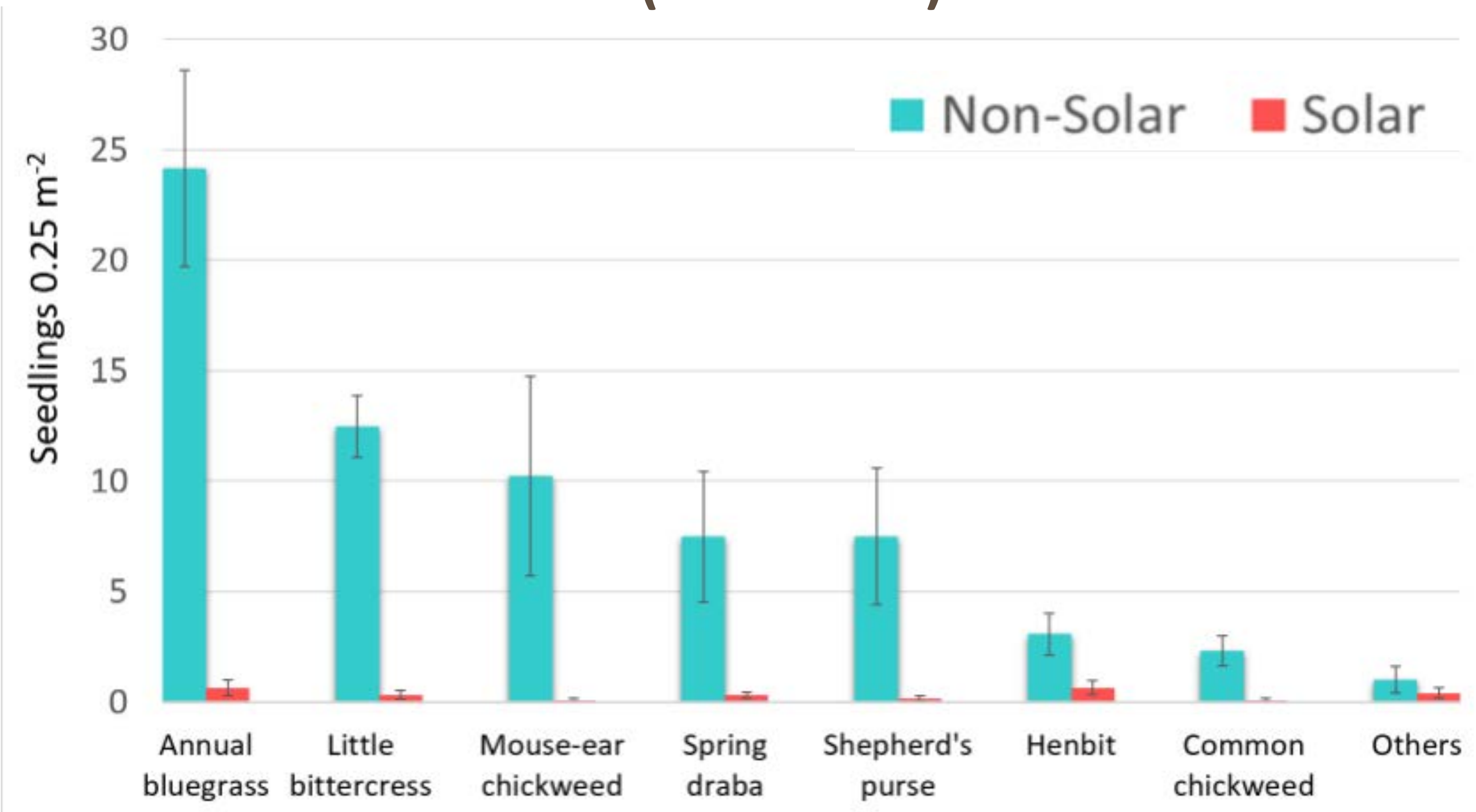
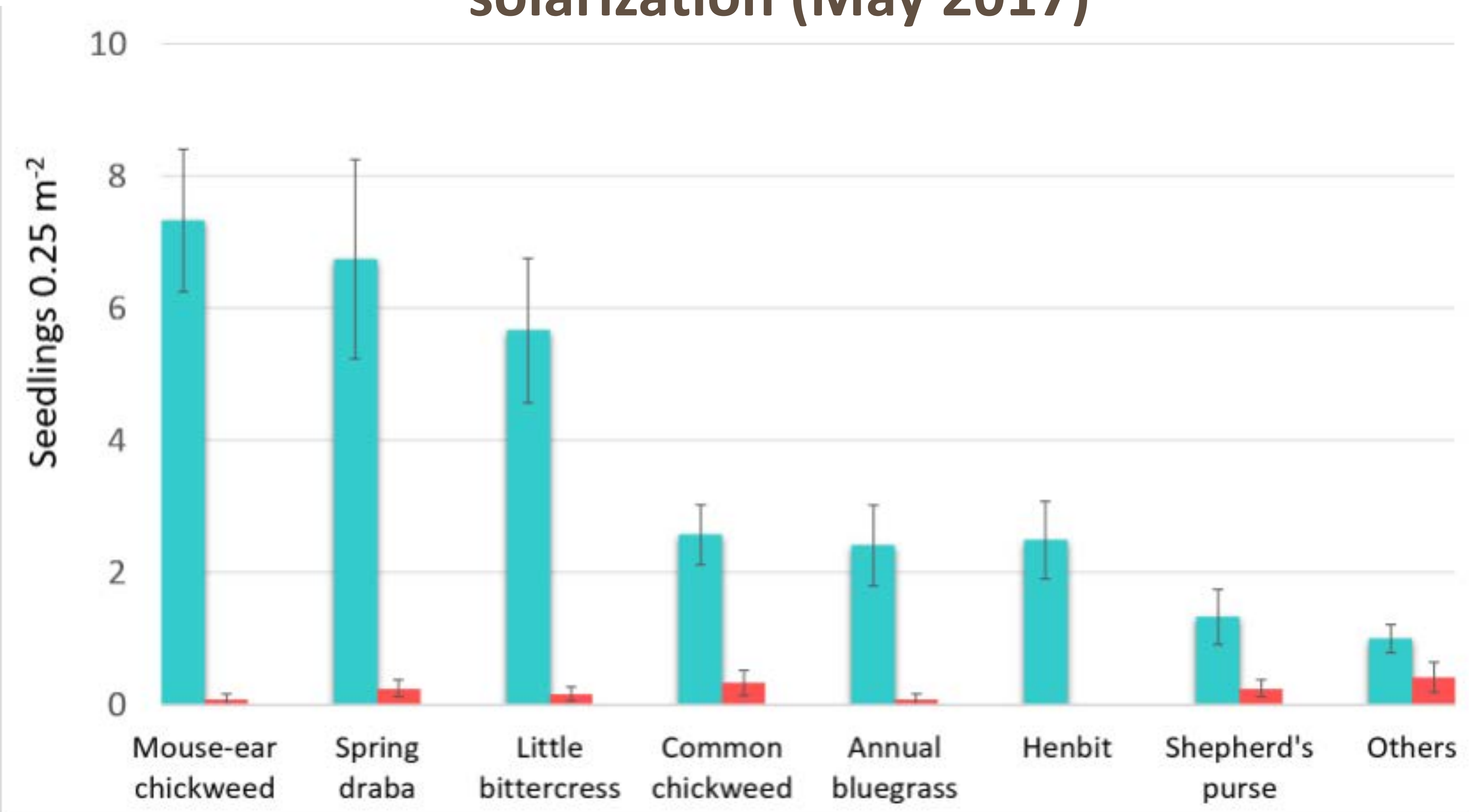
Method 2: **Weed Emergence**

- Evaluate naturally-occurring weeds in following seasons following solarization

Reduction in fall season weeds following solarization (Nov. 2016)

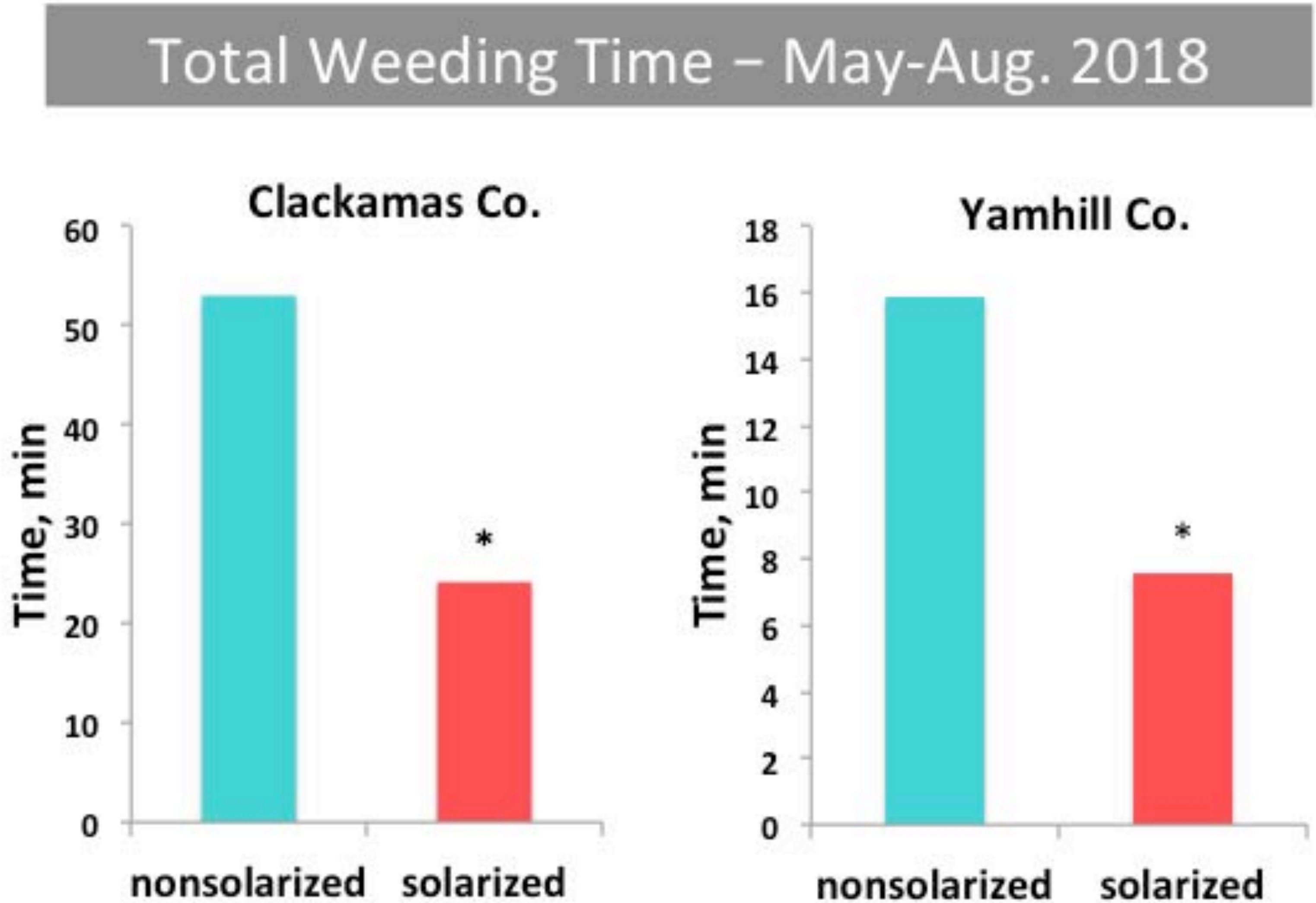


Reduction in spring season weeds following solarization (May 2017)




2018 Spring Weed Emergence
Solarized
Photo by Brian Hill
Non-Solarized

Method 3: **Labor for hand weeding**



52-54% reduction in labor time

Expt. 2: Moisture x Duration

- 16 treatments:
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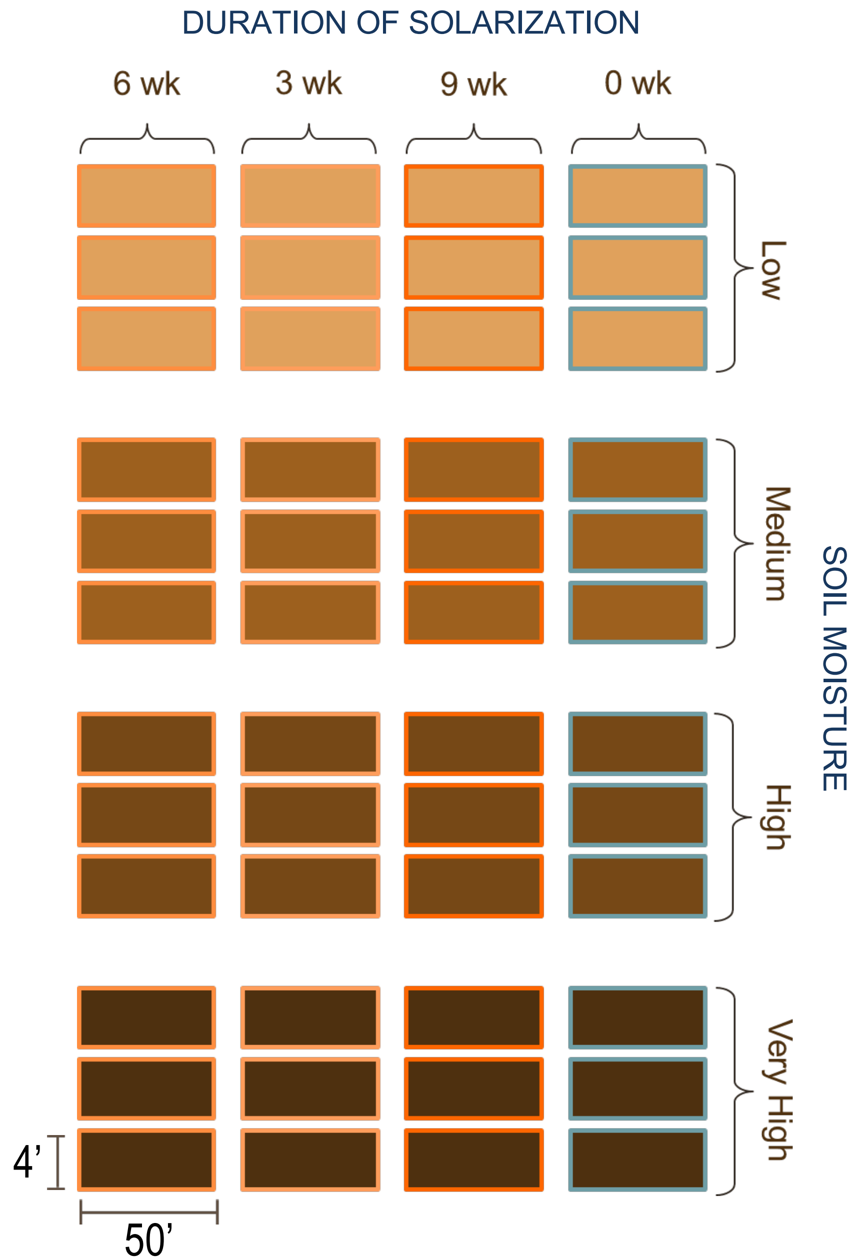
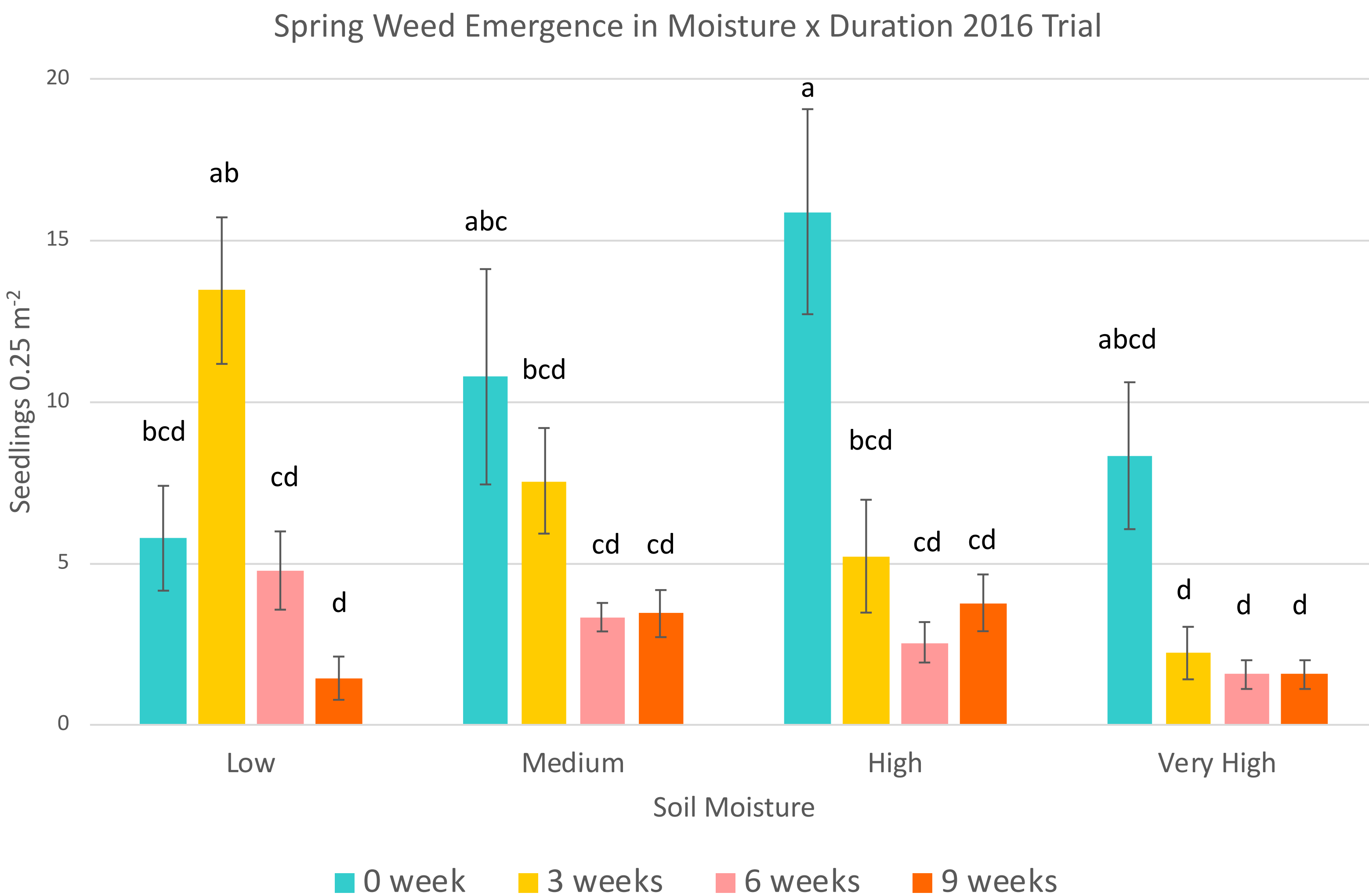
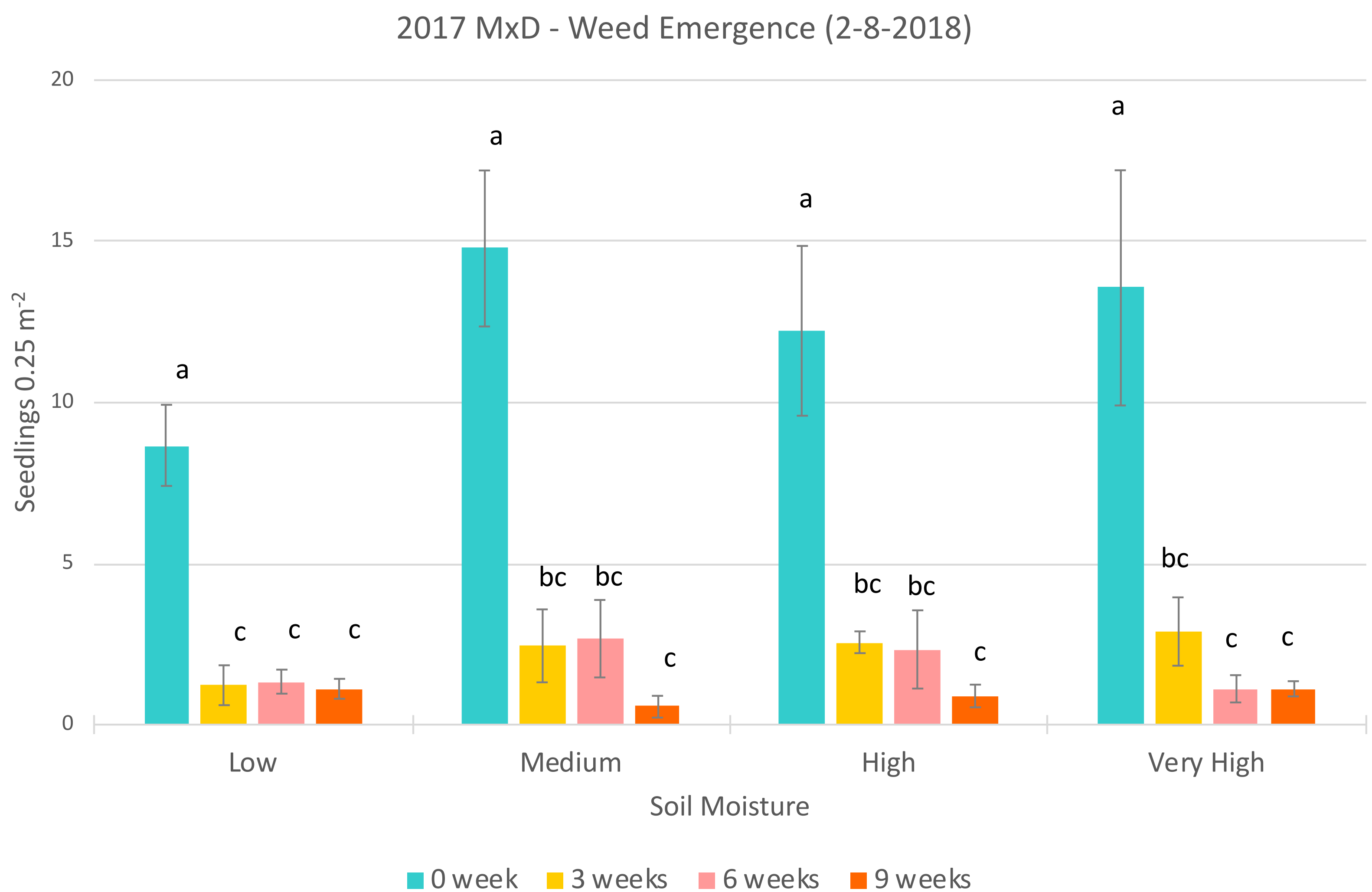


Emergence After a Cooler Solarization Season



Emergence After a Warmer Solarization Season



Solarization For Weed Control

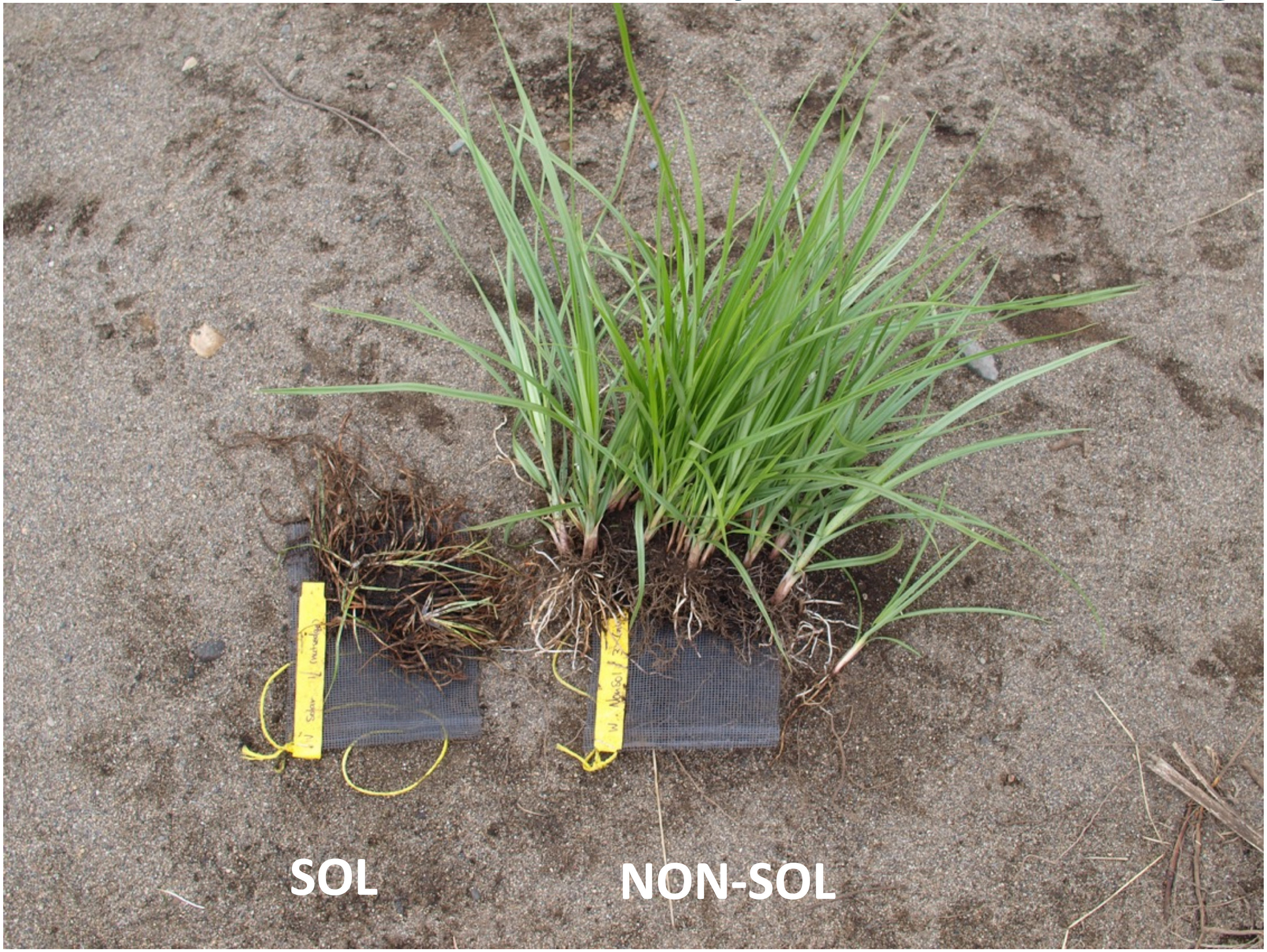
- Will not be effective on all weed species
- Moisture level and length of solarization are more important with lower temperatures

Common purslane

Soil Solarization – Weed Control Factors

- The main factor involved in weed control is **thermal killing** of seeds (Katan and DeVay, 1991)
- Annual weeds are more effectively controlled than perennials (Rubin and Benjamin, 1983)
- **Winter annual** weeds have lower thermotolerance and **summer annuals** are more resistant to solarization (Egley, 1990; Elmore, 1990)

Solarization did not kill yellow nutsedge



Thurston Co. WA

Conclusions

- Solarization can be a viable option to manage weeds in these nurseries because tree seeds are sown in fall following solarization, with minimal soil disturbance

- Solarization can:
  - reduce herbicide inputs
  - reduce hand weeding costs
  - benefit organic production

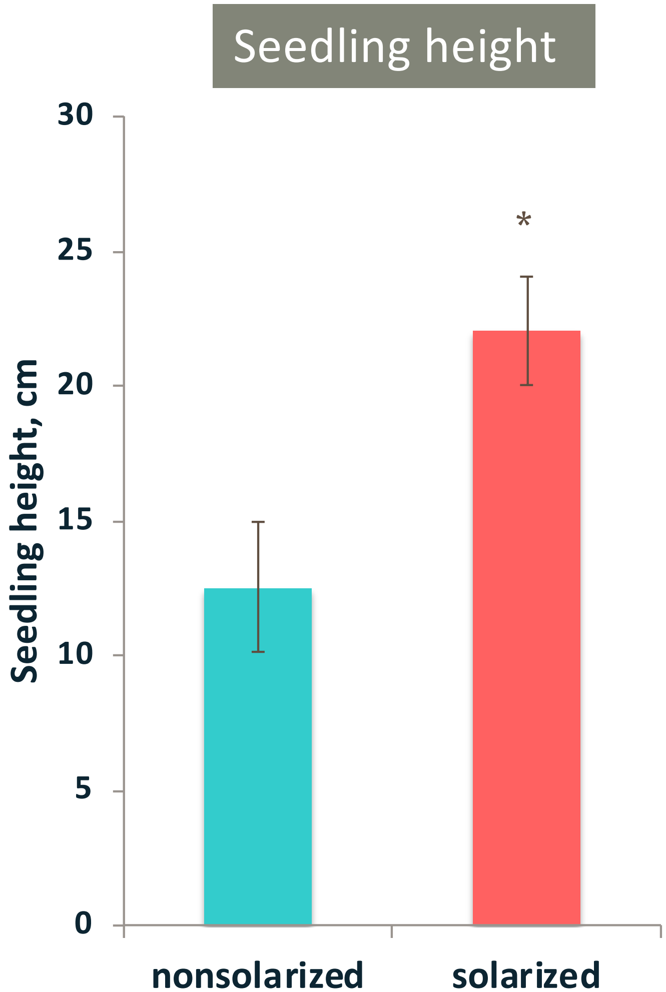
Oregon State University

Solarization effects on crop growth and soil biology

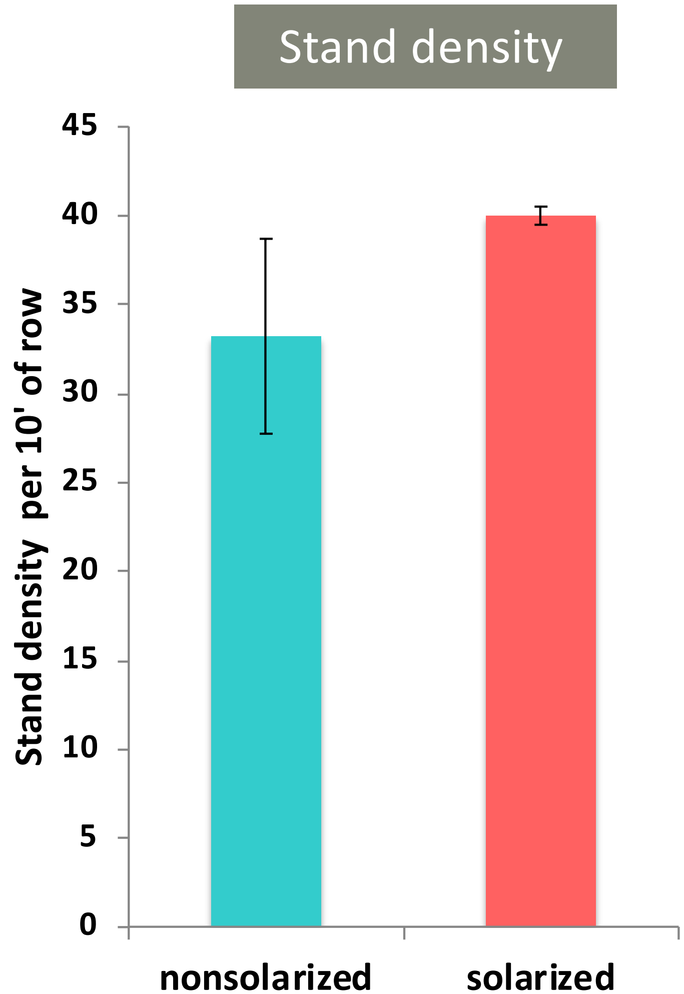

Clackamas Co. July 2017
Clackamas Co. July 2018
Mazzard cherry

Impact on crop growth

Clackamas Co. 2018



76% increase

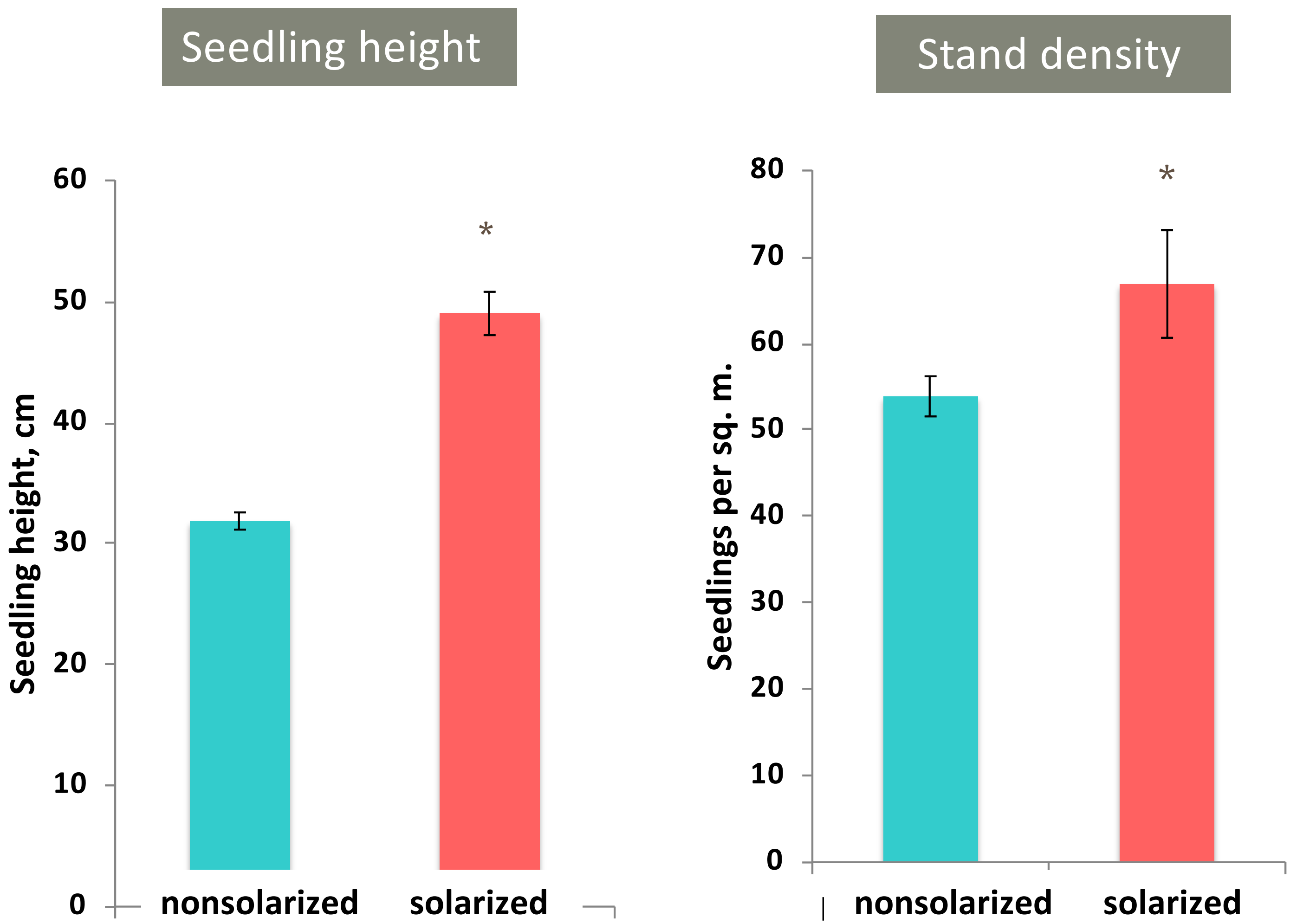


20% increase

Mazzard cherry

Impact on crop growth

Yamhill Co. 2018



54% increase

24% increase

Malus domesticus

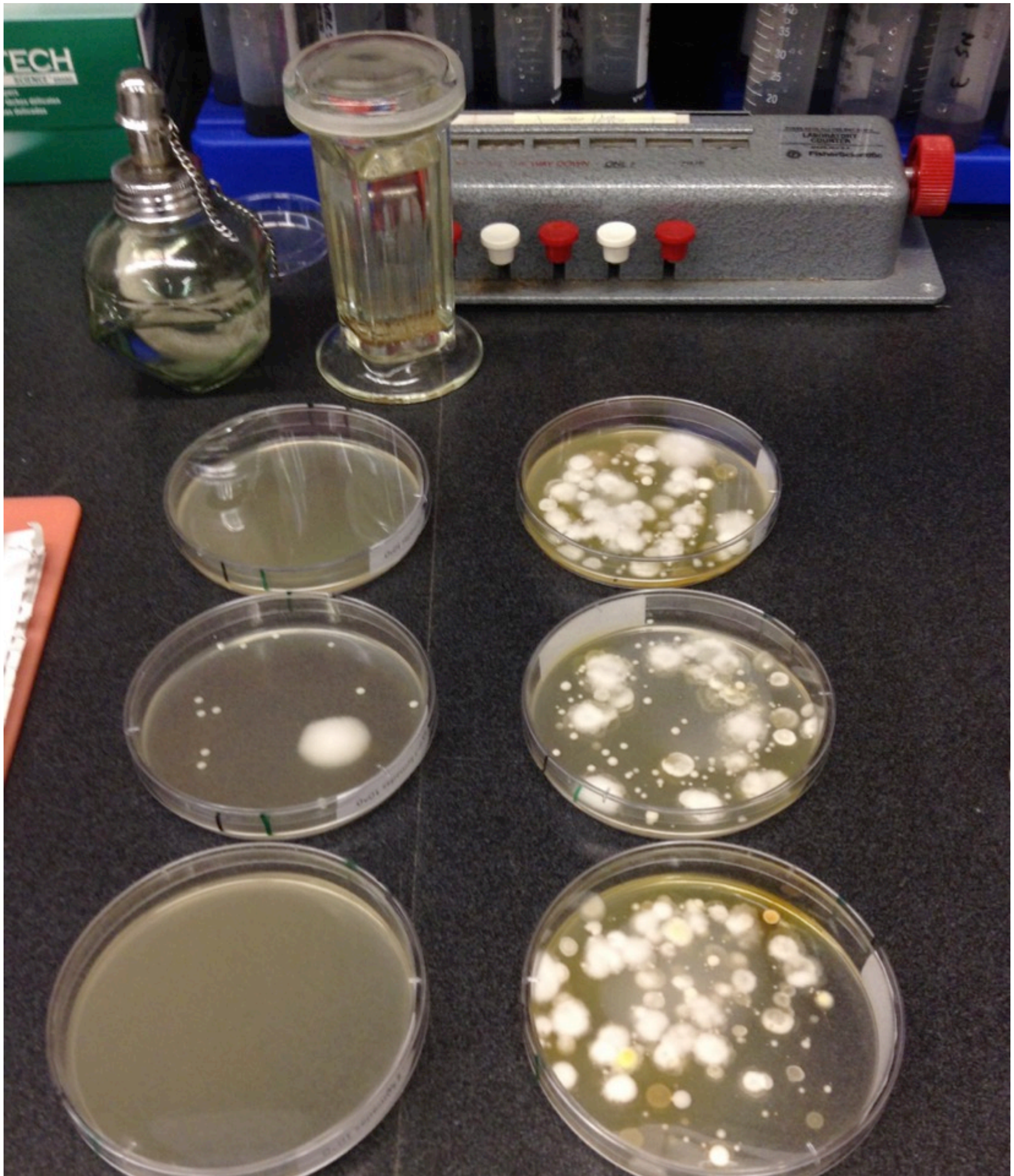
Seedling damping-off

Seedling damping-off

Methods for Evaluating Soilborne Pathogens and Soil Microbial Communities

Composite soil from each site buried at 2” and 6”

- Solarized vs Non-Solarized
  - 3 replications each
  - 3 sites
  - 2 depths (2” and 6”)
- 6-week Treatments
  - July – August, 2016 & 2017
- Evaluation Methods:
  - *Fusarium oxysporum* and *Pythium* spp: dilution plating
  - Amplicon sequencing
  - qPCR



From solarized plots | From non-solarized plots

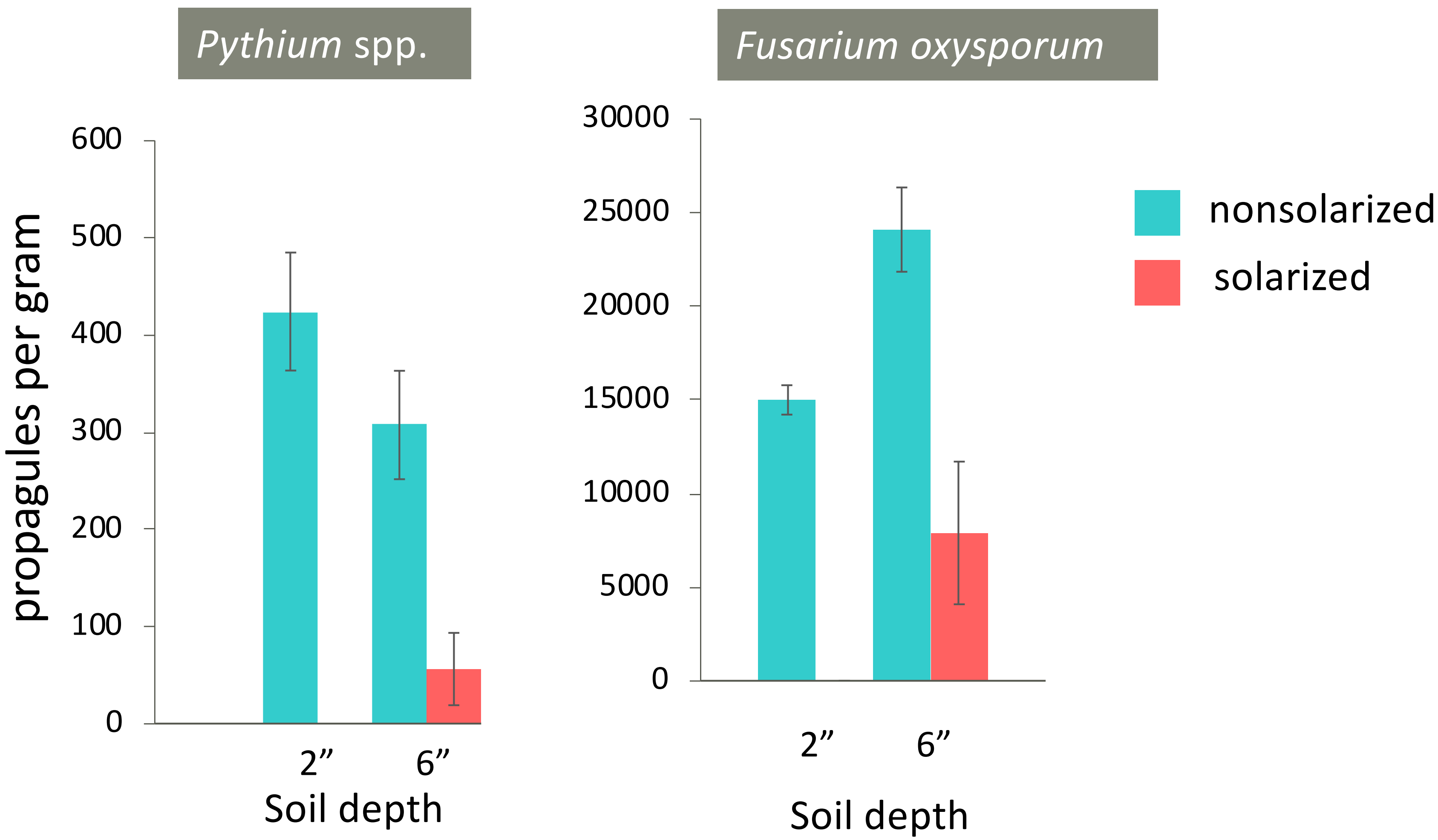
Fusarium and *Pythium* populations are greatly reduced by solarizing.

Fusarium oxysporum

Clara Weidman photo

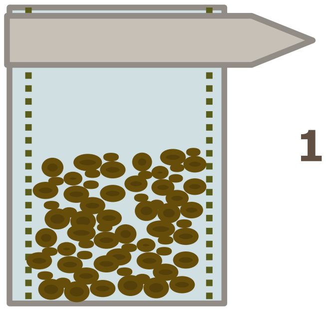
Impact on soilborne plant pathogens

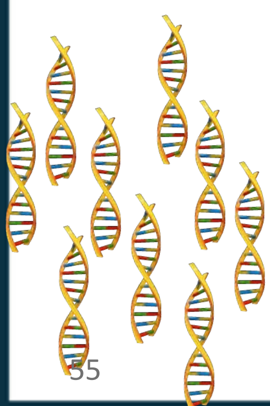
Clackamas Co. 2017



Solarization eliminated *Pythium* spp. and *Fusarium oxysporum* in the top 2”

DNA-based Methods





1) DNA extraction:

- 10 g soil sample from soil sachets
- Soil DNA extraction kits

2) DNA amplification (PCR):

- With primers selective for bacteria, fungi and oomycetes
- 16S and ITS1 amplicons

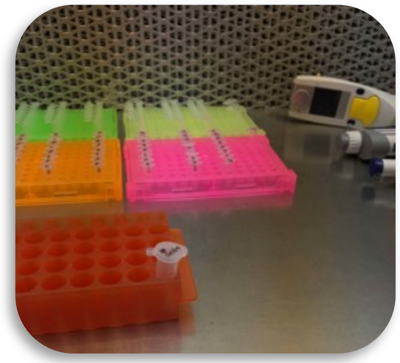
3) Amplicon sequencing:

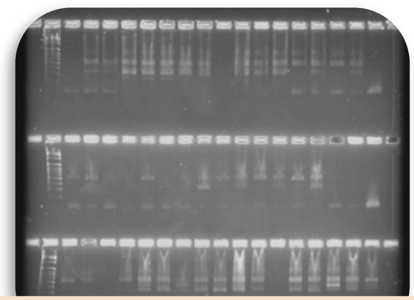
Illumina Miseq platform at CGRB

4) Sequence analysis

5) qPCR for *F. oxysporum* and *P. ultimum*

Dr. Neelam Redekar



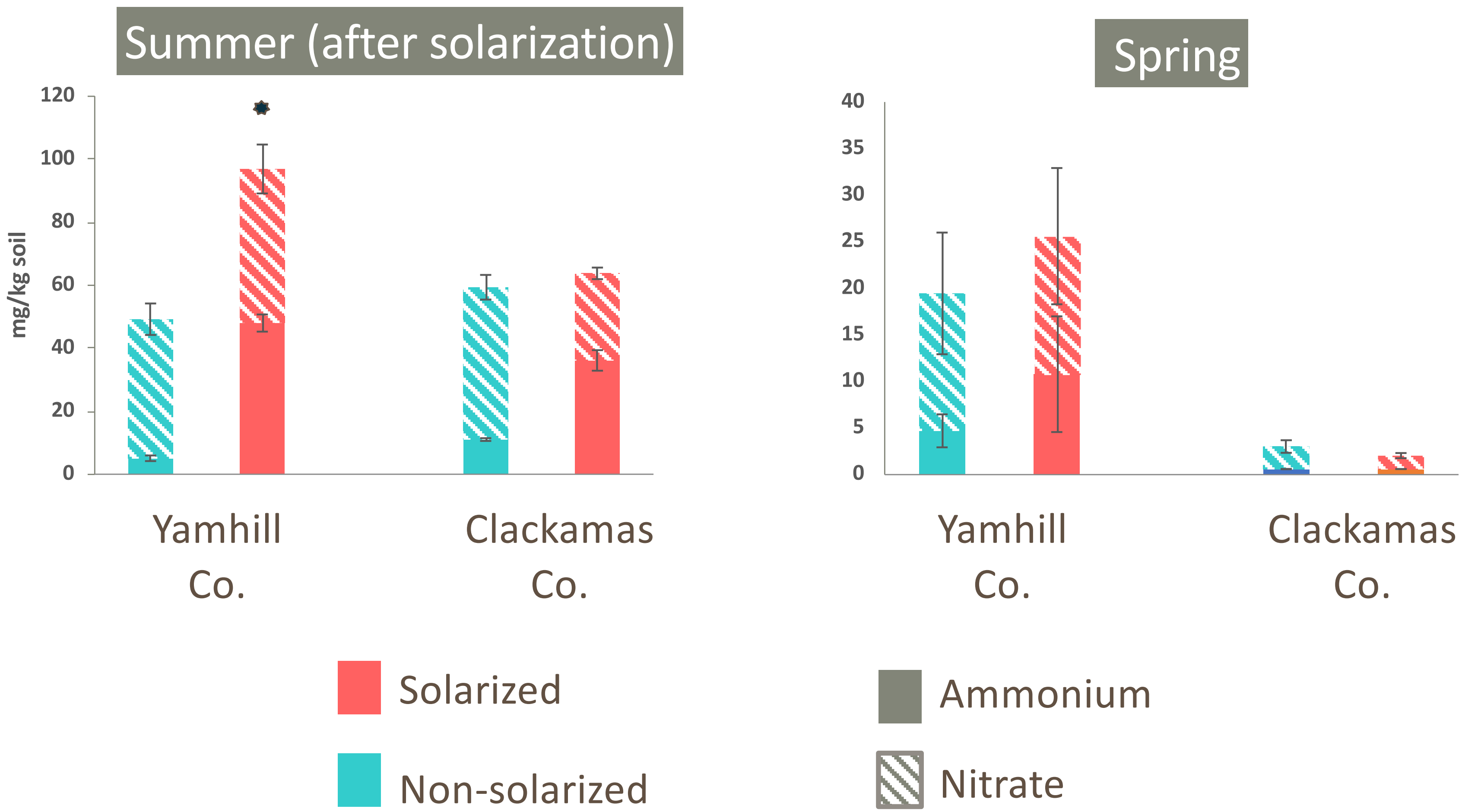


CENTER FOR GENOME RESEARCH & BIOCOMPUTING

Solarization reduced populations of certain plant pathogens, but could there be other possible causes of plant growth increases?

- Soil nutrient changes
- Soil microbial community changes

Solarization Effects on Plant Available Nitrogen



Changes Following Solarization

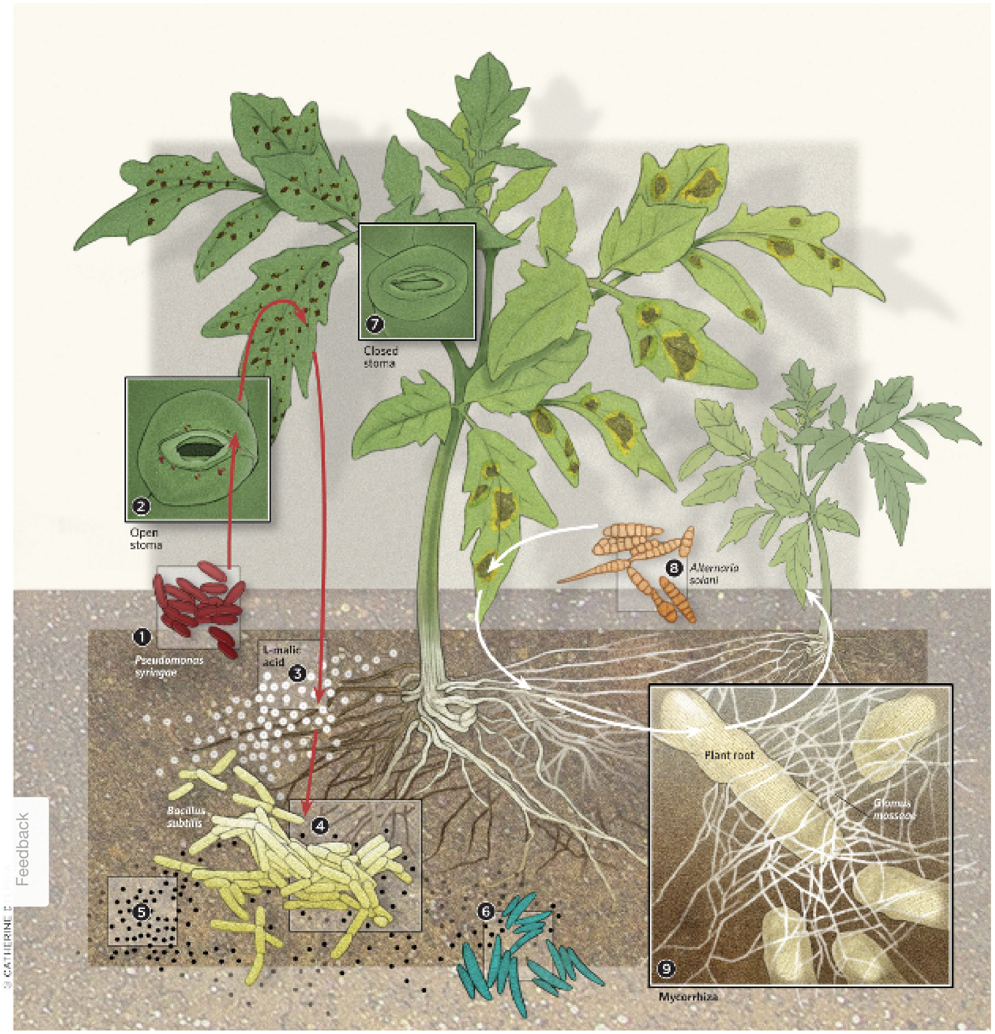
$\uparrow NH_4^+ + \downarrow NO_3^- = \downarrow$ Nitrification activity?

Ammonification

Organic Nitrogen $\rightarrow$ NH_4^+ $\rightarrow$ NO_3^-

Nitrification

The Soil Microbiome



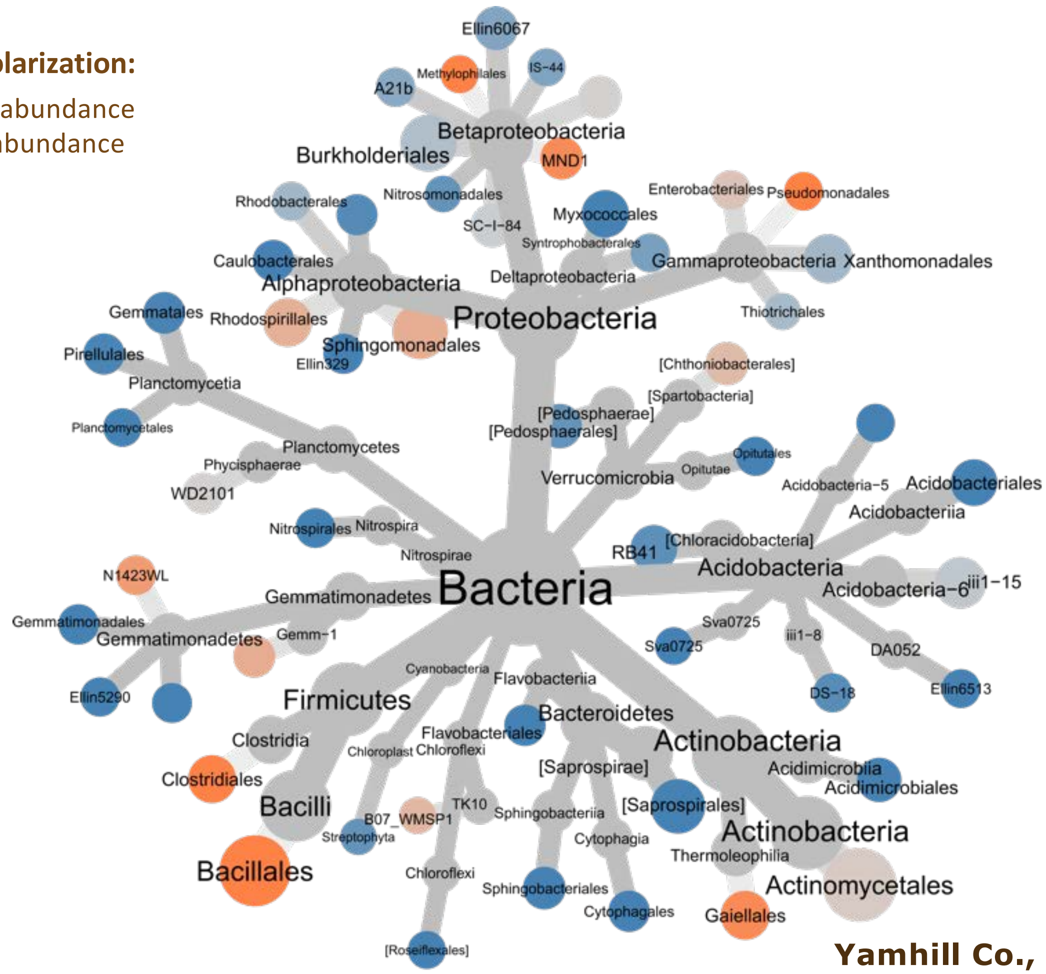
from The Scientist (2013)

How does soil solarization affect the soil microbiome?

Significantly Influenced Bacterial Taxa

Change with solarization:

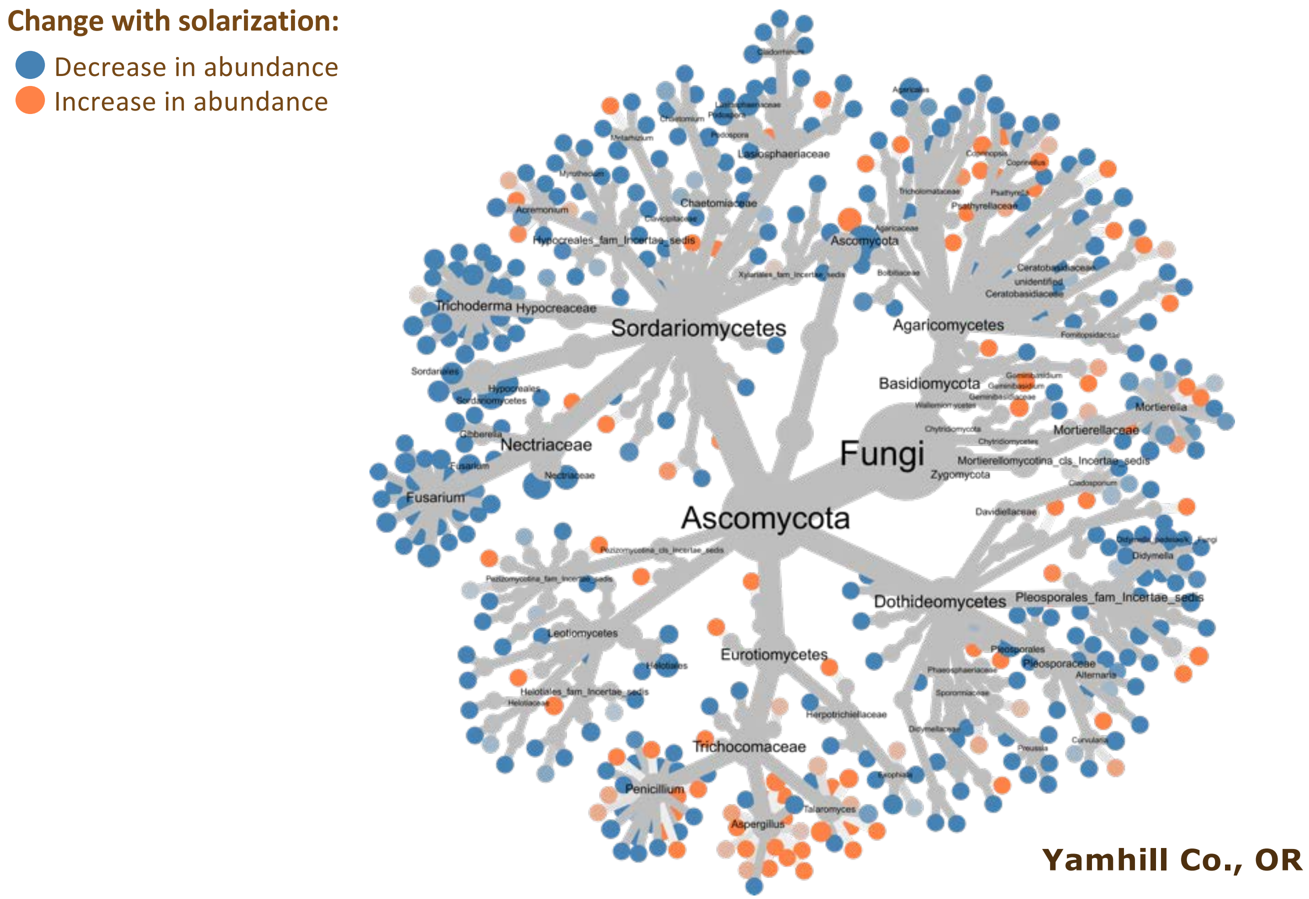
- Decrease in abundance
- Increase in abundance



Yamhill Co., OR

MetacodeR trees (Foster et al., 2017)
Bacterial community composition of significantly influenced taxa
Log_2 fold change associated with SS at 5 cm

Significantly Influenced Fungal Taxa

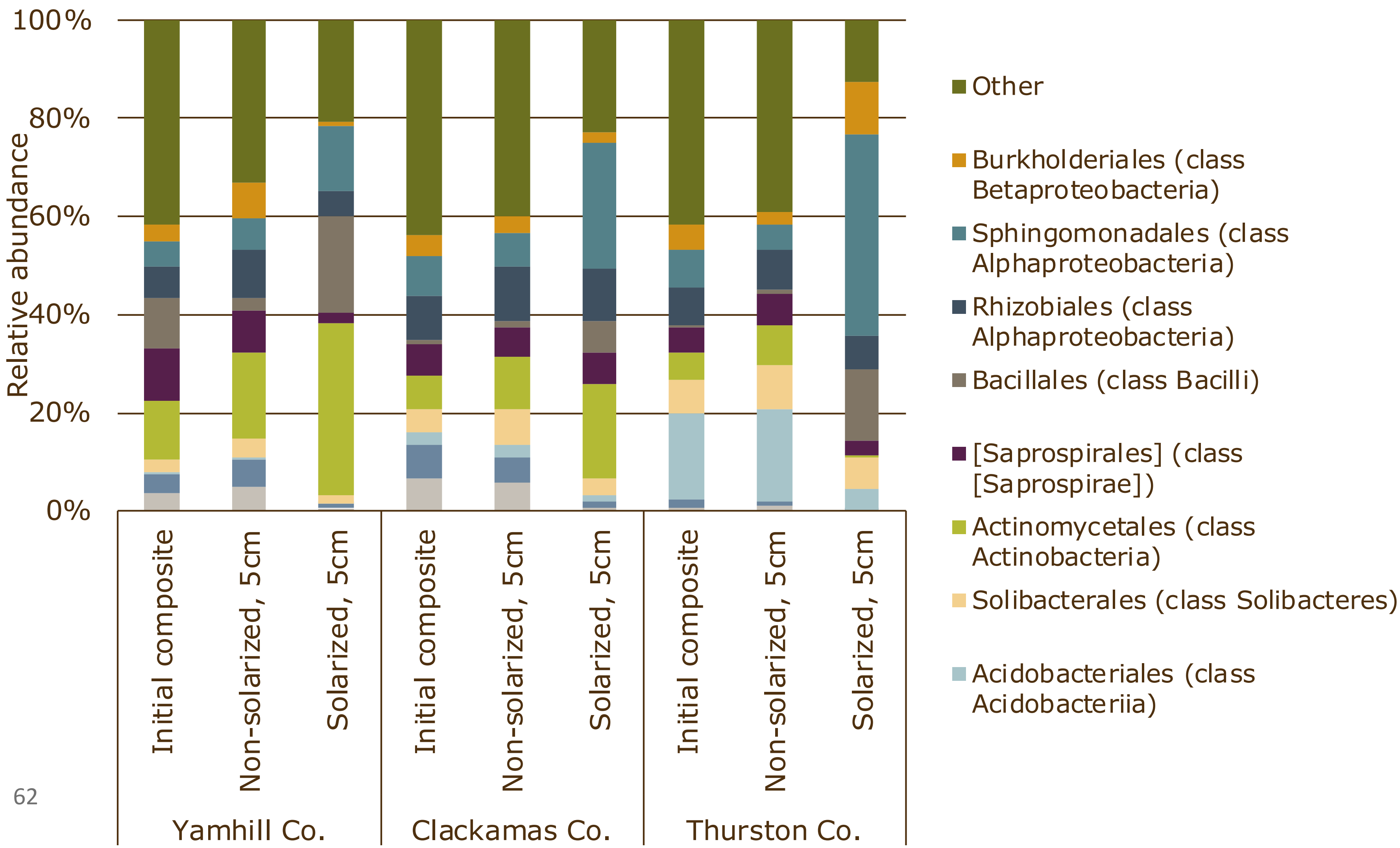


MetacodeR trees (Foster et al., 2017)

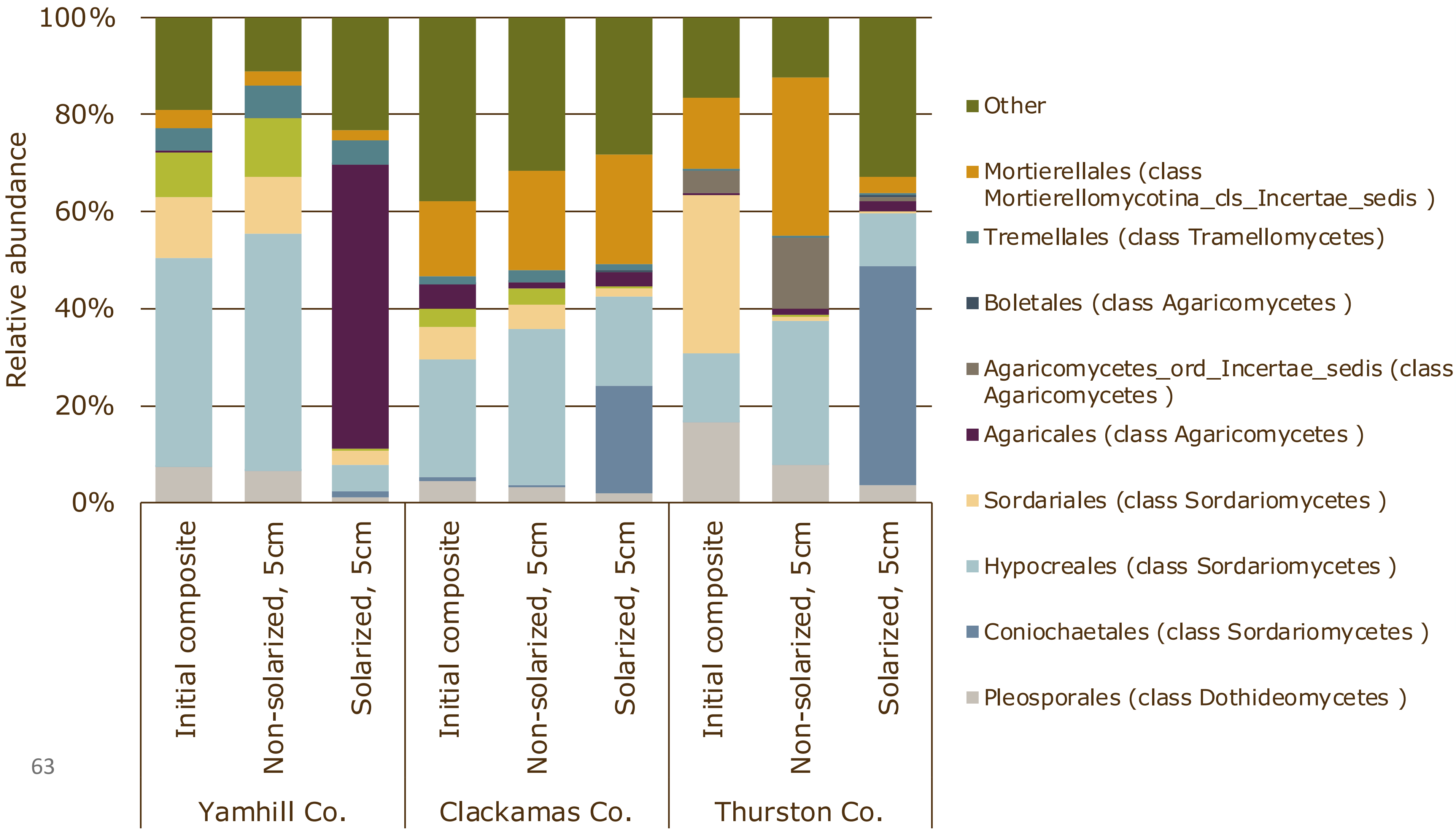
Fungal community composition of significantly influenced taxa

Log_2 fold change associated with SS at 5 cm

Most Abundant Bacterial Orders



Most Abundant Fungal Orders



Crop growth response summary

- Soil solarization generally results in significantly increased crop growth relative to growth in non-solarized soil
- Mechanisms include a reduction of damping-off diseases, and potentially shifts in the soil microbial community, particularly at shallower depths. Crop growth enhancement does not appear to result from increased nutrient availability.

Other Applications of Soil Solarization

Solarization for establishing wildflowers buffer strips for pollinators

April 2019
OSU Organic Farm

Solarization in restoration and remediation

Phytophthora-infested restoration plantings in SF Bay Area

SFPUC contracted to have 9,000 small solarization 'basins' installed at great cost. Many failed. Why? Too small.

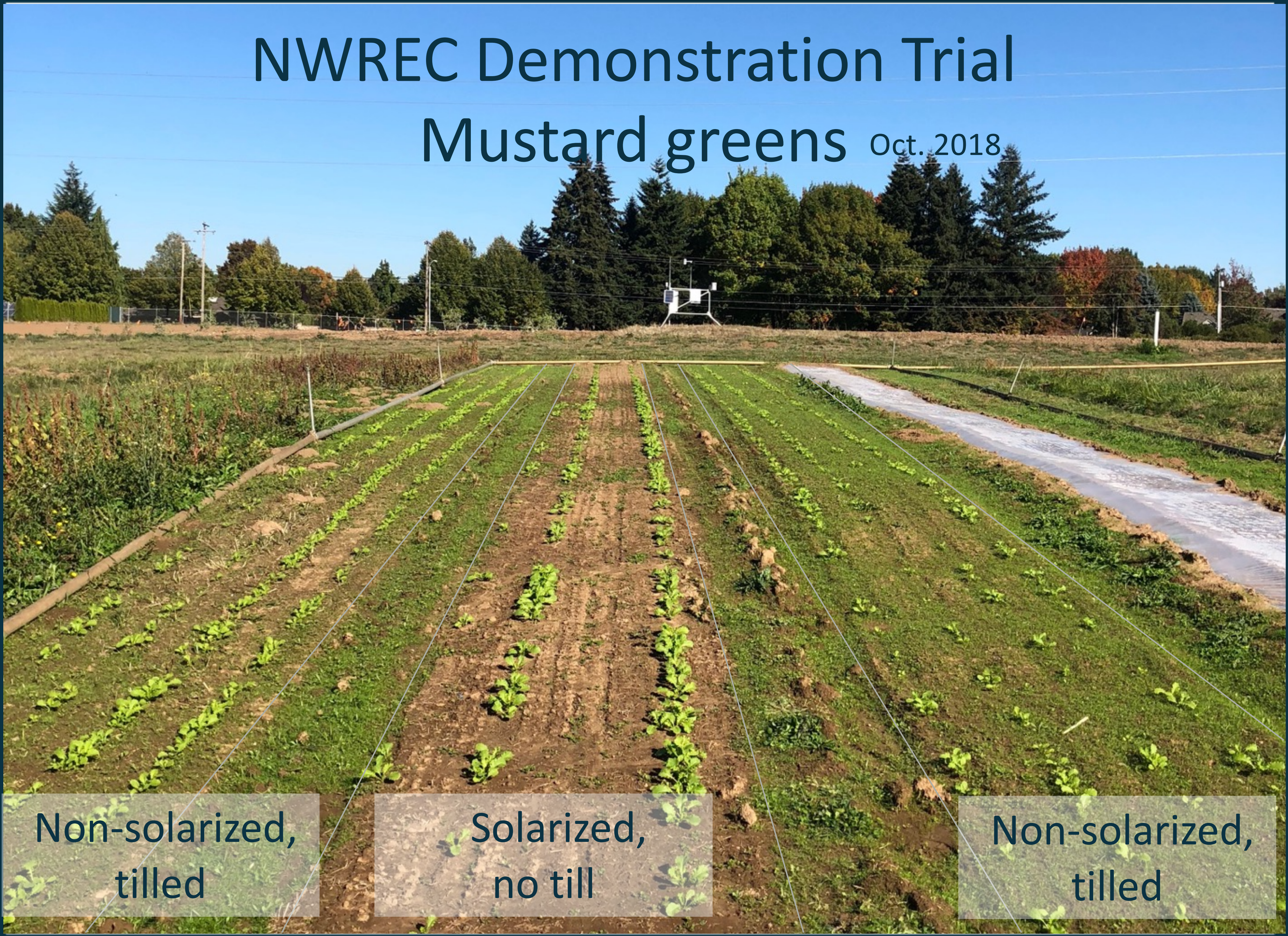
Solarization in restoration and remediation: what is the minimum effective plot size and duration for killing soilborne *Phytophthora* spp.?

NORSDUC quarantine facility in San Rafael, CA

OSU BPP Farm, in Corvallis, OR

Which plot size and treatment period kills *Phytophthora ramorum* to a soil depth of 12”?

	Solarization Period			
Plot size	2 wks	4 wks	6 wks	12 wks
NS control	no	no	no	no
20 x 20”	no	no	no	no
40 x 40”	no	no	yes/no	yes
75 x 75”	yes	yes	yes	yes


NWREC Demonstration Trial
Mustard greens Oct. 2018
Non-solarized, tilled
Solarized, no till
Non-solarized, tilled

Potential solarization "window" for vegetable cropping systems in the PNW

Farm	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Adaptive Seeds	SOL	fall-planted crops grown for seed										
Montecucco Farms	SOL	fall planted perennial										
Koch Family Farm	SOL	cauliflower				cover crop						

Buckland et al. (unpublished)

Practical Tips for Soil Solarization

Plastic film

- Color: transparent (clear)
- Thickness: measured in "mils" [1 mil= 0.001 inch]
  we have used 1.4-mil to 6-mil thick
- Properties: anti-condensation = anti-drip [AC or AD],
  infrared [IR] if possible
- Sold as: horticultural, high tunnel, or solarizing film
- Produced by several manufacturers: Ginegar Plastics; RKW Klerks; RPC bpi Agriculture (formerly AT Films); Polyag. Special orders only.
- Ginegar C-921 (6-mil, AC, IR) stocked at: T & R Lumber, Woodburn, OR
- Widths: 24', 32', 36', 42' (can be cut in half)
- Length: Cut to order

How to solarize

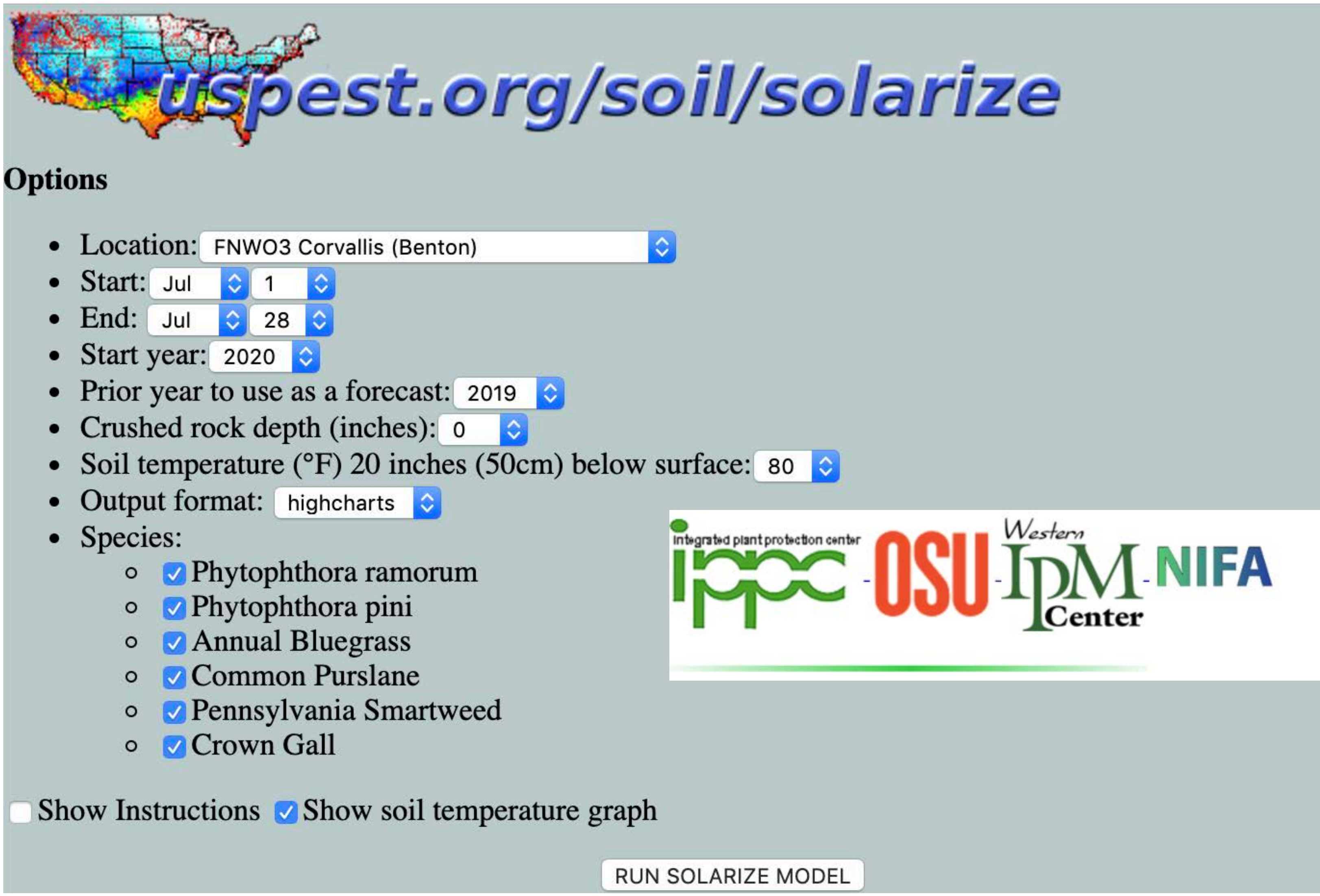
- Till to make a good seedbed
- Remove vegetation, weeds, or lumps on the surface
- Shape beds as if for planting
- Orient beds north-south
- Moisten soil with drip or overhead irrigation
- Cover tightly with solarization plastic
- Seal the ends and edges with soil – an 8-12” band
- Repair any holes or tears with greenhouse repair tape
- Remove plastic just before planting
- When planting seeds or transplants, disturb the soil as little as possible. DO NOT TILL as this will bring non-heated soil and weed seeds up to the surface.

When to solarize, and for how long

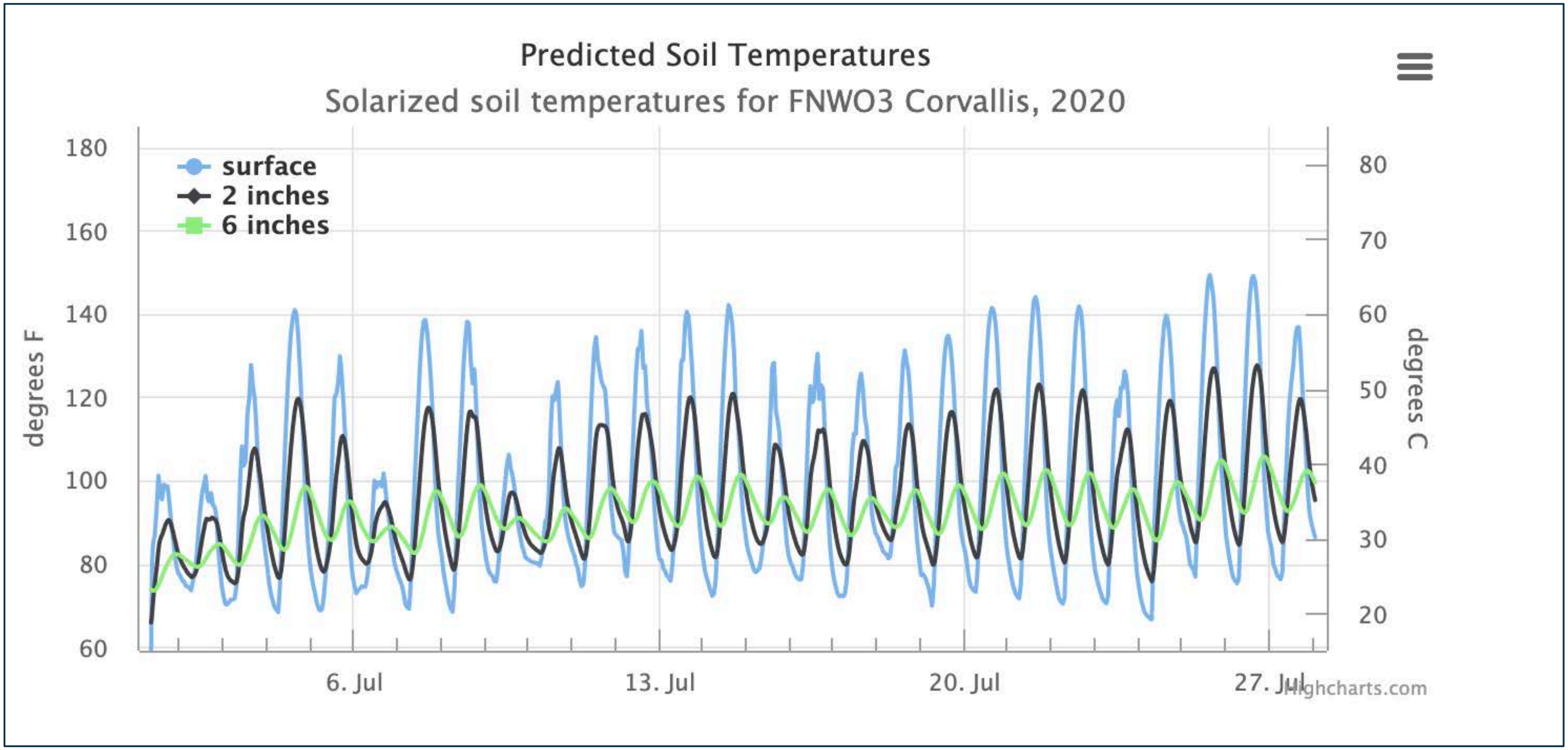
- Solarize for at least 3 weeks. Longer is even better.
- In Oregon: mid-June /early July through August is the best time to solarize.
- Check the online forecasting tool for the required duration for your location and target species

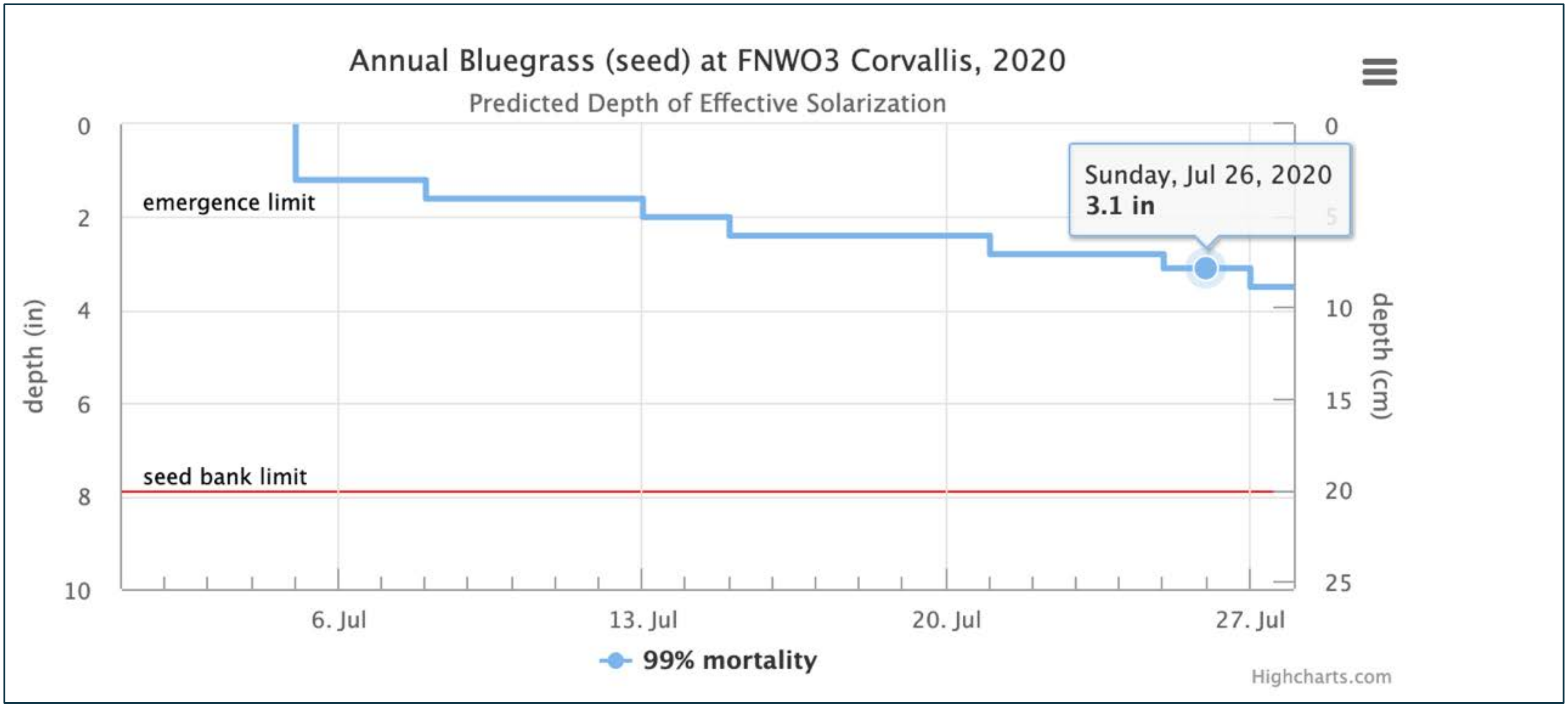
On-line Soil Solarization Forecasting Tool

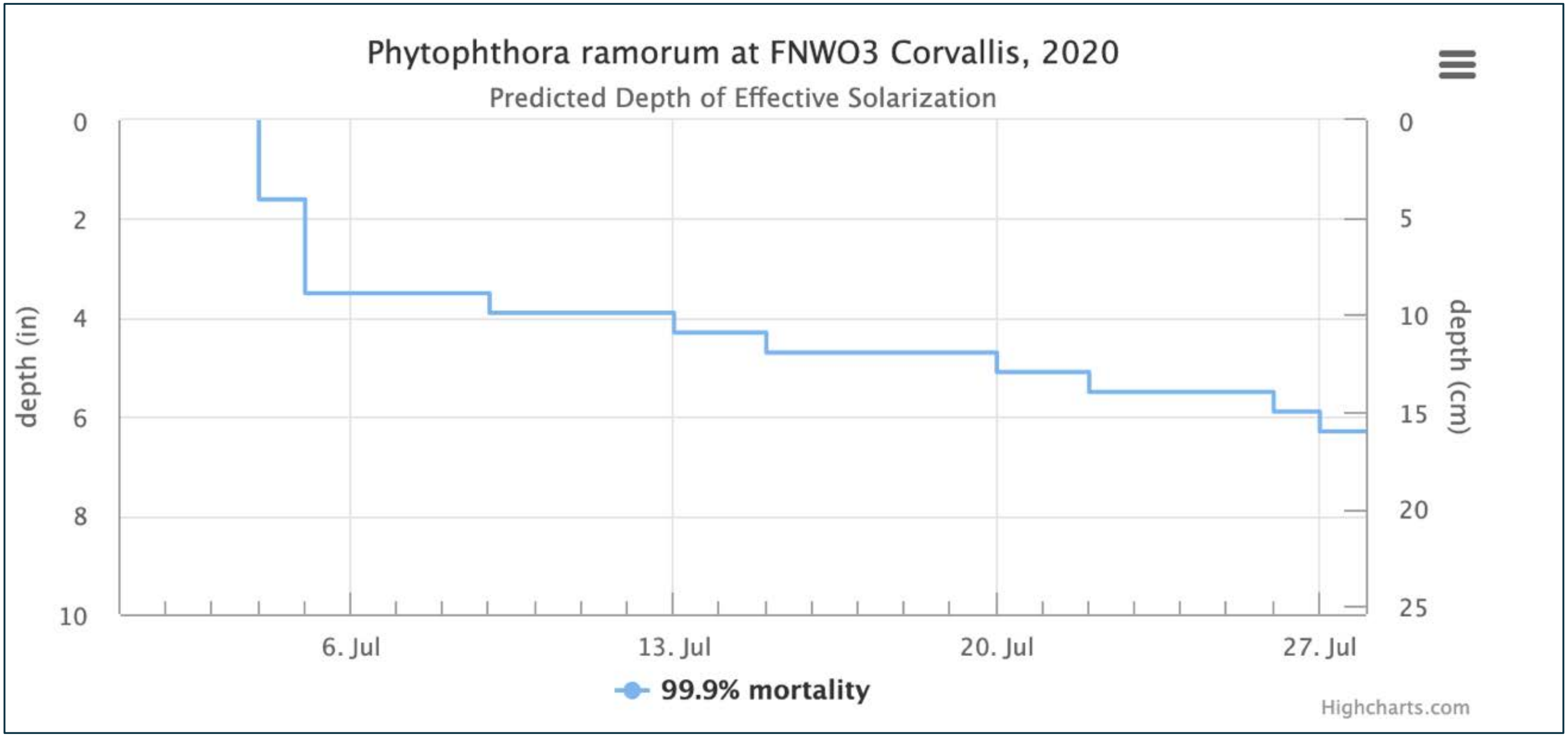
https://uspest.org/soil/solarizeV2beta1

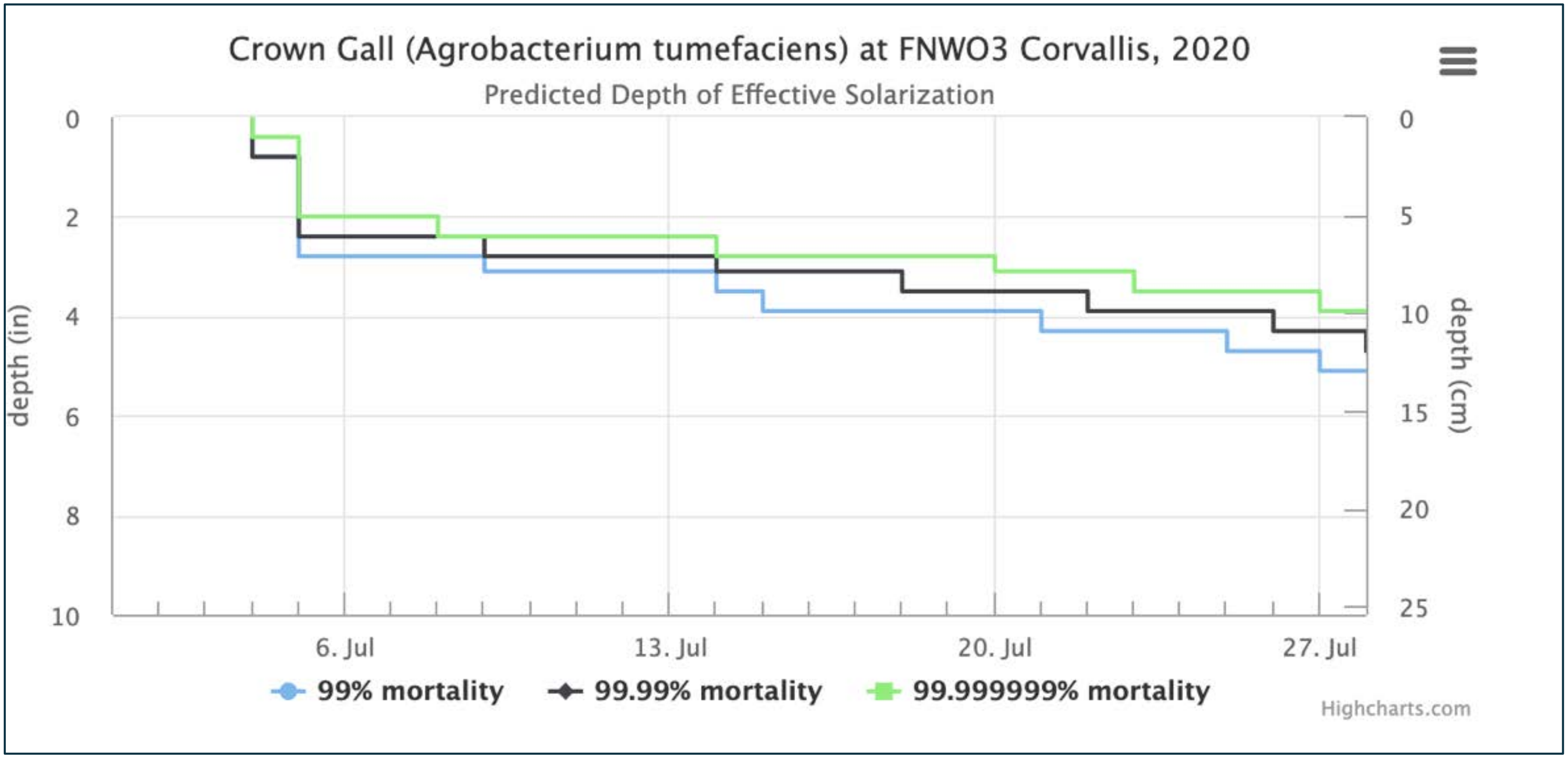


On-line Soil Solarization Forecasting Tool




Annual Bluegrass (seed) at FNWO3 Corvallis, 2020
Predicted Depth of Effective Solarization
emergence limit
seed bank limit
Sunday, Jul 26, 2020
3.1 in
depth (in)
depth (cm)
0
2
4
6
8
10
0
5
10
15
20
25
6. Jul
13. Jul
20. Jul
27. Jul
99% mortality
Highcharts.com


Phytophthora ramorum at FNWO3 Corvallis, 2020
Predicted Depth of Effective Solarization
depth (in)
0
2
4
6
8
10
depth (cm)
0
5
10
15
20
25
6. Jul
13. Jul
20. Jul
27. Jul
99.9% mortality
Highcharts.com


Crown Gall (Agrobacterium tumefaciens) at FNWO3 Corvallis, 2020
Predicted Depth of Effective Solarization
depth (in)
depth (cm)
0
2
4
6
8
10
0
5
10
15
20
25
6. Jul
13. Jul
20. Jul
27. Jul
99% mortality
99.99% mortality
99.999999% mortality
Highcharts.com

Soil Solarization

Disadvantages

- Specialized equipment or hand labor to install
- Plastic cost ~$500 per acre (4' wide beds on 7' centers)
- Plastic manufacture uses fossil fuels but is recyclable in Oregon (Agri-plas Co.)
- Solarization "window" (3+ weeks in mid-summer) not compatible with some cropping systems

Benefits

- Reduction in labor for hand weeding
- Reduced need for herbicides, fumigation, and tillage
- Suitable for organic crops
- Likely long-term reduction in the weed seed bank
- Crop growth benefits
- Reduced seed costs
- Best for fall-planted overwintering crops

For More Information

Online soil solarization model (OR, WA, CA)
https://uspest.org/soil/solarizeV2beta1

Soil solarization for gardens & landscapes (Univ. Calif.)
http://ipm.ucanr.edu/PDF/PESTNOTES/pnsoilsolarization.pdf

Solarization and tarping for weed management on organic farms in the NE USA (Maine)
https://articles.extension.org/pages/74713/solarization-and-tarping-for-weed-management-on-organic-vegetable-farms-in-the-northeast-usa

OSU Soil Solarizers

Oregon State University

Western IPM Center

WESTERN SARE
Sustainable Agriculture Research & Education