2024 NORTH AMERICAN BIOCHAR CONFERENCE

— USBI —

CALIFORNIA, USA

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Biochar's effect on carbon dynamics of manure compost, soil, and it's effect on plant productivity

Melinda L. Gonzales

Brendan P. Harrison, Touyee Thao, Si Gao, Samuel Lee, Alicia Corcuchia, Gerardo Diaz, Teamrat A. Ghezzehei, Rebecca Ryals

Environmental Systems

UC Merced multi-department collaboration:

- Engineers
- Economist
- **Soil biogeochemist**
- **Soil physicist**
- **Agroecologist**

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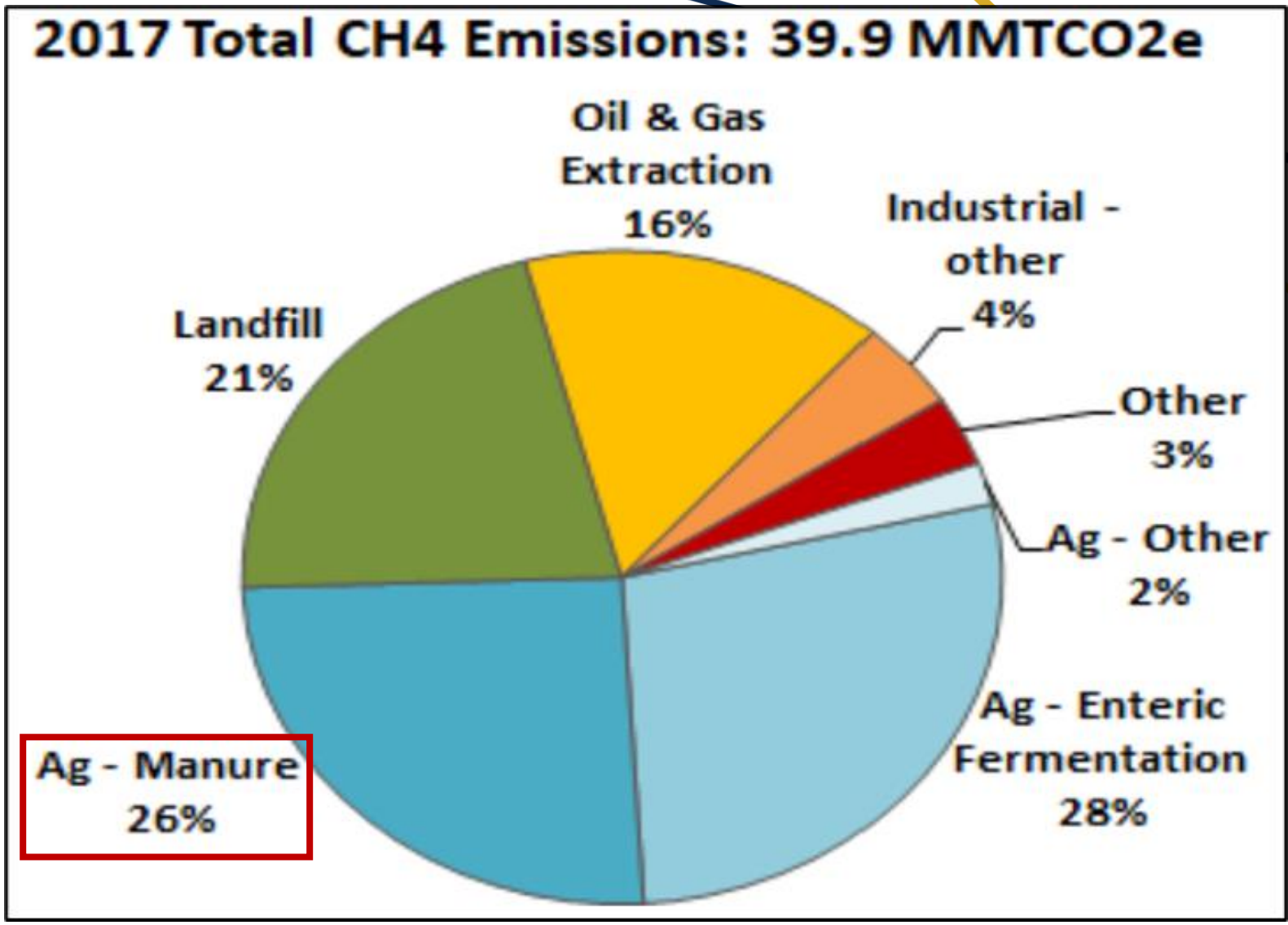
Our studies




Dairy Manure accounts for over ½ of state methane emissions



CARB, 2019

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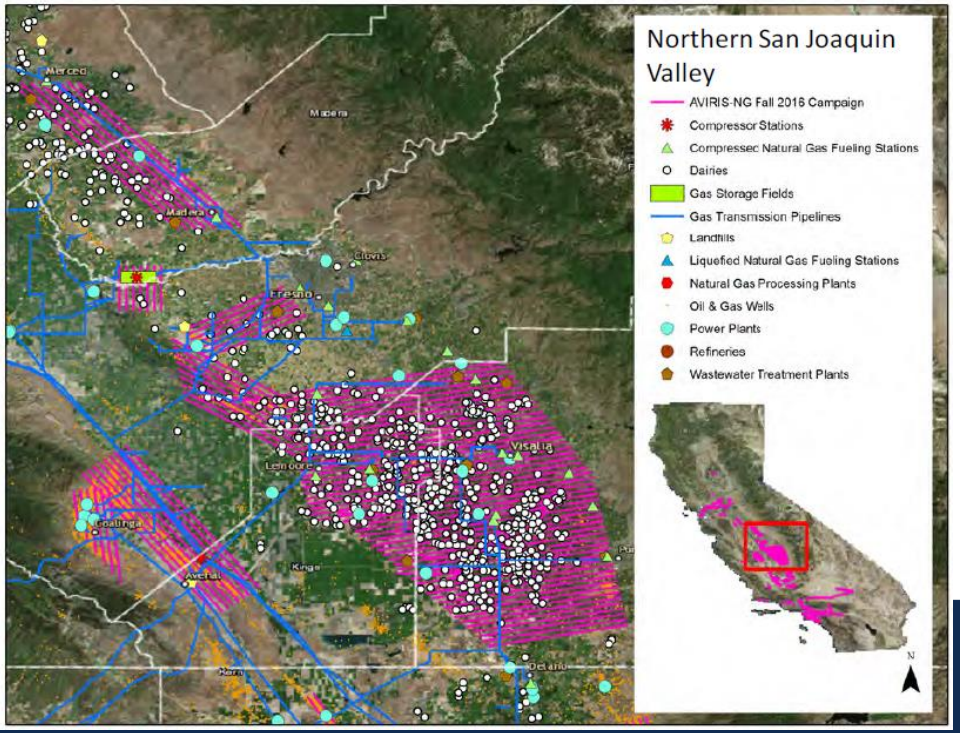

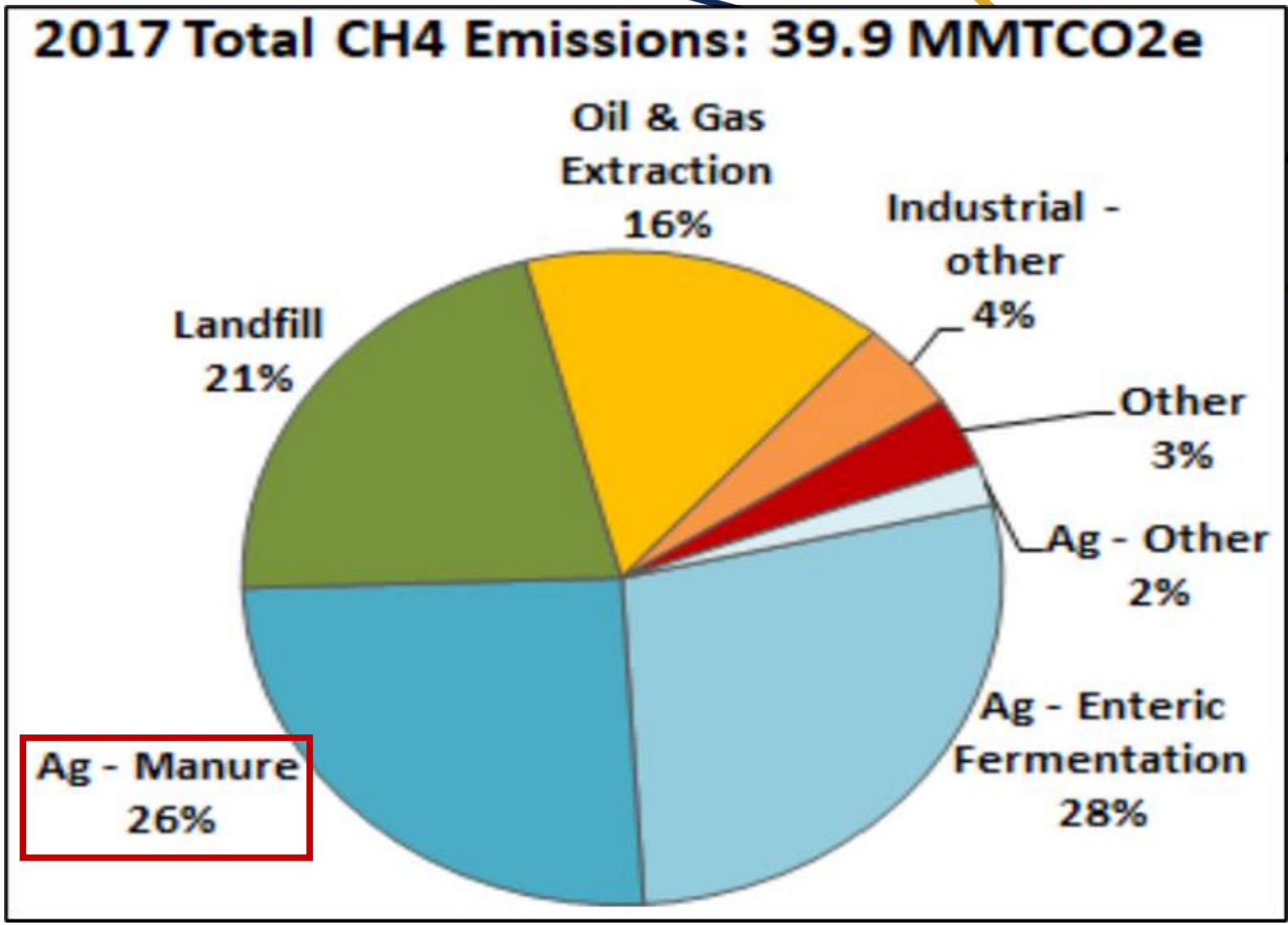

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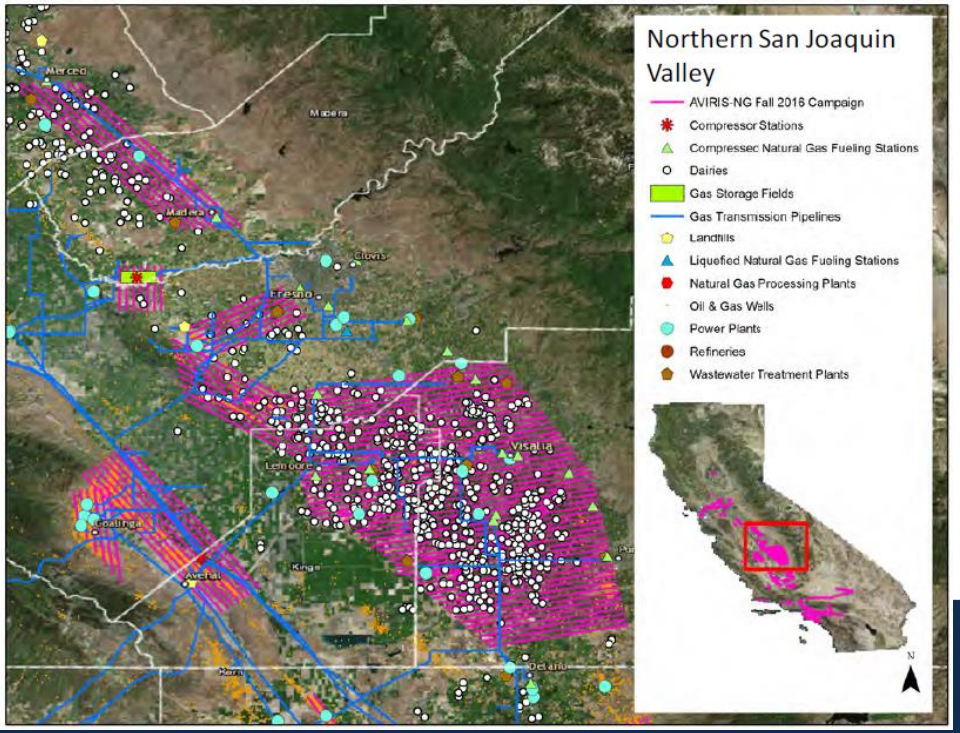
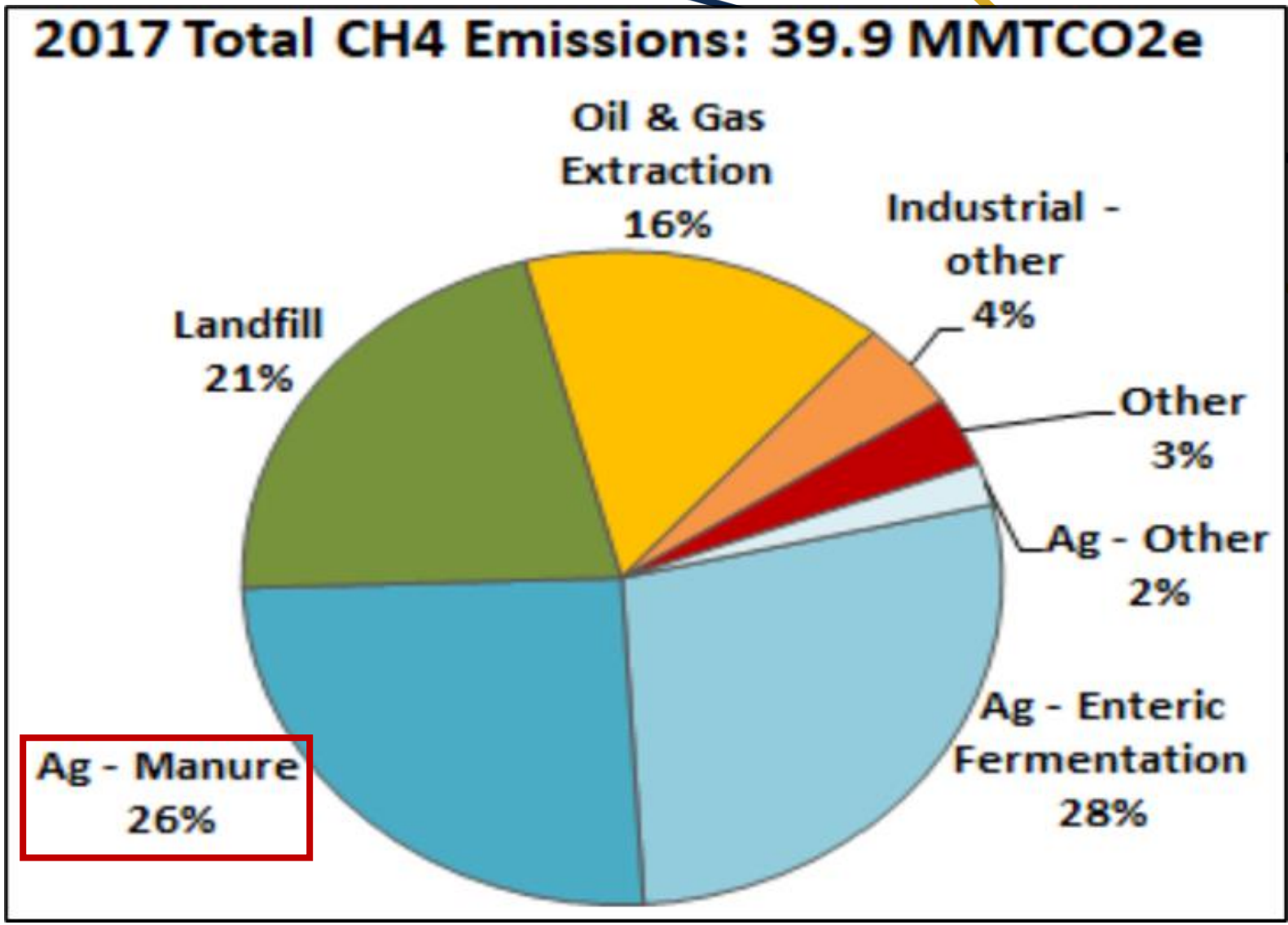




Senate Bill: 1383

CARB, 2019

Agriculture in the Central Valley (CA)

Productivity

CDFA,2014; 2017; 2018

Horwath, 2016

Agriculture in the Central Valley (CA)

Productivity

CDFA,2014; 2017; 2018

Horwath, 2016

Waste/Resource

Estimated from statistics by Fischer, 1998

Parsons, 2020

Current Linear Models

Almond prunings → Open burning → Air pollution

Dairy manure → Lagoons, stockpiles → CH_4, N_2O emissions

Fertilizer, Raw manure → Crop production → NO_3 leaching, N_2O emissions

Circular Model

Pyrolysis

Biochar

Almond shells & prunings

Digestion, Composting

Biochar co-compost

Dairy manure

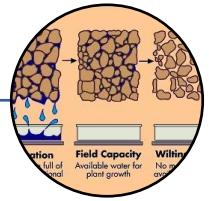
Crop production

Air pollution, GHG, N loss, fertilizer & water use

Biochar: a potential CH_4 mitigation and alternative waste management strategy

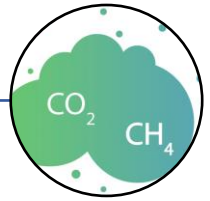
Benefits of biochar

Increase C sequestration



Increase soil nutrient and water retention

Alternative waste management



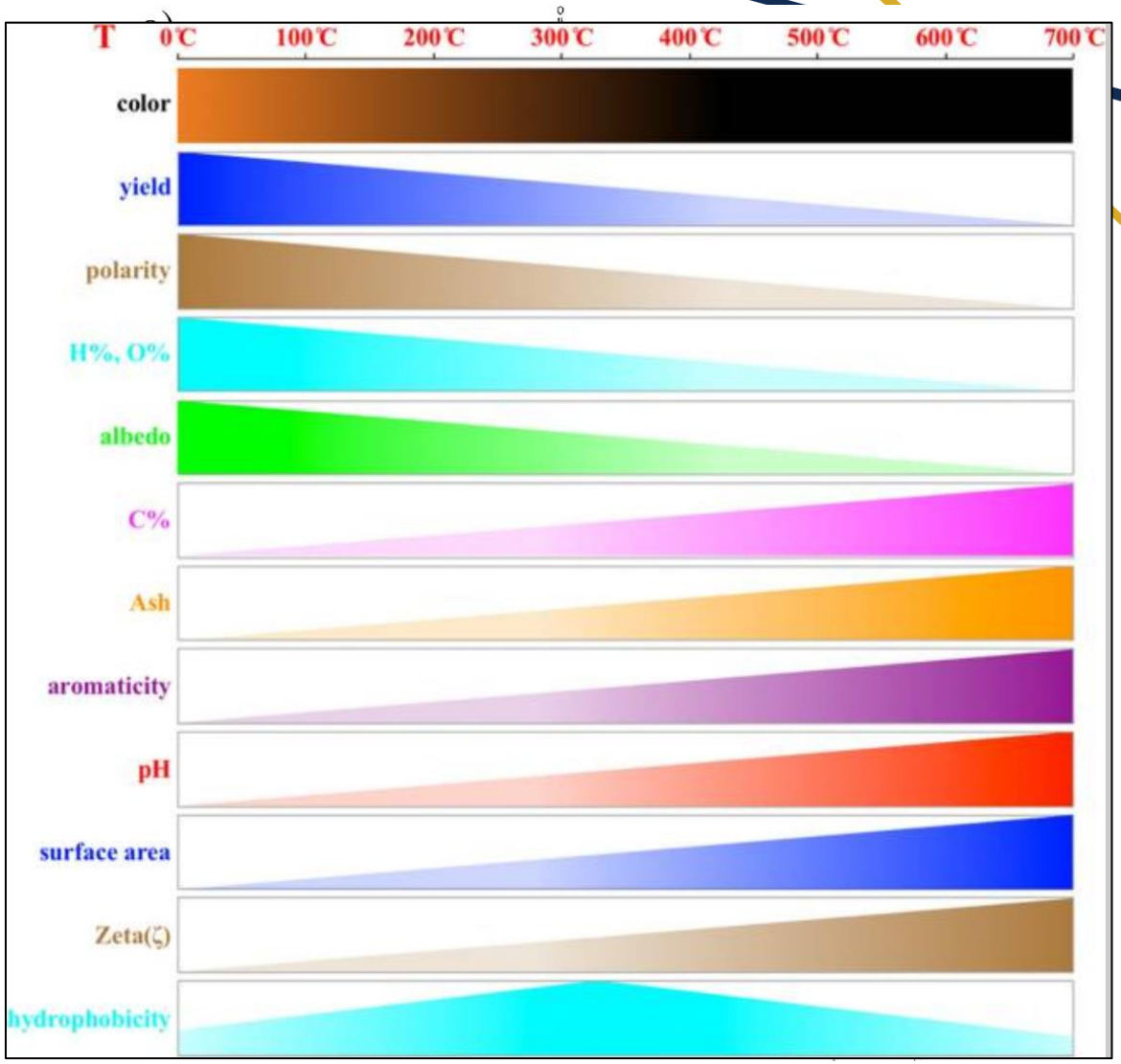
Mitigate GHG emissions

Oomori et al., 2016, Feng et al., 2012, Liu et al., 2011, Yuan et al., 2018, He, et al., 2017, Qi et al., 2018, Koyama et al., 2016

What is biochar?

Partial combustion product of plant matter

Biochar physical and chemical composition varies depending on pyrolysis conditions



Xiao et al, 2018

What we want to know…

Feedstock

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Application Rate

5 t ha^{-1}	10 t ha^{-1}	20 t ha^{-1}

What we want to know…

Feedstock

Application Rate

5 t ha^{-1}	10 t ha^{-1}	20 t ha^{-1}

Soil Application

Our studies




Our studies

Biochar co-composting

Purpose:

Can biochar reduce methane emissions in dairy manure composting?

Our studies

Biochar co-composting

Our studies

Biochar co-compost amendment

Purpose:

How does biochar influence emissions and nutrient retentions?

Our studies

Biochar co-composting

Biochar co-compost amendment

Field Experiments

- To answer our broader questions

Our studies

Purpose

How does biochar type and application rate influence methane emissions in dairy manure composting?

Biochar co-composting

Our studies

Biochar co-composting

Biochar co-compost amendment

Our studies

Purpose

How does biochar co-compost influence plant biomass and how does it compare to synthetic fertilizer?

Biochar co-compost amendment

Our studies

Lab/Greenhouse Scale Experiments

- To answer more questions at a feasible scale

Biochar co-composting

Biochar co-compost amendment

Biochar

- 350°C (mobile pyrolysis unit)
  - Walnut Shell
  - Almond Shell
  - Almond Tree Clippings

- 900°C (Oregon Biochar Solutions)
  - Rogue Biochar

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OREGON BIOCHAR SOLUTIONS

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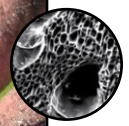
OREGON BIOCHAR SOLUTIONS

Biochar Characterization

Proximate Analysis

Elemental Analysis

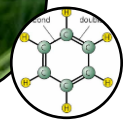


Surface Area, Porosity, & Roughness

Dissolved Organic C

Hydrophobicity

pH, EC, & CEC

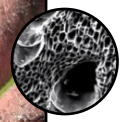


Functional Groups

Biochar Characterization

Proximate Analysis

Elemental Analysis



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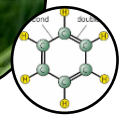

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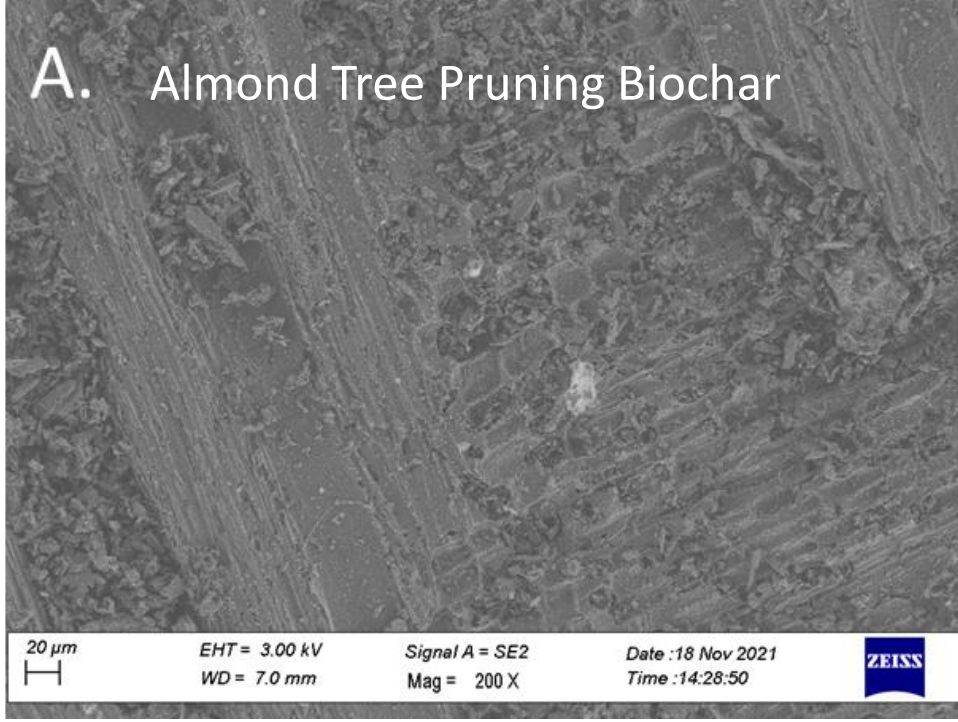

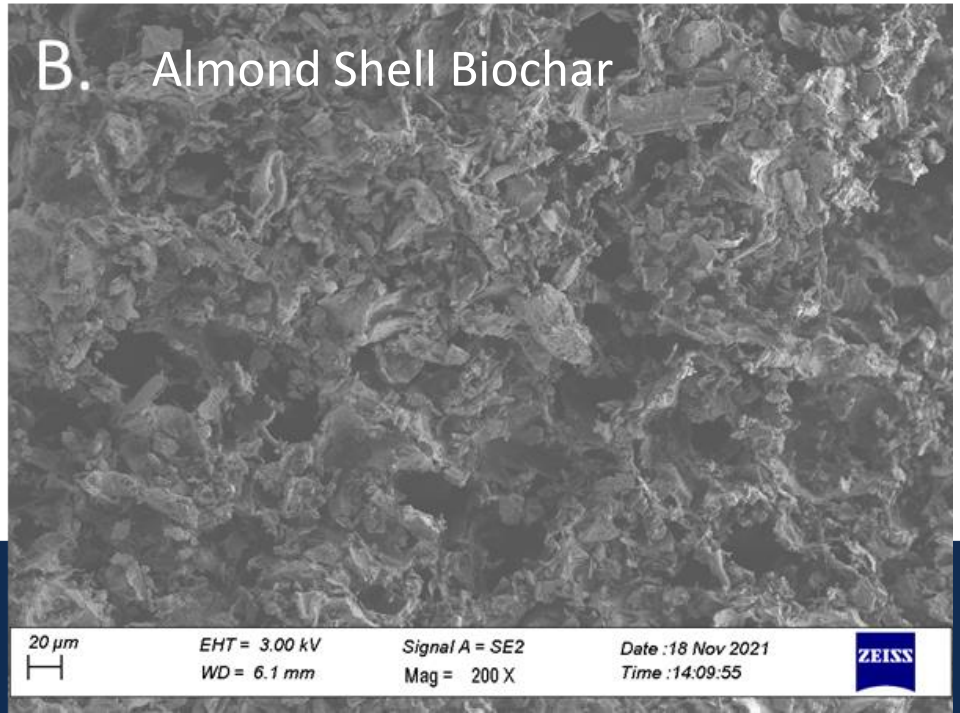

Our studies

Biochar Co-composting

Harrison, B. P., et al. (2022) Environ. Sci. Technol. 56, 15, 10987-10996

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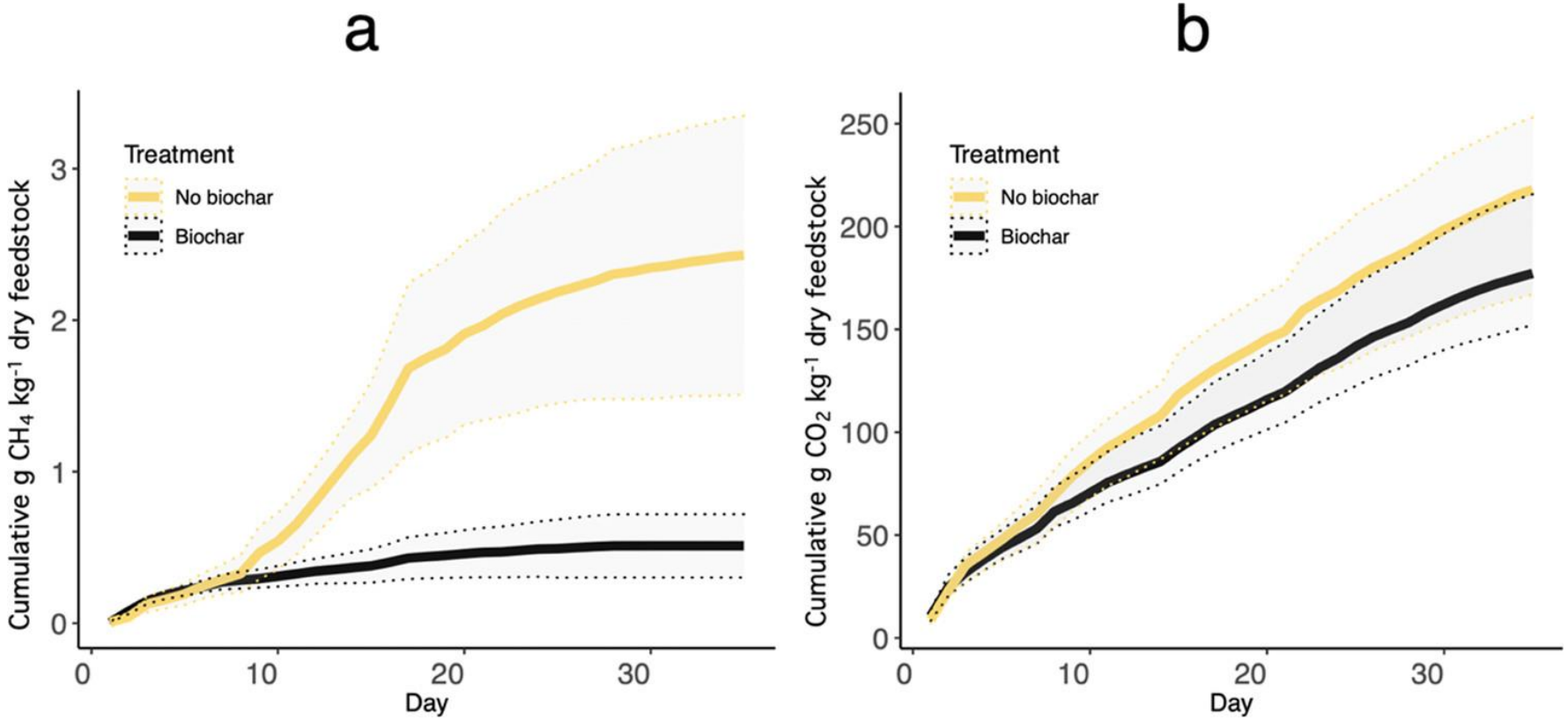
Biochar reduced methane emissions by 84%!



Our studies

Biochar application to soil

Gao, S., et al. (2023) GCB Bioenergy 15:462–477

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We applied amendments for winter wheat season

- Main crop is tomatoes

Biochar application to soil

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Four Treatments

- Rogue Biochar (~900°C)
- Biochar co-compost
- Dairy manure compost
- Control (no amendment)

Biochar application to soil

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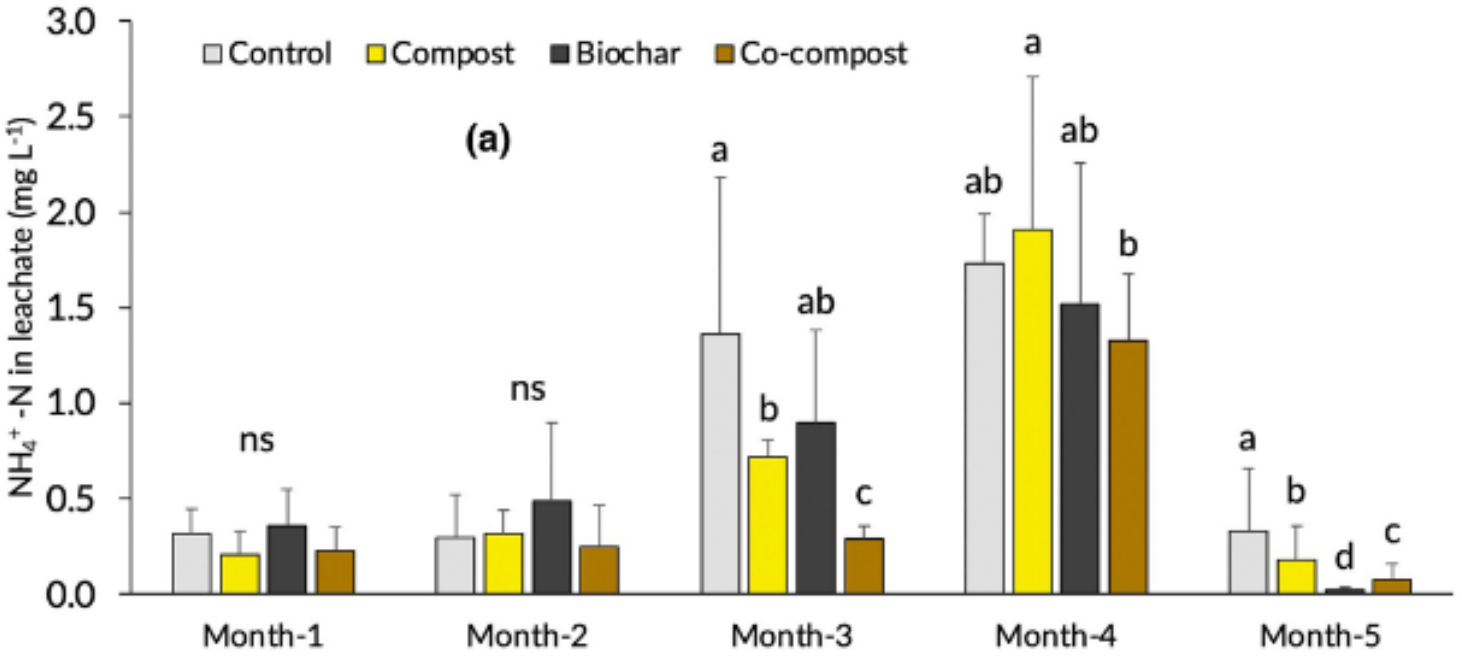

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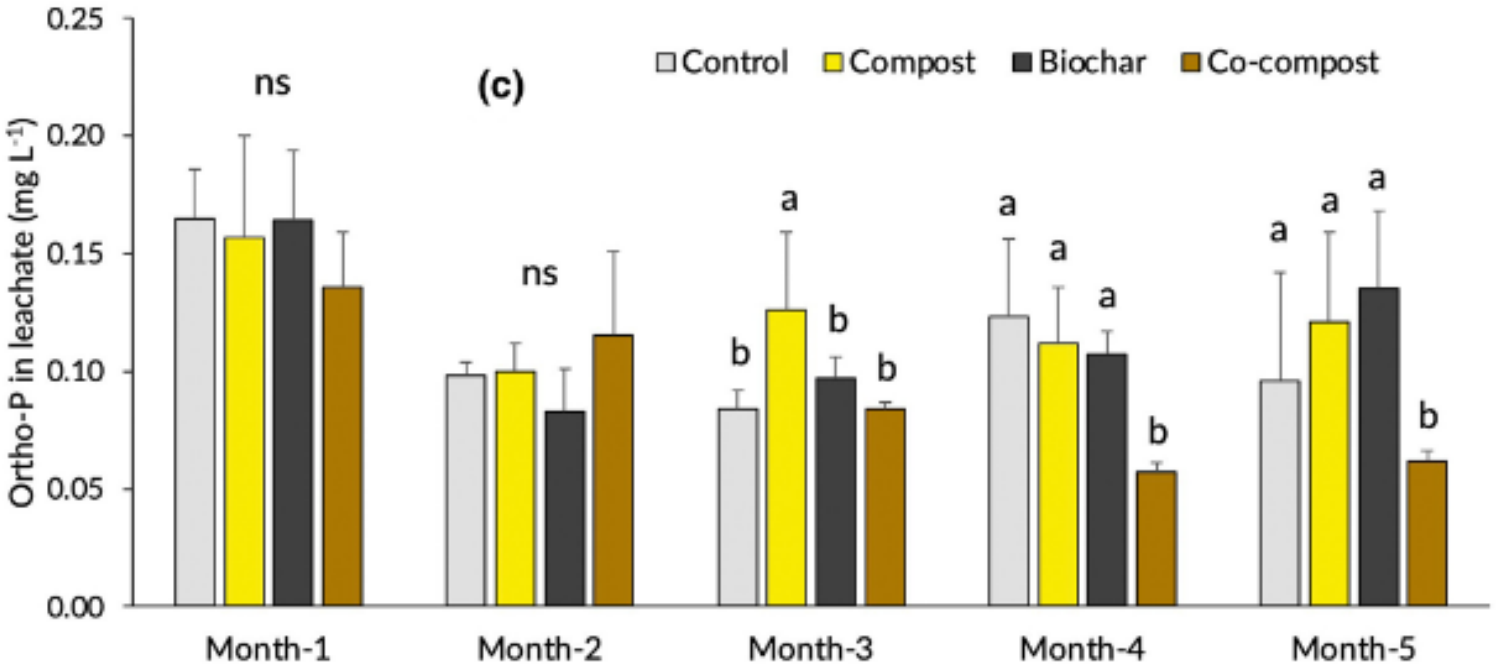

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Biochar decreases nutrient loss!

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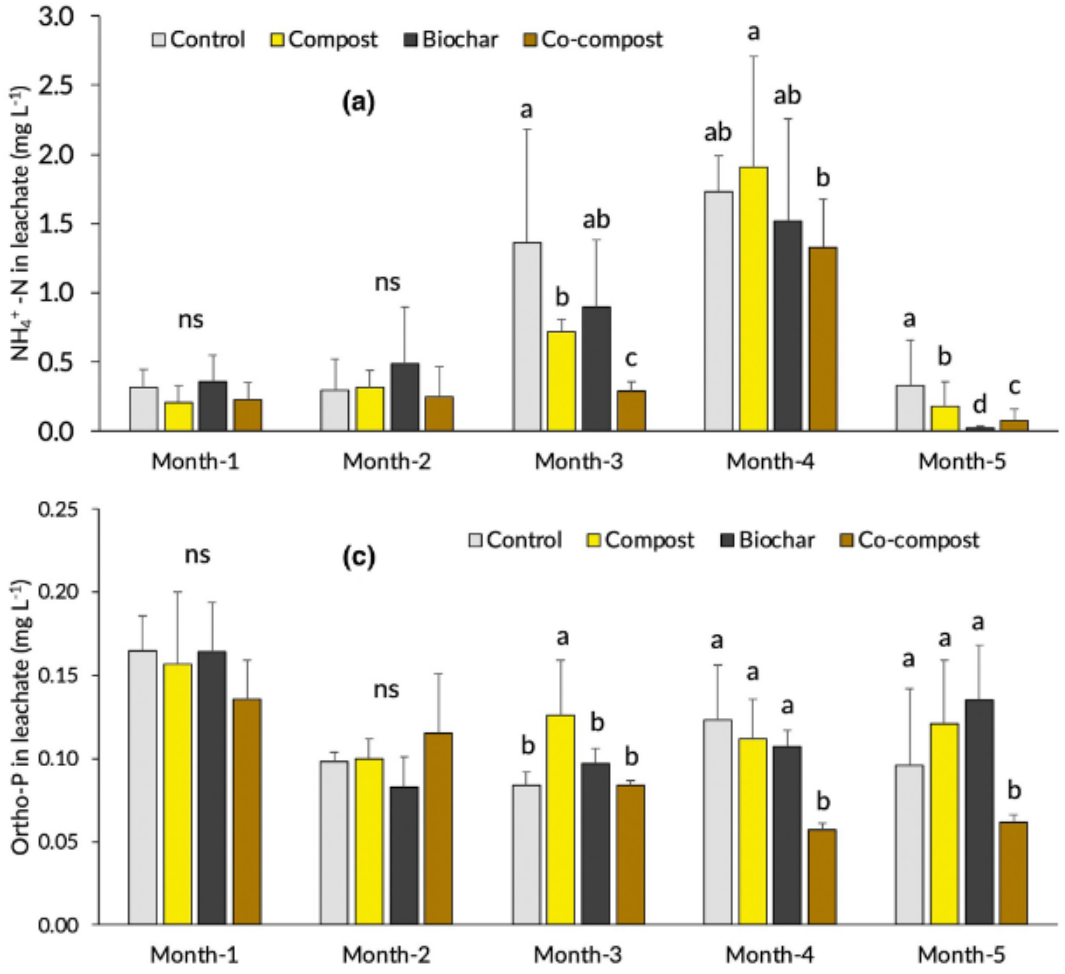

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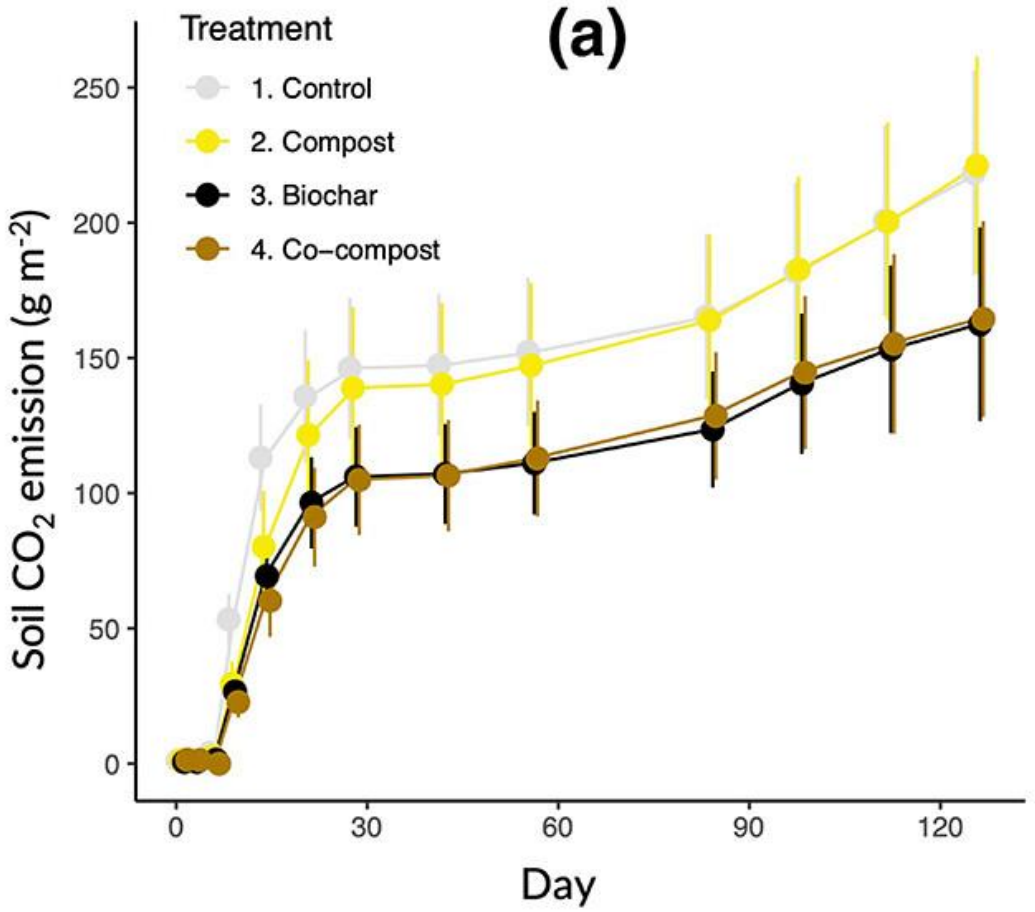

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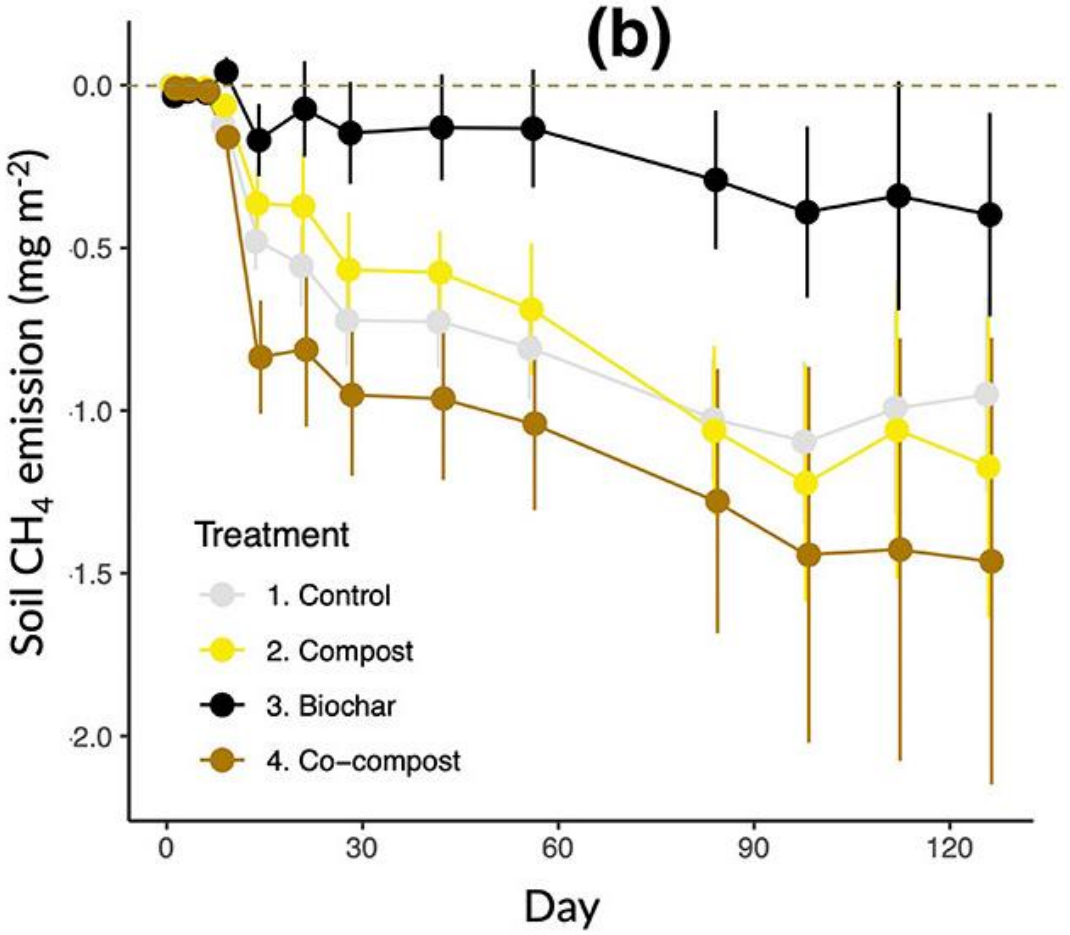

Biochar application to soil

Biochar reduced total greenhouse gas emissions!

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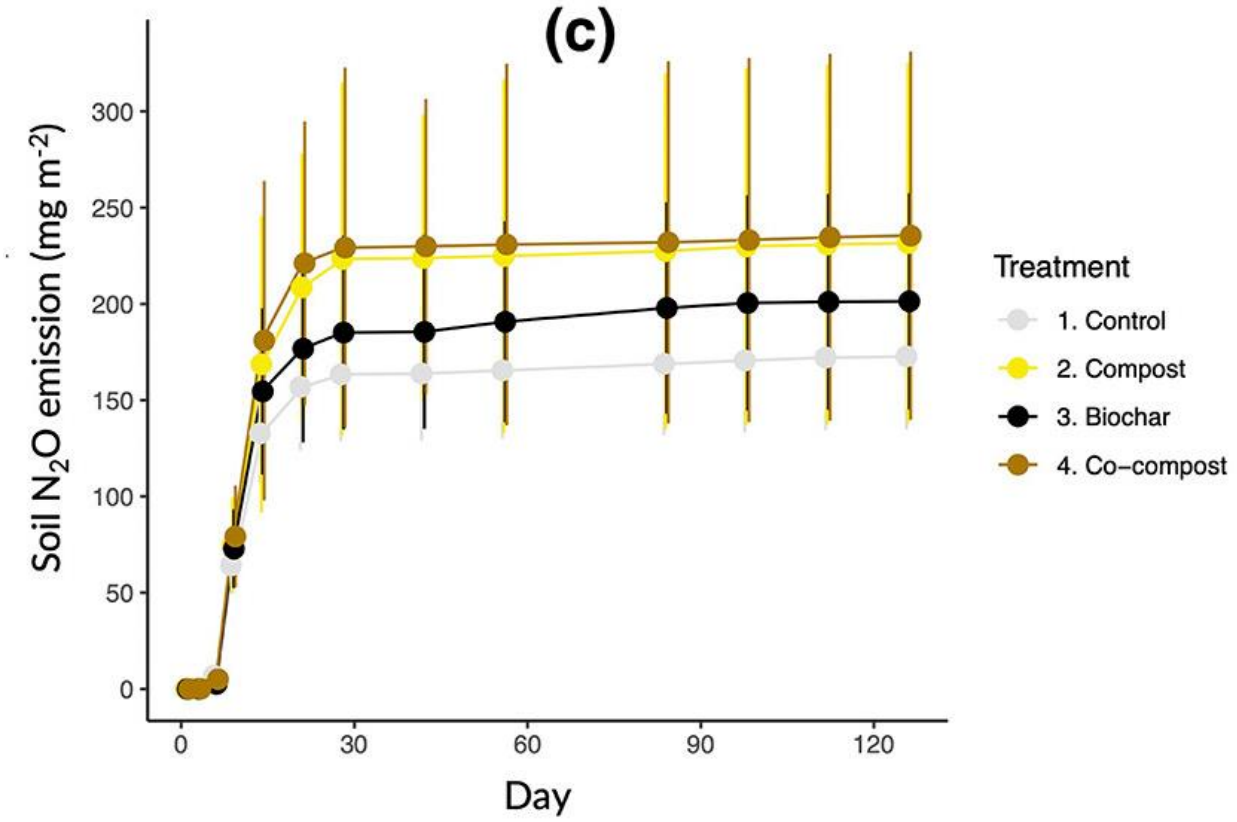

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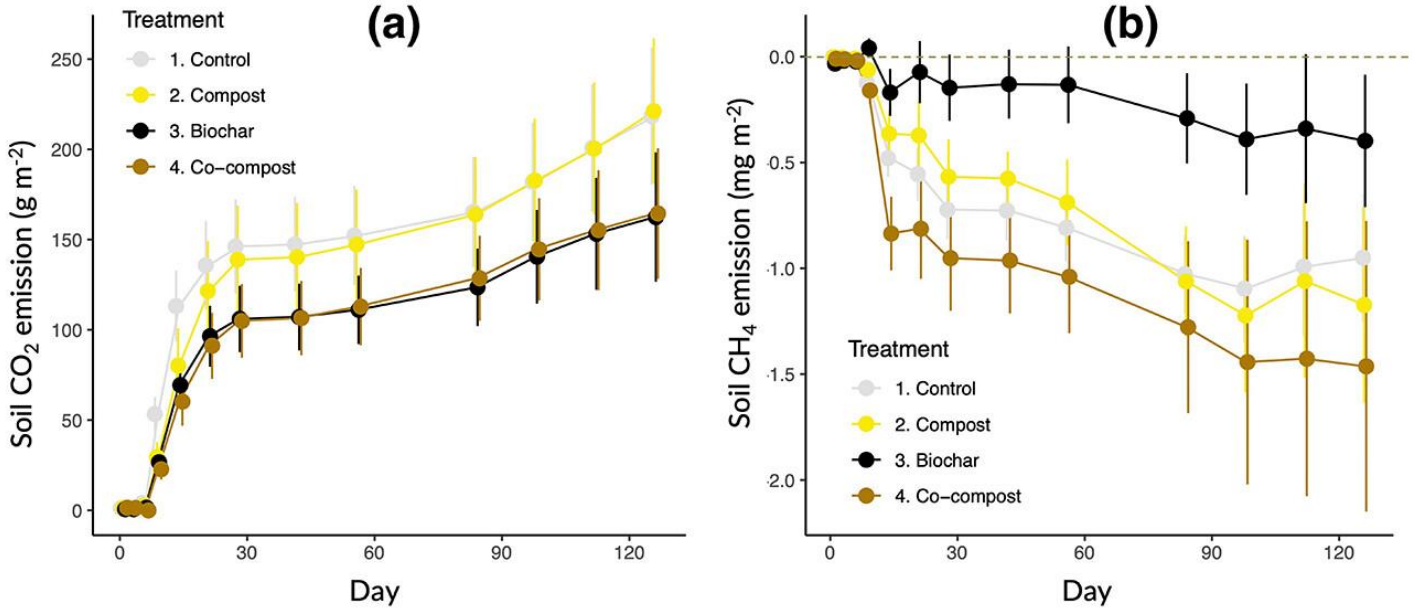

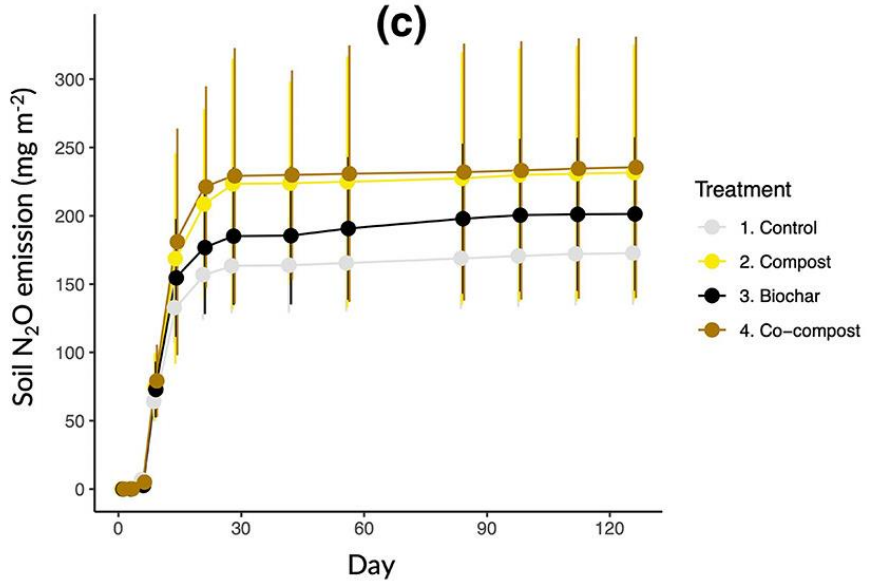

Our studies

Lab-Scale Composting Experiment

- Composted dairy manure with biochar derived from almond shell, walnut shell, and almond orchard clippings
- Low and high application (5% and 20% dry weight)

Harrison, B., et al. (2023) GCB Energy 16(1):13121

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Lab-Scale Composting Experiment

TABLE 1 Mean (±standard error) cumulative CO_2, CH_4, N_2O NH_3, and 100-year GWP for treatments grouped by application rate.

Biochar co-compost at lower application rate (5% dry weight) had lower methane emissions!

	0% biochar (control)	5% biochar	20% biochar
Cumulative CO_2 ($g\,CO_2\,kg\,TS^{-1}$)	896 ± 55.3 a	784 ± 21.3 b	612 ± 35.1 c
Cumulative CH_4 ($mg\,CH_4\,kg\,TS^{-1}$)	15.4 ± 2.13 a	15.9 ± 1.80 a	177 ± 28.7 b
Cumulative N_2O ($mg\,N_2O\,kg\,TS^{-1}$)	127 ± 35.1 a	46.2 ± 11.5 ab	20.6 ± 3.68 b
Cumulative NH_3 ($mg\,NH_3\,kg\,TS^{-1}$)	837 ± 224 a	563 ± 72.6 a	297 ± 25.6 b
GWP ($g\,CO_2e\,kg\,TS^{-1}$)	34.2 ± 9.32 a	12.7 ± 3.04 b	10.4 ± 4.07 b

Note: The 0% application rate is the same as the no-biochar control. Letters denote statistical significance between application rates ($p < 0.05$).

Abbreviation: GWP, global warming potential.

Harrison, B., et al. (2023) GCB Energy 16(1):13121

Lab-Scale Composting Experiment

Emissions are driven by biochar application rate and aggregate formation

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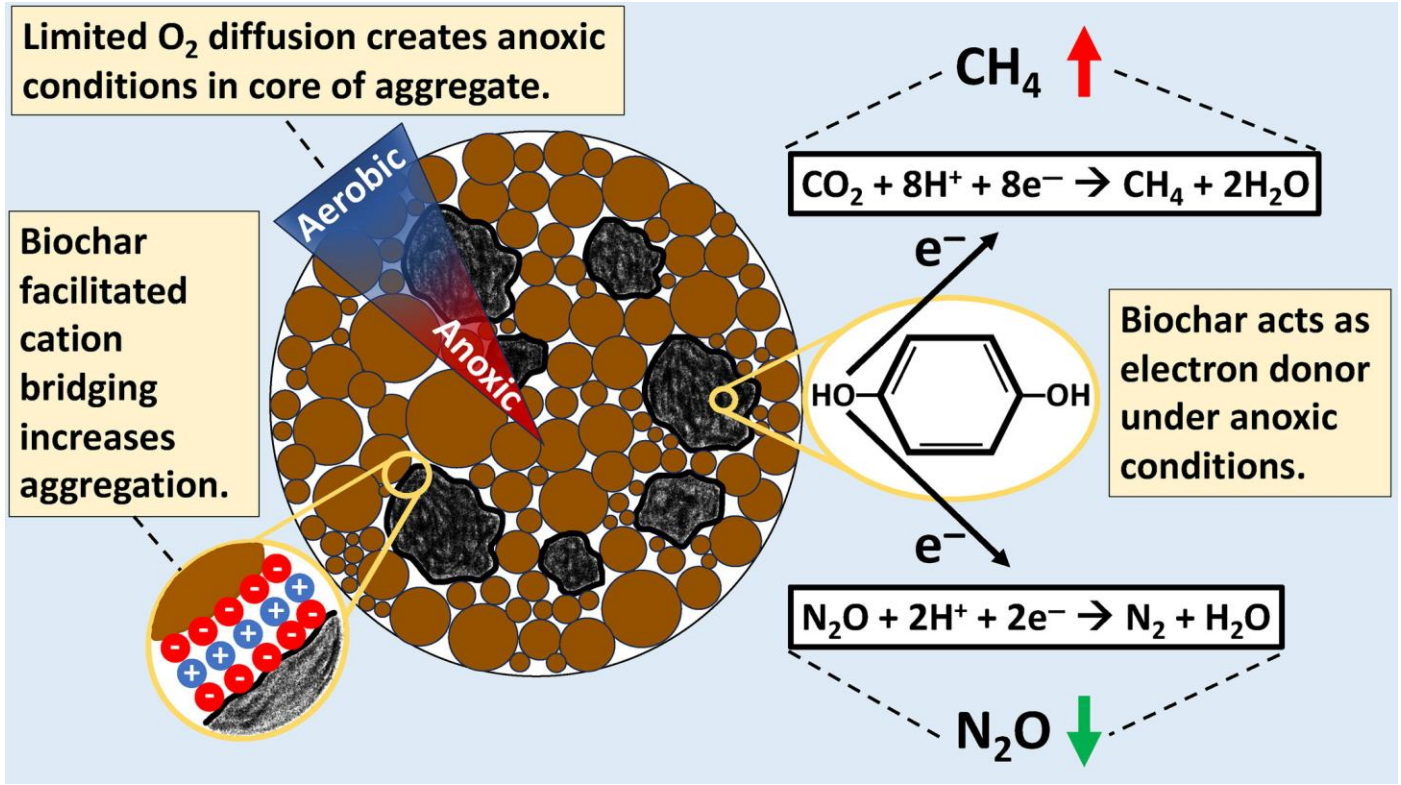
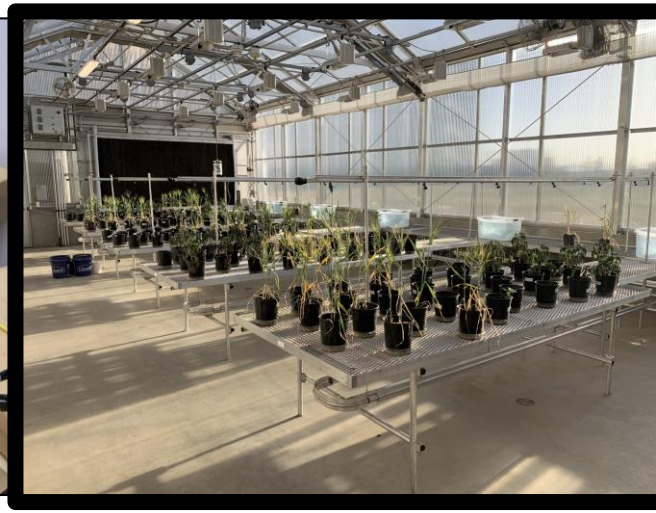


Our studies



Greenhouse Experiment

Greenhouse Experiment

- Used field soil from Madera, CA

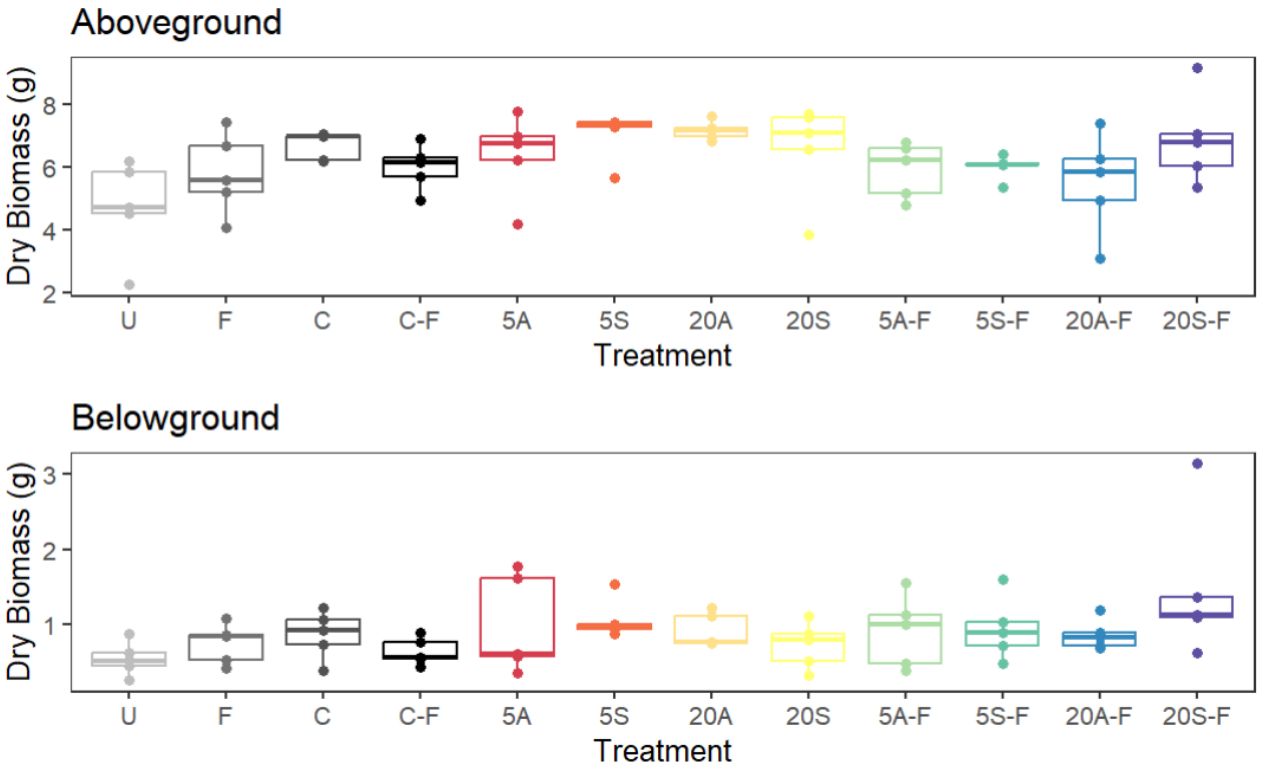
Greenhouse Experiment

- Used field soil from Madera, CA
- Treatments
  - Unamended (control)
  - Compost
  - Fertilizer
  - Fertilizer + Biochar co-compost
  - Biochar co-compost

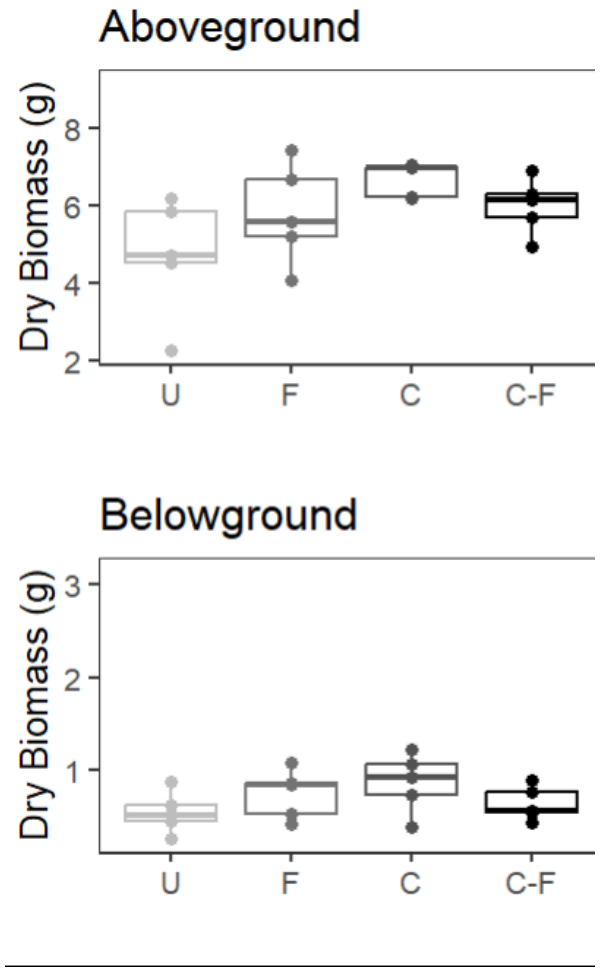
Greenhouse Experiment

- Used field soil from Madera, CA
- Treatments
  - Unamended (control)
  - Compost
  - Fertilizer
  - Fertilizer + Biochar co-compost
  - Biochar co-compost
- Plants
  - Barley
  - Cherry Tomatoes

Greenhouse Experiment



Biochar co-compost has higher biomass



Controls

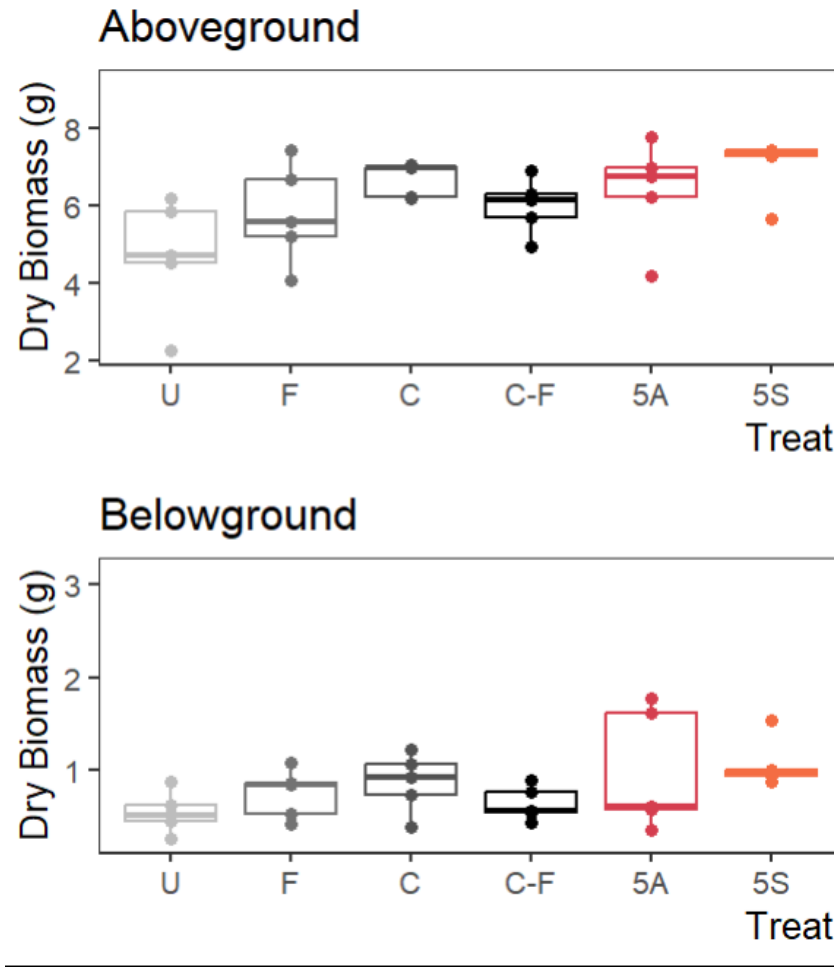
Unamended

Fertilizer

Compost

Compost and **F**ertilizer

Biochar co-compost has higher biomass



Biochar 5% of manure compost dry weight

Almond tree pruning biochar

Almond **S**hell biochar

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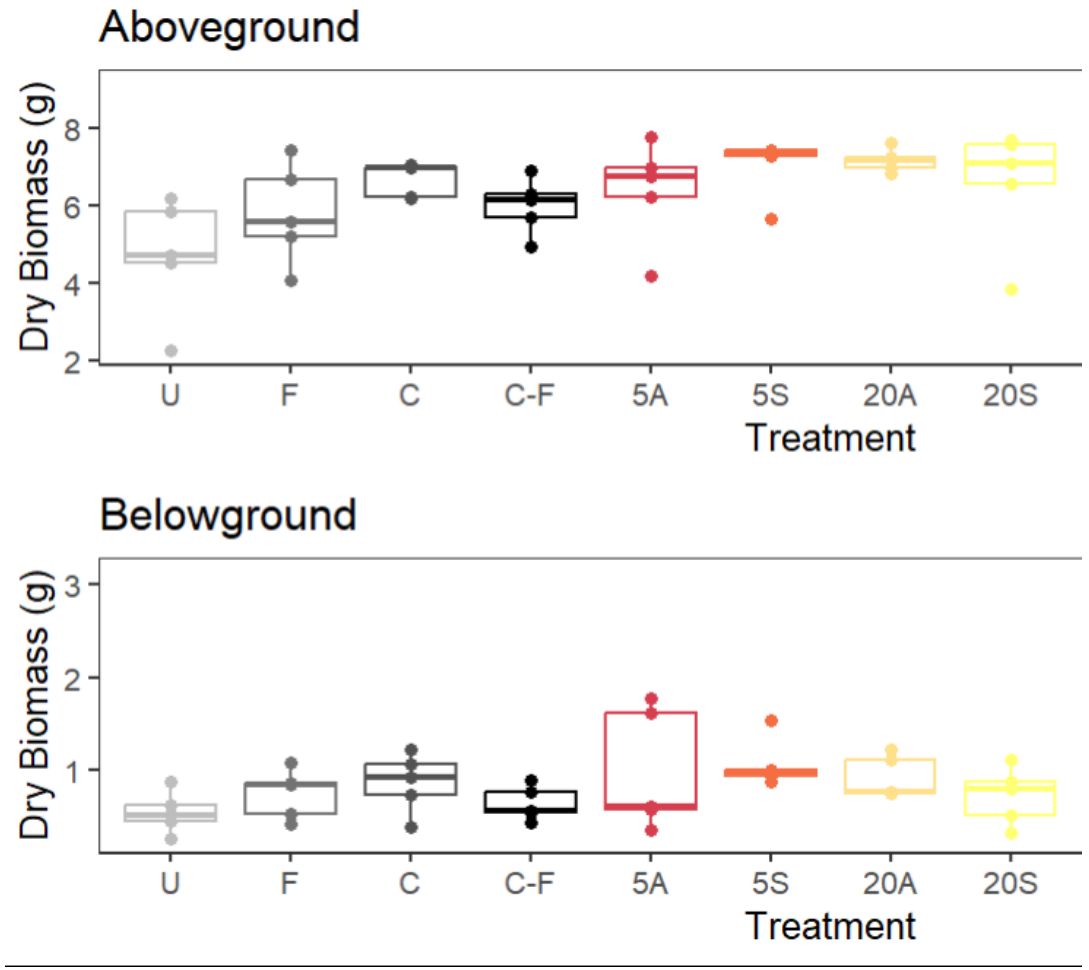
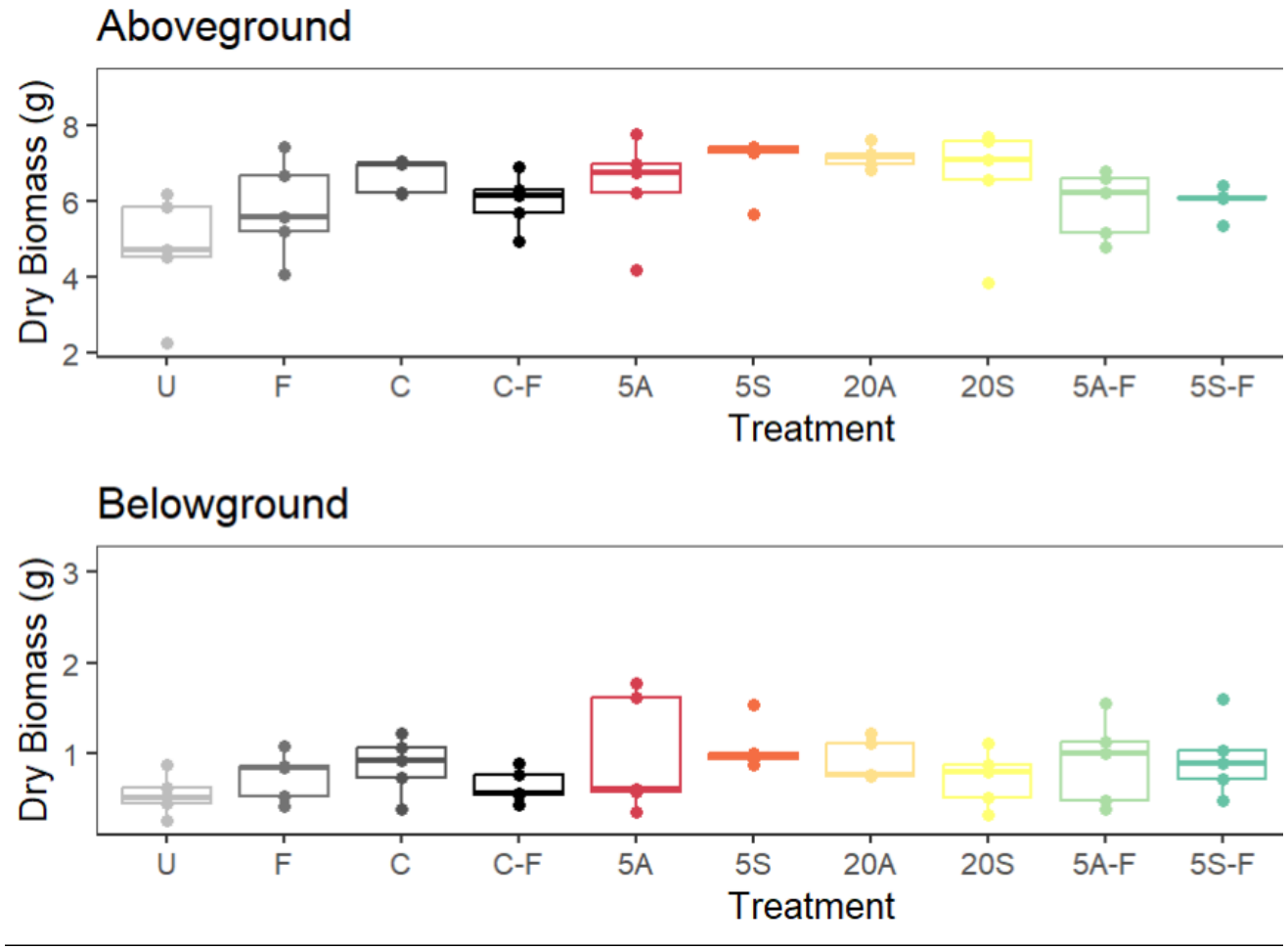


Biochar 20% of manure compost dry weight

Almond tree pruning biochar

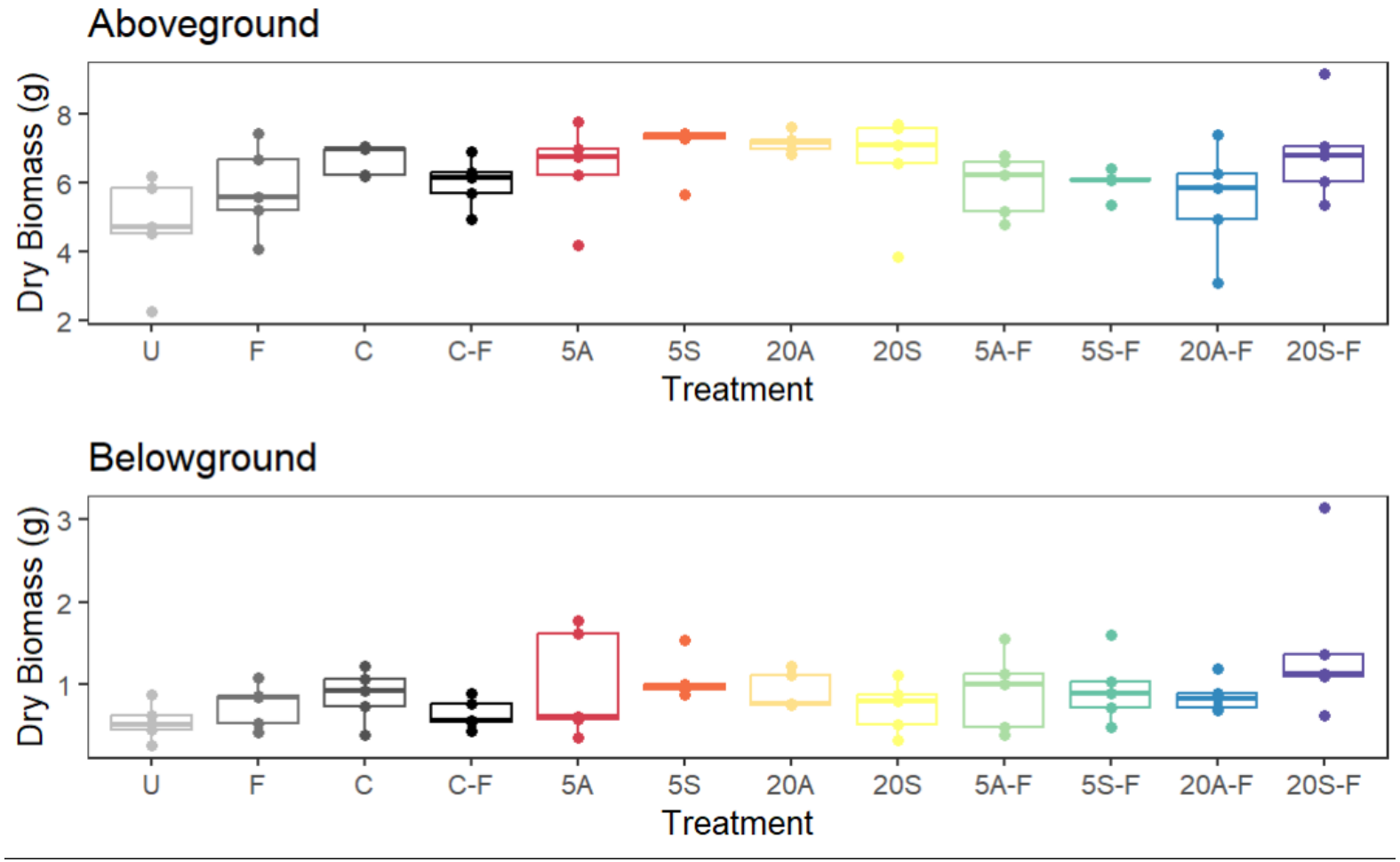
Almond **S**hell biochar

Biochar co-compost has higher biomass

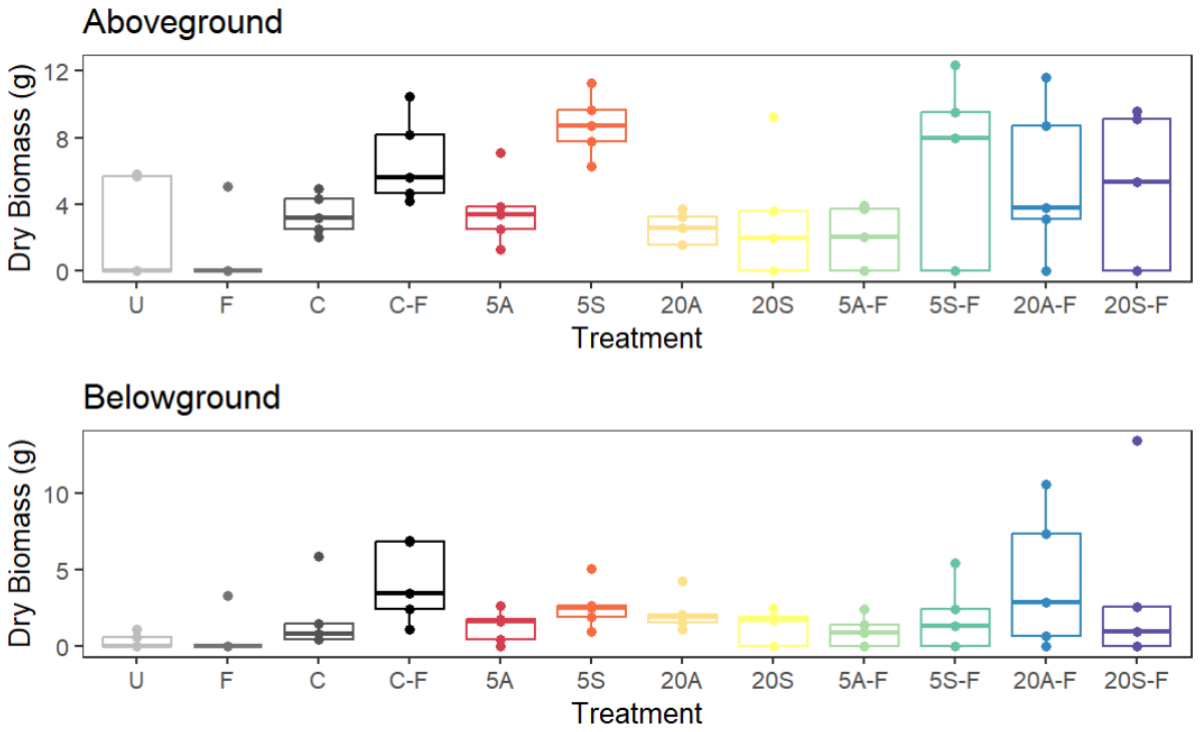


Biochar 5% of manure compost dry weight with Fertilizer

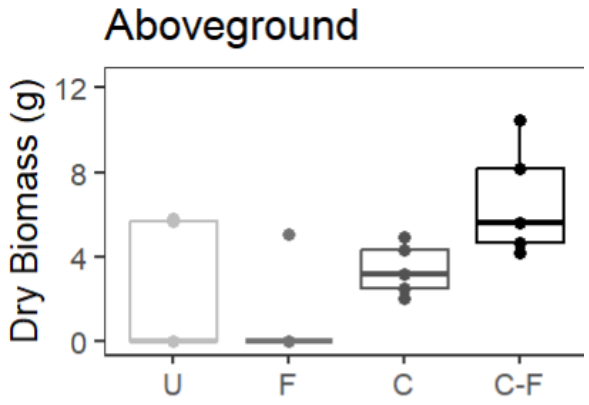
Biochar co-compost has higher biomass

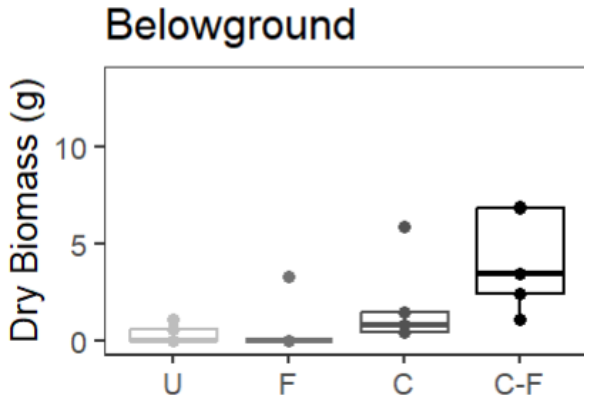


Greenhouse Experiment



Almond shell biochar co-compost has higher biomass yields





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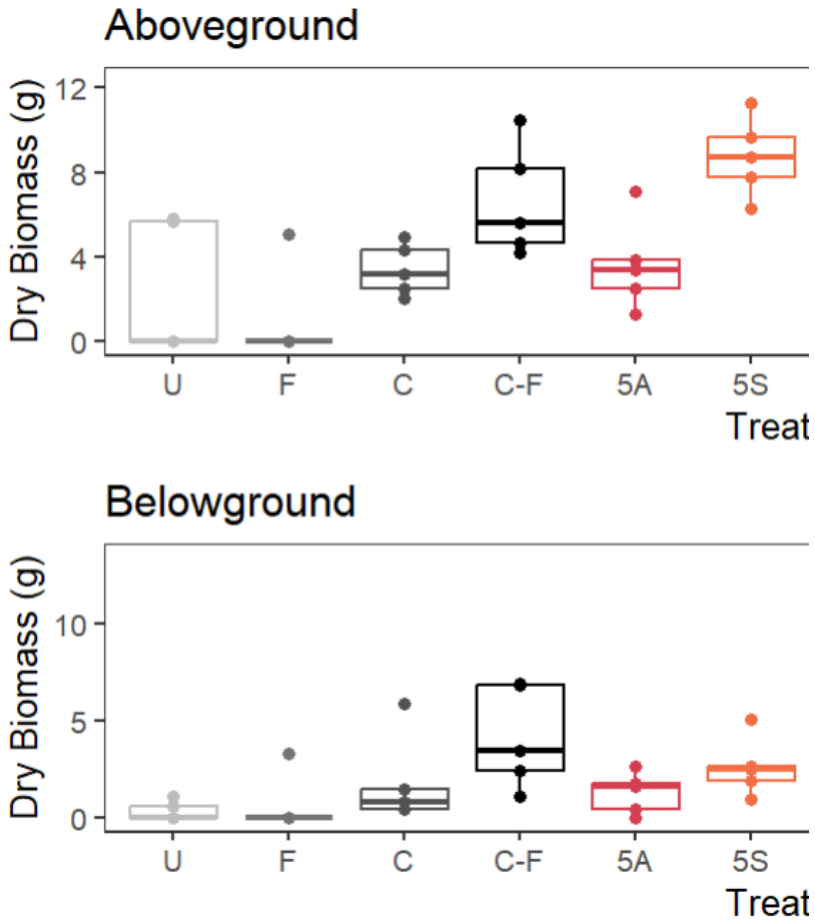

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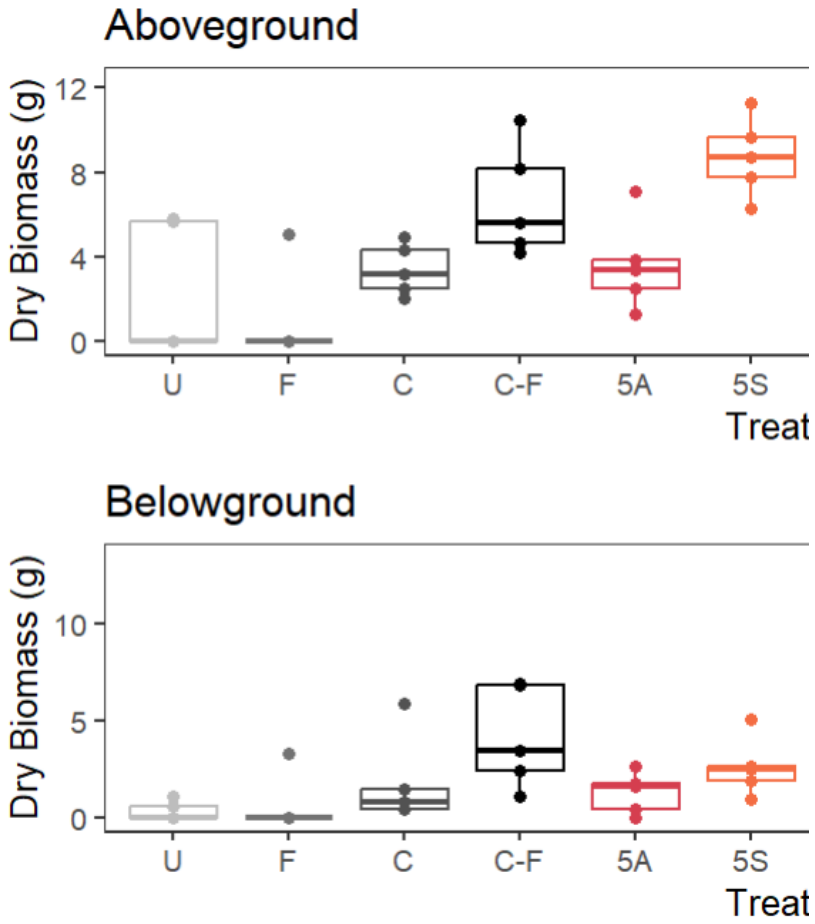

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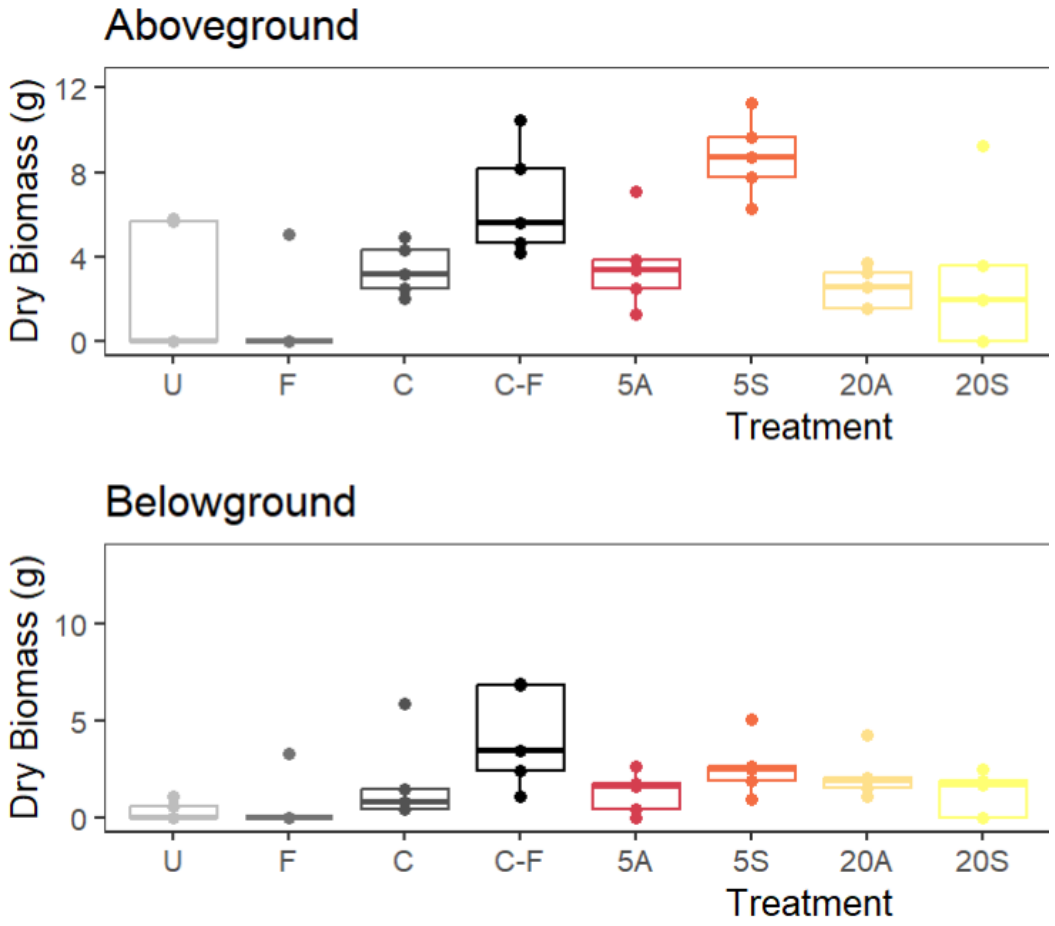

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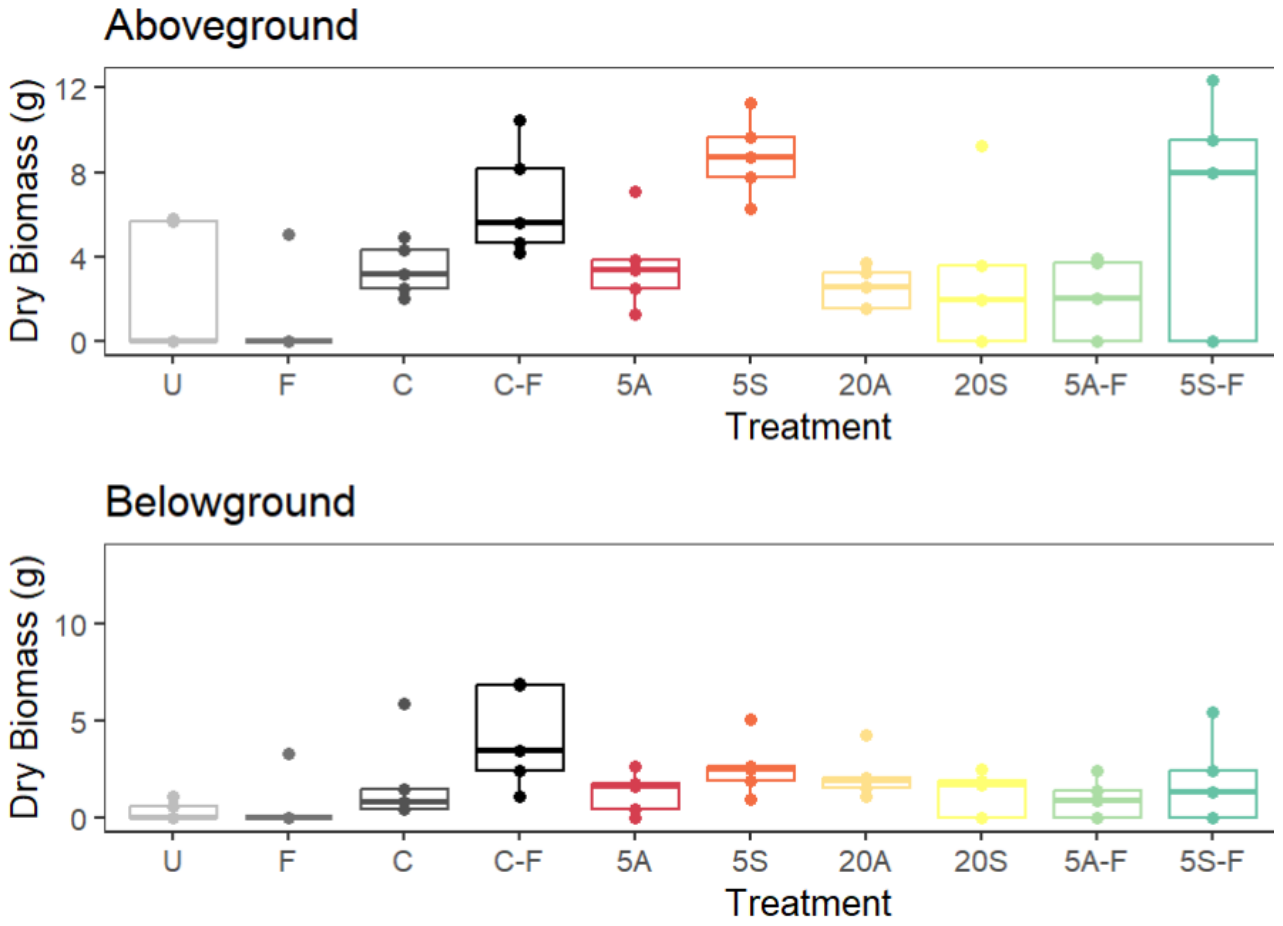

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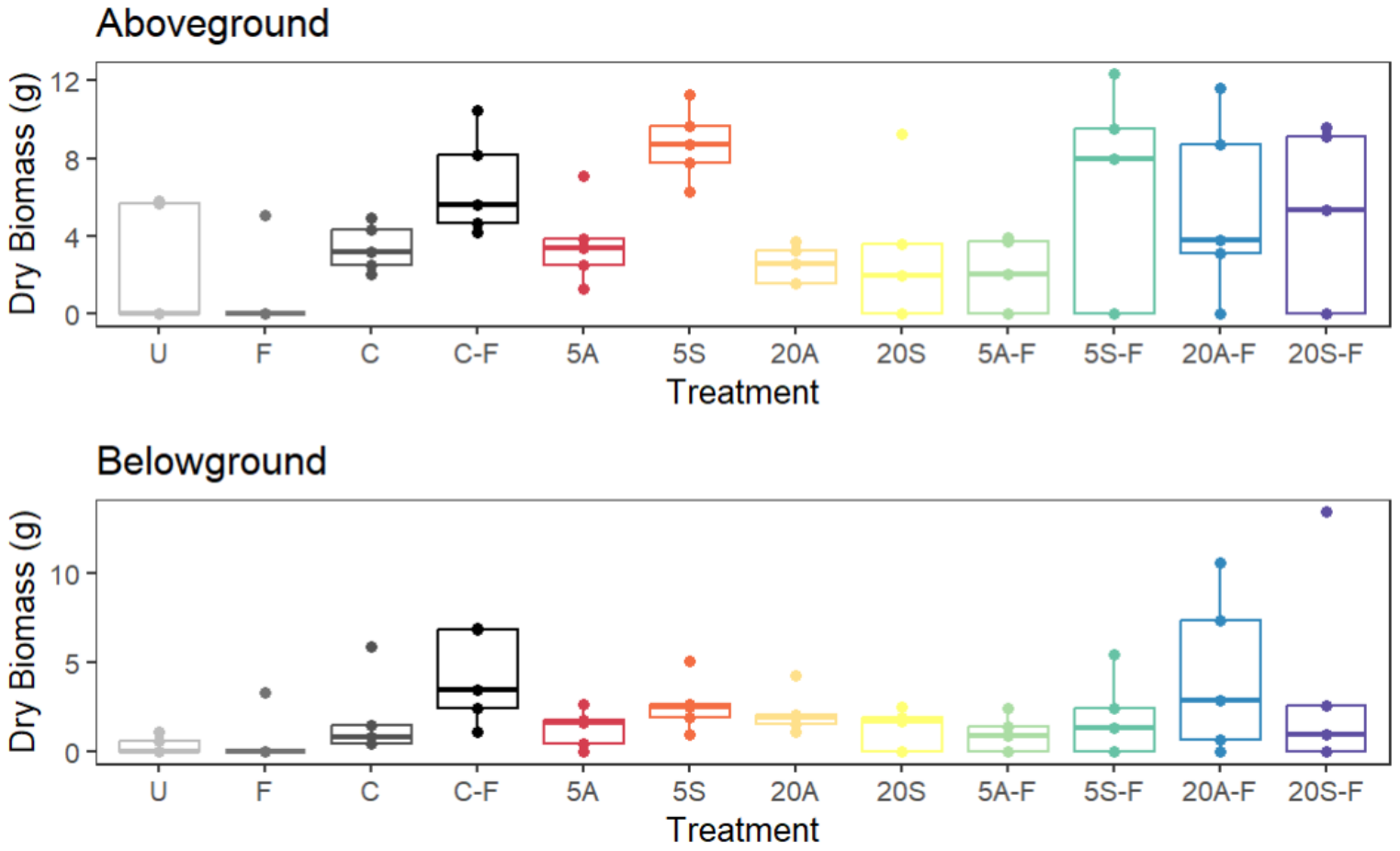

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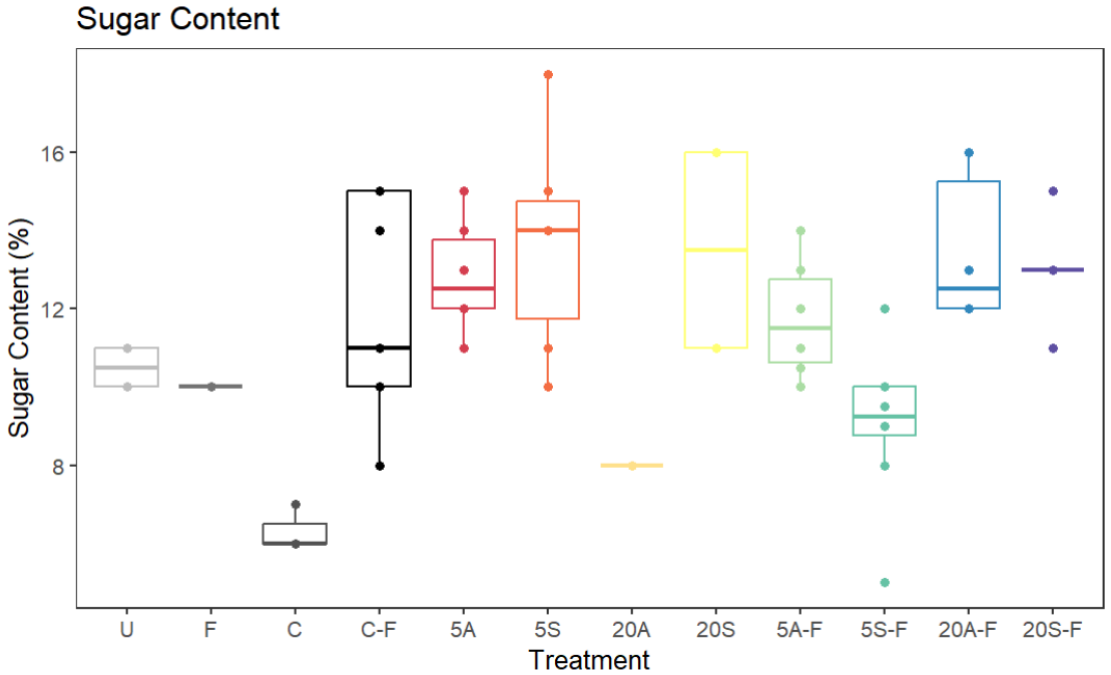
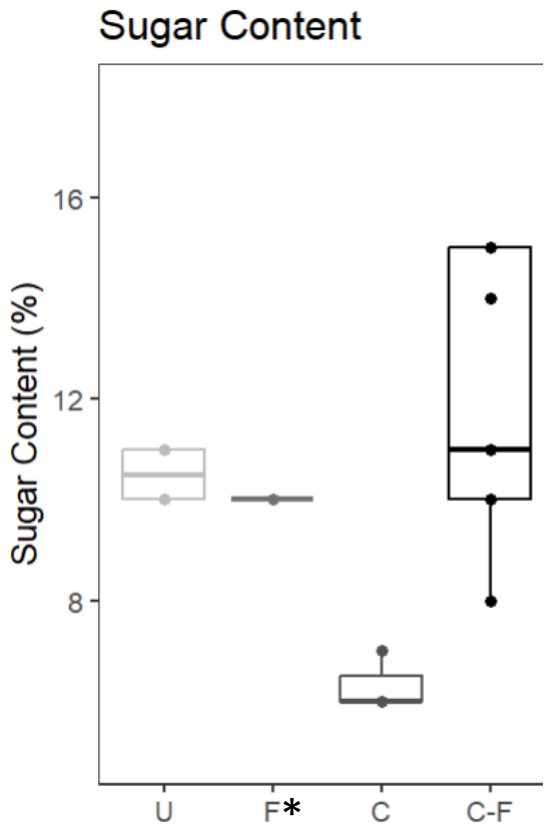


Tomatoes from biochar co-compost more mature



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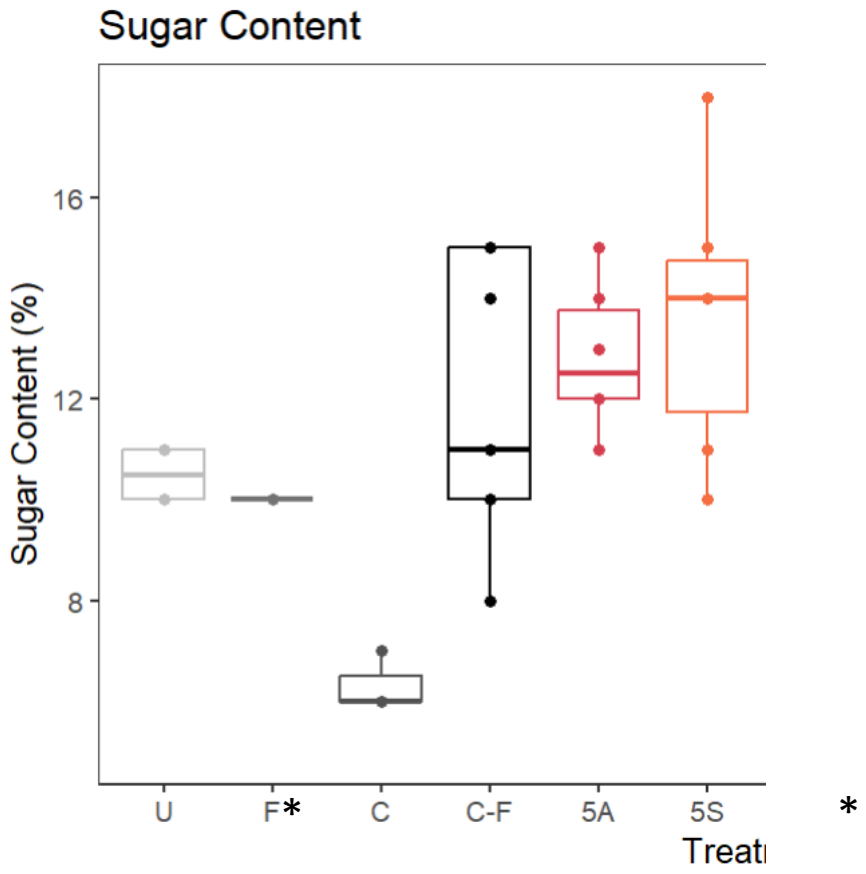
* Low production

Tomatoes from biochar co-compost more mature



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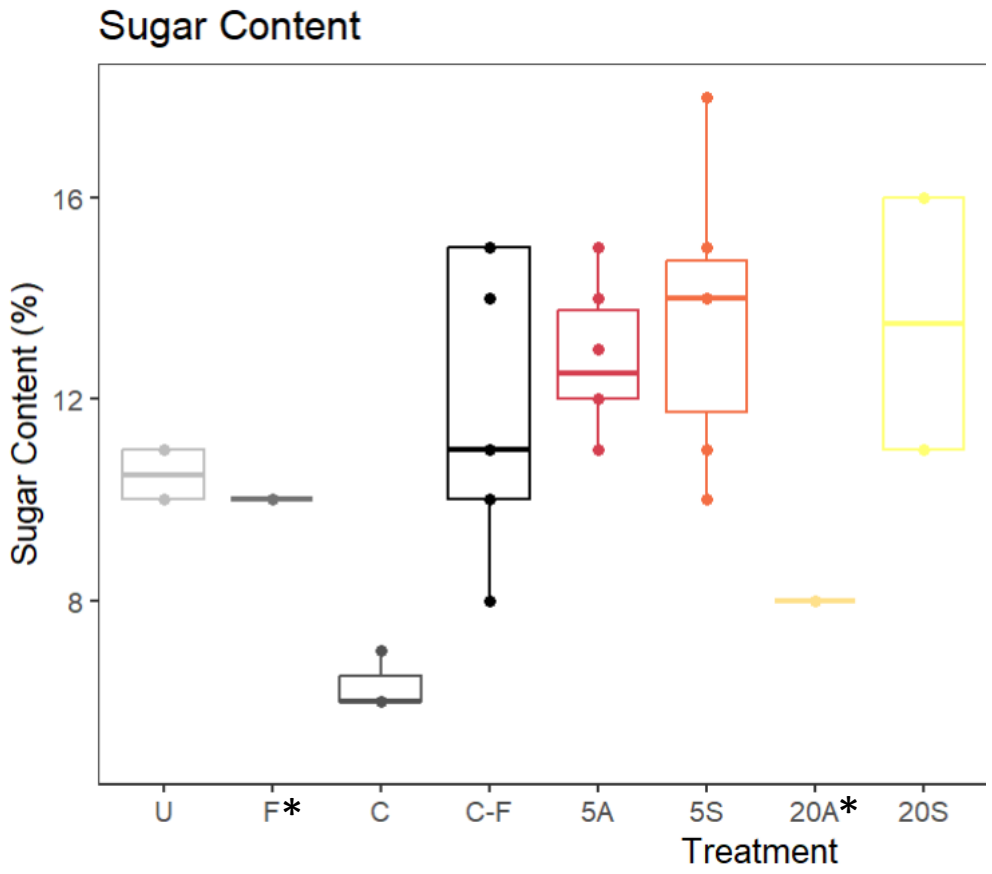

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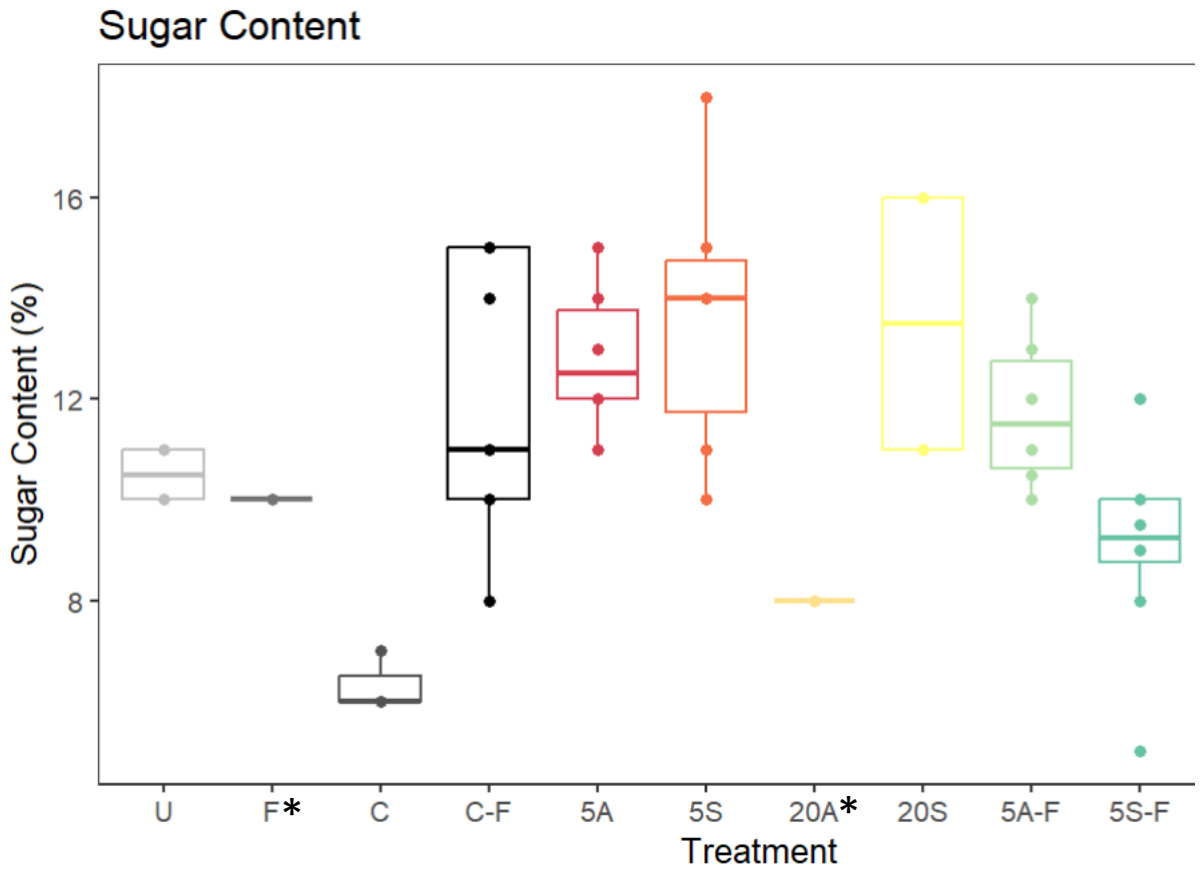

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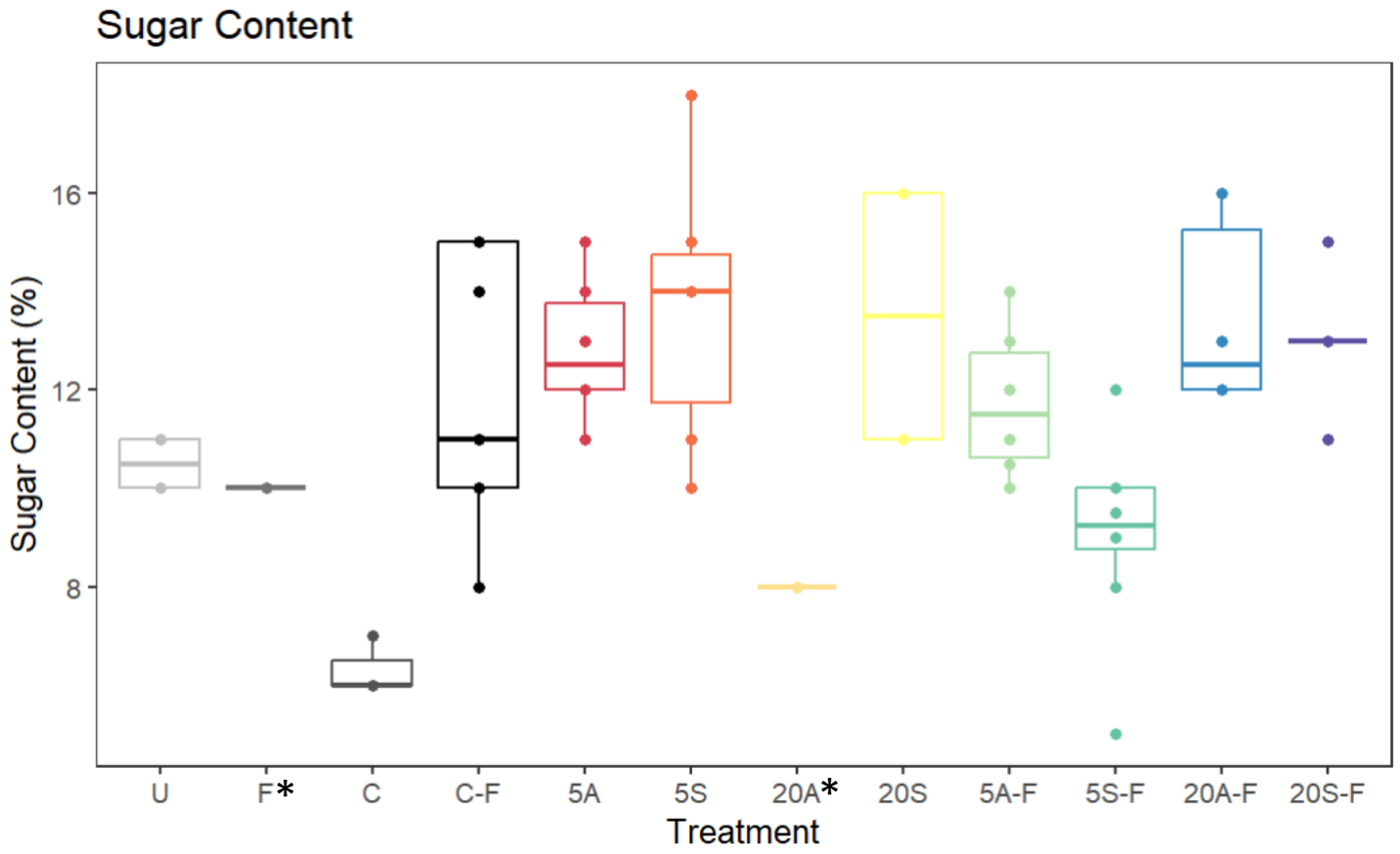

* Low production

Greenhouse Experiment

- The impacts are less clear on short-term growing seasons
- Almond-shell 5% dry weight (dw) biochar co-compost overall had higher biomass yields and tomato maturity
- Biochar co-compost could be an alternative organic rich amendment compared to synthetic fertilizer and still contribute to below-ground C sequestration
- The 20% dw biochar may show the cap to the amount of biochar needed in compost for benefits

Study Conclusions

Biochar reduces GHG emissions in dairy manure composting

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Low application of biochar reduces GHGE in diary manure composting

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Biochar co-compost can reduce nutrient loss in soil

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Biochar reduces GHG emissions in dairy manure composting

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Biochar co-compost can reduce nutrient loss in soil

Biochar co-compost can be an alternative amendment to synthetic fertilizer

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Questions?

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Biochar Co-composting

Harrison, B. P., et al. (2022) Environ. Sci. Technol. 56, 15, 10987-10996

Applied Rogue Biochar (~900°C)

Manure Composting Components:

- Dairy Manure (3.37 t dry wt)
- Orchard clipping residues (1.2 t dry wt)
- Biochar (0.91 t dry wt) (~6-8%)

Biochar application to soil

Gao, S., et al. (2023) GCB Bioenergy 15:462–477

Organic amendments were applied at equivalent C rates (8 Mg C ha−1) dry weight basis

- compost applied = 20 Mg ha−1
- biochar applied at 10 Mg ha−1
- biochar manure co-compost applied at 17.5 Mg ha−1

Greenhouse Experiment

- Used field soil from Madera, CA
- Treatments
  - Unamended (control)
  - Compost
  - Fertilizer
  - Fertilizer + Biochar co-compost
  - Biochar co-compost
- Plants
  - Barley
    - treatments applied based on 17 N kg/ha
  - Cherry Tomatoes
    - treatments applied based on 55 N kg/ha