Impacts of Soil Steaming on Chickweed and Microbes in High Tunnels

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VVBGA Annual Meeting 1/25/21

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The University of Vermont

Leafy greens revenue losses with Chickweed infestation--more than 50%

Chickweed biology makes it hard to control

Photos: https://aggie-horticulture.tamu.edu/galveston/Weeds/1200_x_800-JPGs/111-Fig_5--Common_Chickweed-GCMGA9999a.jpg

Chickweed germinating in spinach, 10/21/20

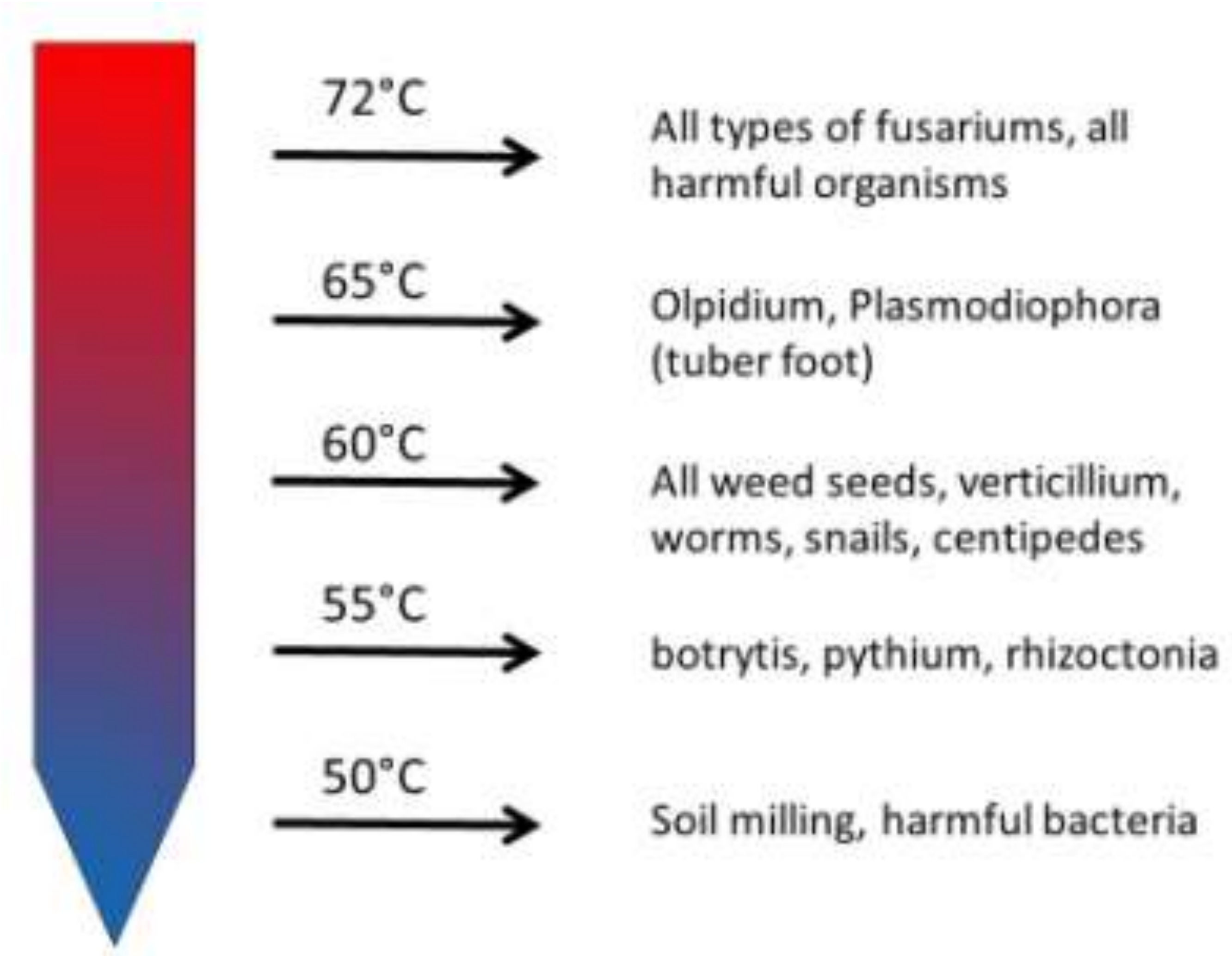
Chickweed thriving, 11/11/20

Chickweed thriving, 1/15/21

Other challenges in high tunnels

So let's steam!

Steaming used to kill many types of organisms



161° F

140° F

Source:
https://royalbrinkman.com/knowledge-center/crop-rotation/steam-soil

Research questions

What is the impact of **different steam temperatures** on **chickweed, soil microbe populations,** and **soil nutrient availability**?

How quickly do microbe populations rebound?

What is the minimum temperature the soil needs to reach during steaming to control chickweed?

Positive, negative, or no impacts on **soil borne disease?**

What are best steaming practices for in-ground high tunnel growing?

- **methods**
- **costs**
- **temperature**
- **time**

Our project

October 2020: **STEAM!**

Blocks w/ different soil temps at 2 inches (120°, 140°, 160° F—target was180° F)

November 2020- Nov 2021:

Soil sample collection (nitrate and microbes): 1 sample PRE steaming, POST steaming samples at 2, 3, 4 weeks, 6 months, and 1 year.

November 2020- September 2022: Track costs, yields, weed populations for 2 years.

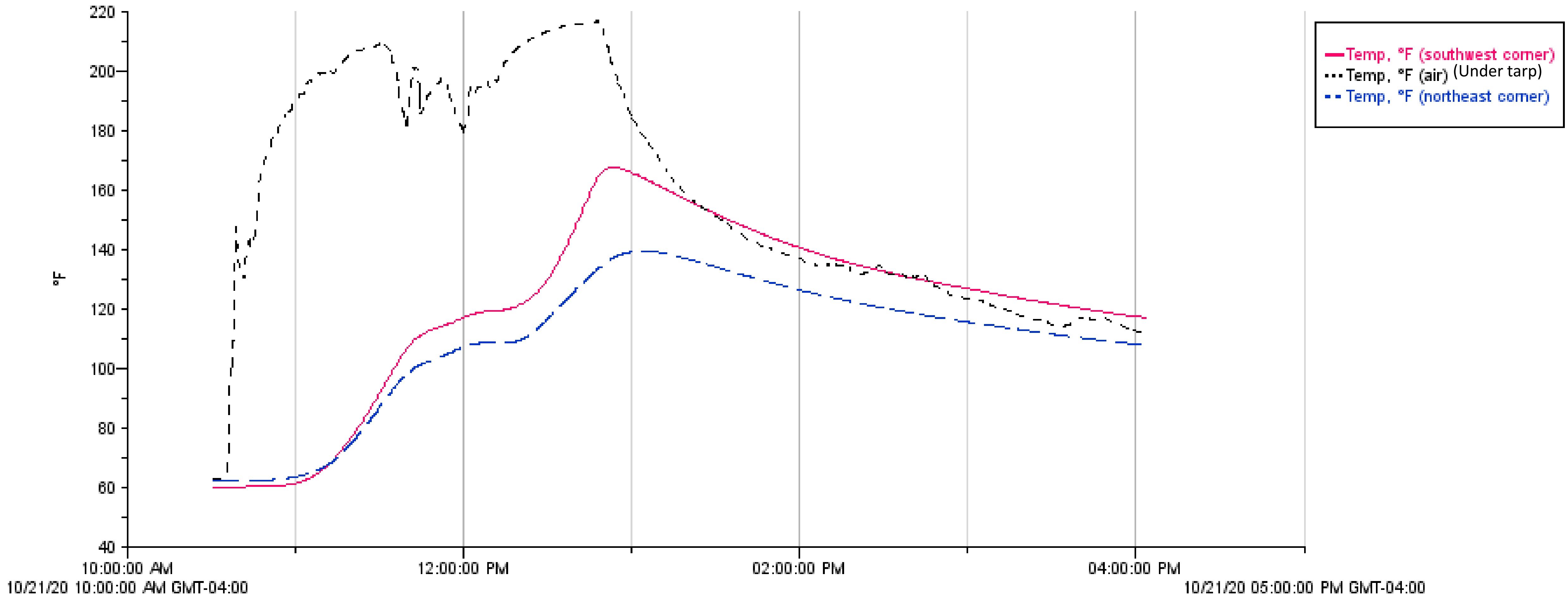
September/ October 2021: STEAM AGAIN?

Methods

- Steamed replicated 16x16 ft blocks
    - 3 temps: 120° F, 140° F, 160° F
- Steam 2” deep, stay at target temp for 30 min
    - Couldn’t reach 180° F as planned
- Pre-moistened soil
- Data log temperatures in multiple places at 2”
- Soil samples taken at 0-4” depth

Trying to reach 180° F soil temp, 2” deep

air temperature and soil temperature in two corners of steam area before and after 1.5 hour steam duration



Challenges

- Learning curve/ achieving temps with new steamer (replaced burner, new valve).
- Timing of steaming vs. planting greens
- Scientific study vs. on farm study.
  - Couldn’t leave a true “control” –chickweed is too much of a problem. Unsteamed areas were determined by unsteamed gaps in tarp.

Calculating duration of steaming needed to hit target temperature

Soil steaming calculation

C. Callahan & B. Maden, 2020 10 12, UVM Extension

Values in blue are adjustable, values in **black** are calculat

Bed width	180	inches	Assumptions		
Bed length	95	feet	1. Assumes perfect steam distribtution in hood / under plastic		
Heating depth	2	inches	2. Does not account for boiler recovery due to makeup water		
Starting temp	65	°F	3. Does not account for any steam super heat, only assumes ambient pressure steam		
Target temp	140	°F	4. Assumes fuel oil as heating fuel.		
Soil texture / type	Silt Loam		5. Does not account for heat transfer within the soil (yet).		
Soil moisture	Moist				
Dry soil density	1.48	g/cm3			
	92.3	lb/ft3			
Actual soil density	2.21	g/cm3			
	138.5	lb/ft3			
Soil heat capacity	0.4	BTU/lb/F			
Thermal conductivity	0.74	BTU/hr/ft2/F			
I know how long I have, but need to know my nozzle sizing.			**I know my nozzle sizing, but want to know how long it will take.**		
Time to heat	180	minutes	Burner nozzle size	5	GPH
Heated soil mass	32884	lb	Boiler efficiency	75	%
Energy input required	986524	BTU	Fuel heating value	140000	BTU/gal for oil
Energy rate (steam)	328841	BTU/hr			
	329	lb/hr	Burner firing rate	700000	BTU/hr
			Energy rate (steam)	525000	BTU/hr
Boiler efficiency	84	%	Heated soil mass	32884	lb
Fuel heating value	140000	BTU/gal for oil			
			Time to heat	**113**	minutes
Burner firing rate	391478	BTU/hr		1.9	hours
Burner nozzle size	**2.8**	**GPH oil**			

Chris Callahan's
steam calculator

Early results: 2 weeks after steaming

STEAMED 130° F

UNSTEAMED

At harvest time…

STEAMED 140° F—10 weeks after steaming

UNSTEAMED—6 weeks after planting

What happens in 1 square foot unsteamed?

25% Spinach damping off

341 Chickweed Seedlings pulled week 1

Same spot

5 weeks later

11 weeks later

What happens in 1 square foot, unsteamed & hand weeded?

Not weeded

Hand weeded

11/11/20

Cost of hand weeding

Weeding time for 1 sq ft = *5.4 minutes* @ $15/ hr = **$1.35 weeding labor**

1 lb/ sq ft expected yield
Crop loss due to lower density @ 50% = *0.5 lb* @ $9/ lb = **$4.50 crop value**

Net = $3.15

Cost of steaming

Steaming costs for 1 sq ft = ***$0.18***

1 lb/ sq ft expected yield @ $9/ lb = **$9 crop value**

Net = $8.82

Detailed cost of steaming

Materials		
Steamer purchase& delivery	$5,800	
Steam hose	$330	
Weights & delivery hose	$100	
	$6,230	Over 10 years, 3 tunnels = **$207 per tunnel annual cost**
Running costs per 30x96 ft tunnel		
Fuel (diesel or kerosene)	4 gal/ hour @$2/ gallon per 250 ft2	
Running costs	12 sets per tunnel* 1.5 hours each	
	$ 144	per tunnel fuel
Person time		
(8 hours per tunnel @ $18/ pe	**$ 144**	per tunnel person
	$ 495	**Annual cost per tunnel**
	$ 0.18	**per square ft**

Comparing temperatures -- 6 weeks after steaming

STEAMED 120 ° F

STEAMED 140 ° F

Impact of soil disturbance during transplanting on chickweed emergence

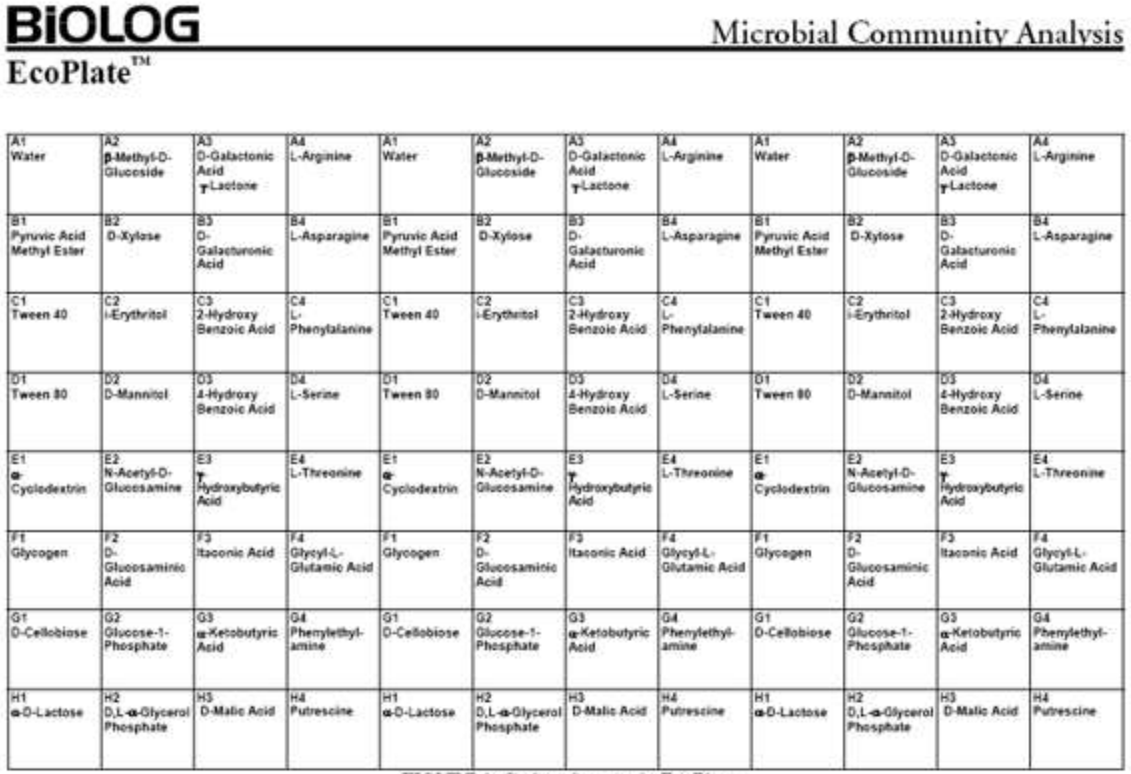
STEAMED 160° F

Impacts on microbial communities

Biolog EcoPlates

Community Level Physiological Profiling (CLPP)

Example of a BIOLOG plate inoculated with a dilution of soil and incubated for 48 hours. The purple wells contain carbon sources that were used by the microbial community. The intensity of the purple coloration indicates the degree of carbon source usage by the community.



A1 Water	A2 β-Methyl-D-Glucoside	A3 D-Galactonic Acid γ-Lactone	A4 L-Arginine	A1 Water	A2 β-Methyl-D-Glucoside	A3 D-Galactonic Acid γ-Lactone	A4 L-Arginine	A1 Water	A2 β-Methyl-D-Glucoside	A3 D-Galactonic Acid γ-Lactone	A4 L-Arginine
B1 Pyruvic Acid Methyl Ester	B2 D-Xylose	B3 D-Galacturonic Acid	B4 L-Asparagine	B1 Pyruvic Acid Methyl Ester	B2 D-Xylose	B3 D-Galacturonic Acid	B4 L-Asparagine	B1 Pyruvic Acid Methyl Ester	B2 D-Xylose	B3 D-Galacturonic Acid	B4 L-Asparagine
C1 Tween 40	C2 i-Erythritol	C3 2-Hydroxy Benzoic Acid	C4 L-Phenylalanine	C1 Tween 40	C2 i-Erythritol	C3 2-Hydroxy Benzoic Acid	C4 L-Phenylalanine	C1 Tween 40	C2 i-Erythritol	C3 2-Hydroxy Benzoic Acid	C4 L-Phenylalanine
D1 Tween 80	D2 D-Mannitol	D3 4-Hydroxy Benzoic Acid	D4 L-Serine	D1 Tween 80	D2 D-Mannitol	D3 4-Hydroxy Benzoic Acid	D4 L-Serine	D1 Tween 80	D2 D-Mannitol	D3 4-Hydroxy Benzoic Acid	D4 L-Serine
E1 α-Cyclodextrin	E2 N-Acetyl-D-Glucosamine	E3 γ-Hydroxybutyric Acid	E4 L-Threonine	E1 α-Cyclodextrin	E2 N-Acetyl-D-Glucosamine	E3 γ-Hydroxybutyric Acid	E4 L-Threonine	E1 α-Cyclodextrin	E2 N-Acetyl-D-Glucosamine	E3 γ-Hydroxybutyric Acid	E4 L-Threonine
F1 Glycogen	F2 D-Glucosaminic Acid	F3 Itaconic Acid	F4 Glycyl-L-Glutamic Acid	F1 Glycogen	F2 D-Glucosaminic Acid	F3 Itaconic Acid	F4 Glycyl-L-Glutamic Acid	F1 Glycogen	F2 D-Glucosaminic Acid	F3 Itaconic Acid	F4 Glycyl-L-Glutamic Acid
G1 D-Cellobiose	G2 Glucose-1-Phosphate	G3 α-Ketobutyric Acid	G4 Phenylethyl-amine	G1 D-Cellobiose	G2 Glucose-1-Phosphate	G3 α-Ketobutyric Acid	G4 Phenylethyl-amine	G1 D-Cellobiose	G2 Glucose-1-Phosphate	G3 α-Ketobutyric Acid	G4 Phenylethyl-amine
H1 α-D-Lactose	H2 D,L-α-Glycerol Phosphate	H3 D-Malic Acid	H4 Putrescine	H1 α-D-Lactose	H2 D,L-α-Glycerol Phosphate	H3 D-Malic Acid	H4 Putrescine	H1 α-D-Lactose	H2 D,L-α-Glycerol Phosphate	H3 D-Malic Acid	H4 Putrescine

FIGURE 1. Carbon Sources in EcoPlate

Distribution of carbon sources in the BIOLOG EcoPlate.

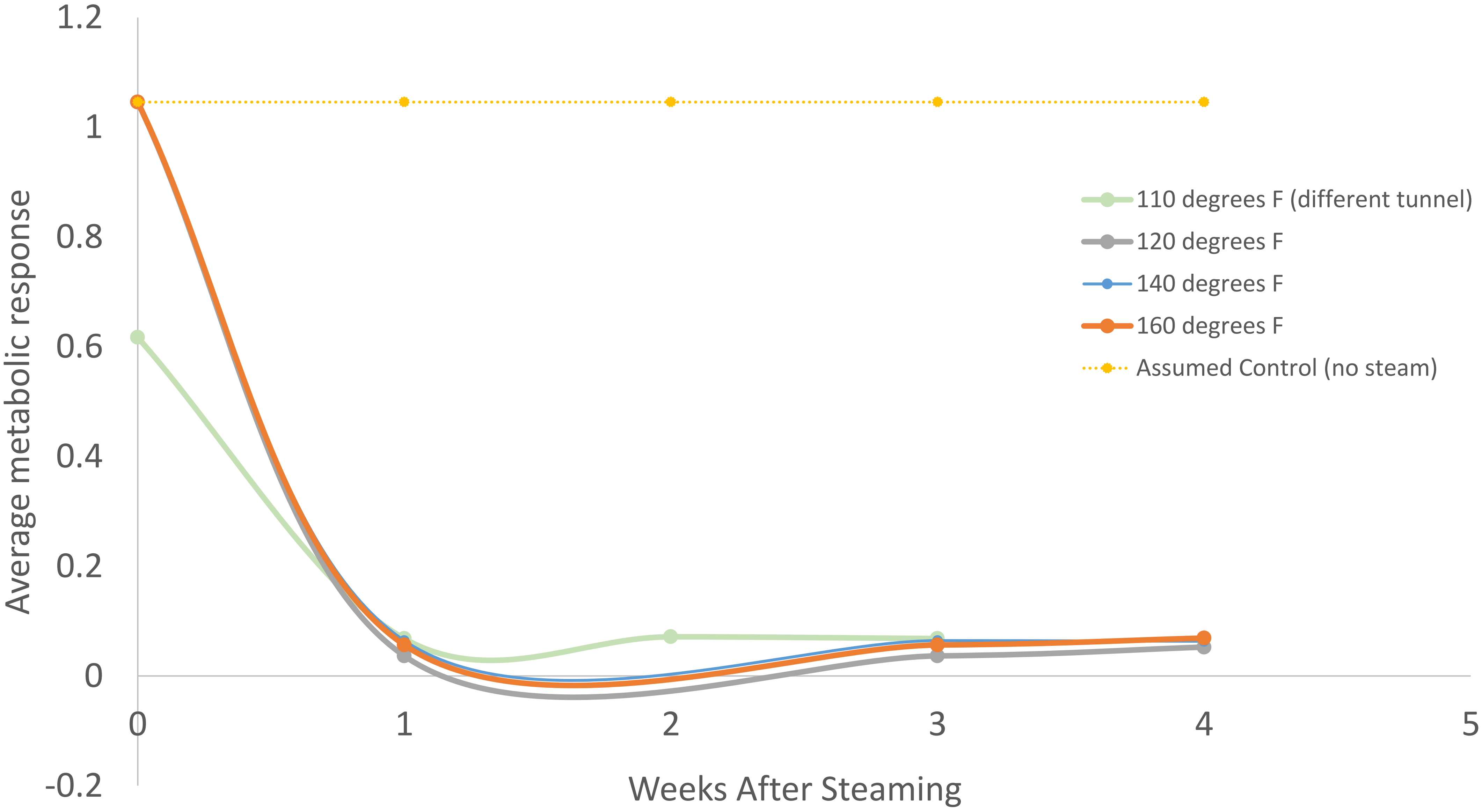
Microbe population data

Average metabolic response (AMR) average respiration of the C sources by the microbial community. Communities can be compared.

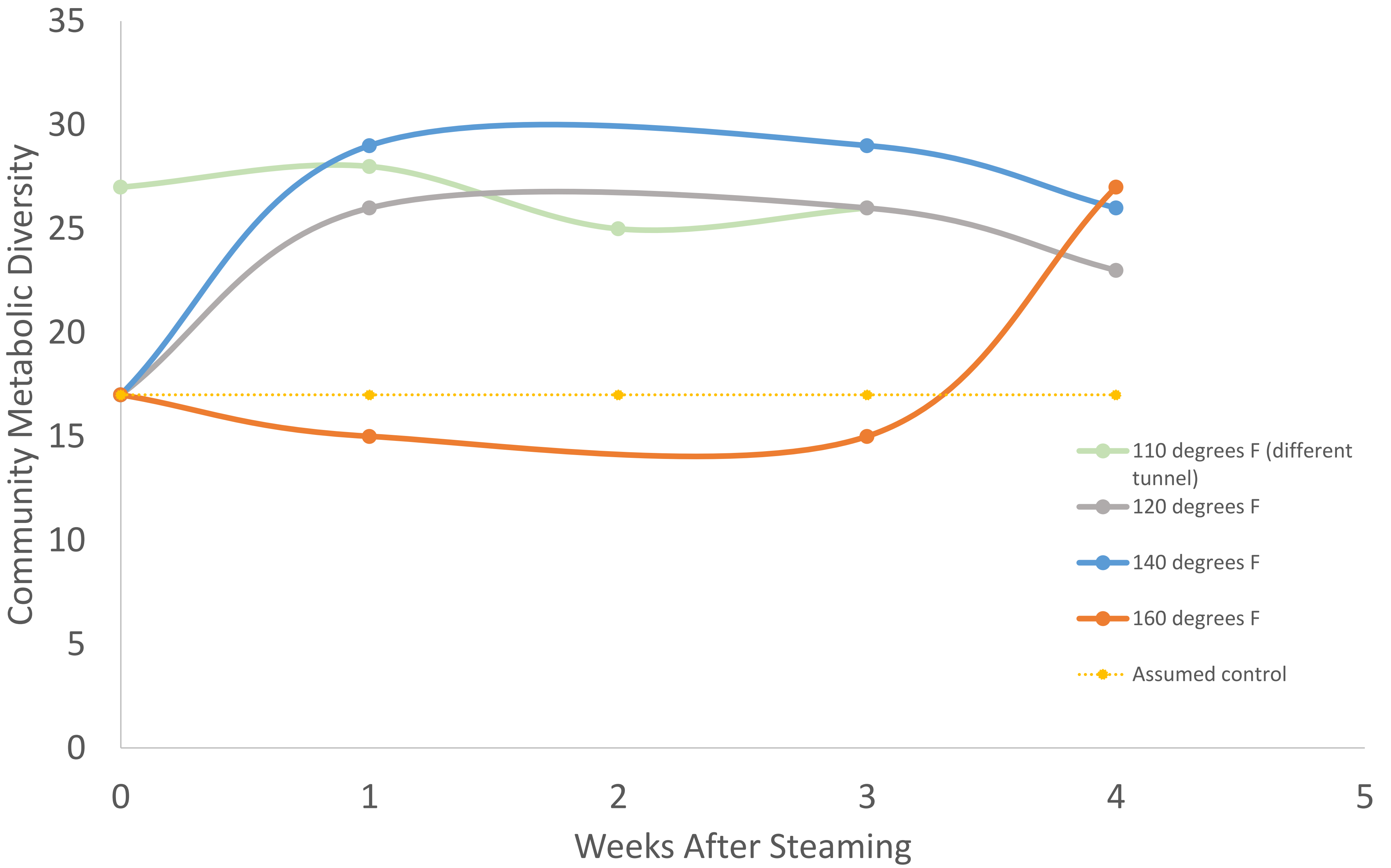
Community metabolic diversity (CMD) is number of substrates utilized by the community. Functional richness or diversity.

Example of a BIOLOG plate inoculated with a dilution of soil and incubated for 48 hours. The purple wells contain carbon sources that were used by the microbial community. The intensity of the purple coloration indicates the degree of carbon source usage by the community.

Impact of steaming on amount of microbe activity



Impact of steaming on microbe community diversity



Preliminary conclusions & future questions

*With **only 1 month of data**, we wonder….*

- **Steam temperature differences –** immediate impact on chickweed control at 130 and above; microbe populations crash at all temps, but community diversity doesn't—why?
- What will we see in **1 year**? **2 years**?
- What impact would **inoculating treatments** with compost or microbial products have?
- **Ultimate impact on diseases & nutrients?**
    - What post steaming management is necessary to maintain healthy crops?

Resources

[Sioux Steamer]

https://soilsteam.com/

https://royalbrinkman.com/knowledge-center/crop-rotation/steam-soil

Marubun Steamer, Japan

FAO Steaming brief

http://soil-steaming-steam-boiler-blog.com/

Thank You!

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