THE IMPACT OF WOOD BIOCHAR ON THE CONTAMINANT UPTAKE OF CORN IRRIGATED WITH RECLAIMED WATER

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AT
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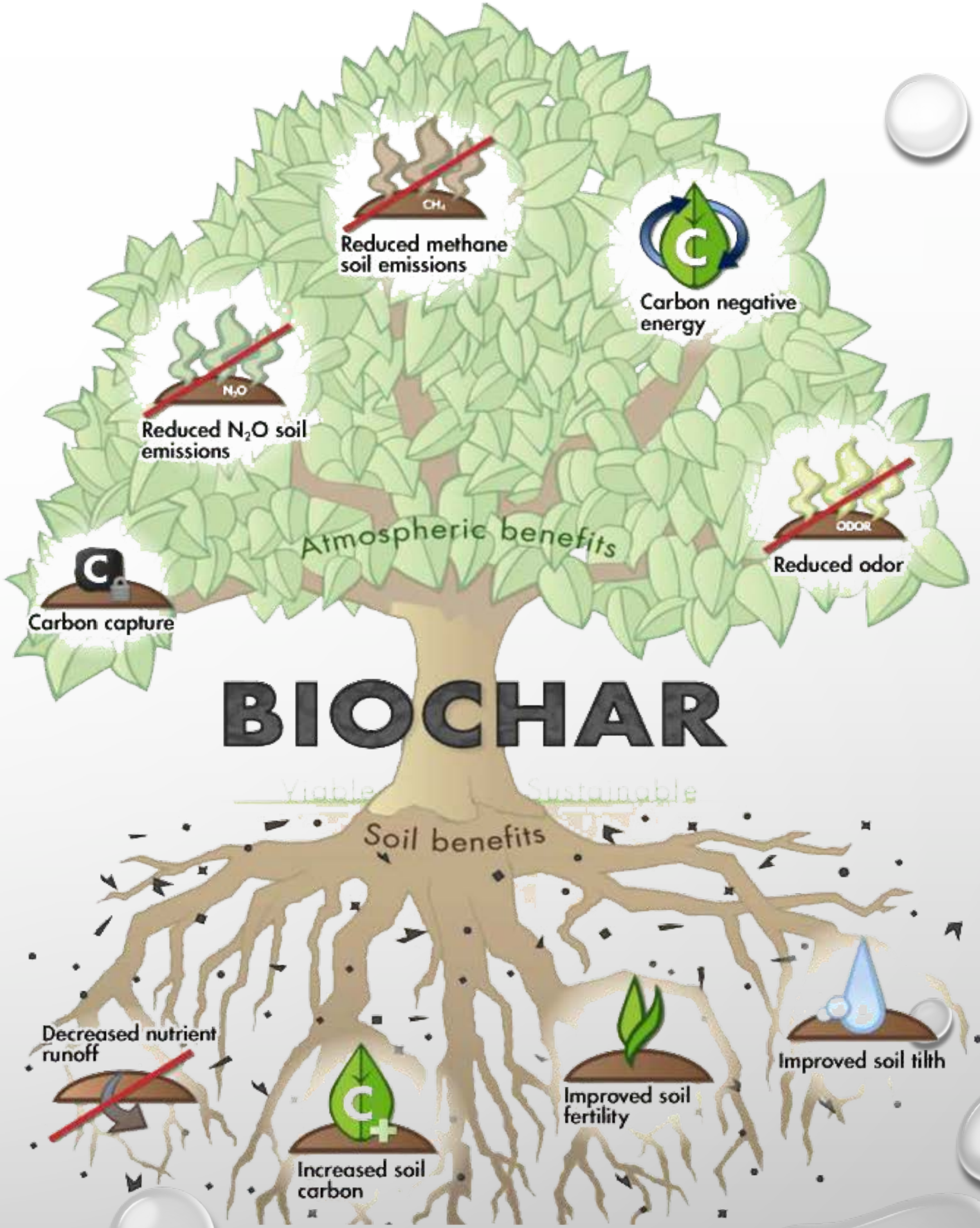
Introduction

- Global water stress is increasing
- Reclaimed water can combat shortages through irrigation
  - Utah is 2nd driest state in the US
- Plants and organisms could be exposed to contaminants
- Pharmaceuticals and Personal Care Products (PPCPs) are often found in reclaimed water

Biochar

- Biochar is biological material which is heated without oxygen (pyrolysis)
- Biochar is an effective sorbent of PPCPs in water (Solanki et al., 2017)
- Reduced pesticides in onions when applied to soil (Yu et al., 2009)
- Improves crop yields (Pudasaini et al. 2012; Yamato et al. 2006; Schultz et al. 2013; Uzoma et al. 2011)
- Helps mitigate greenhouse emissions



Objectives

- ❑Find the impact of wood biochar on plant growth and PPCP bioavailability

- ❑Quantify the contaminant sorption rates (Kd) in the soil/sand mixtures

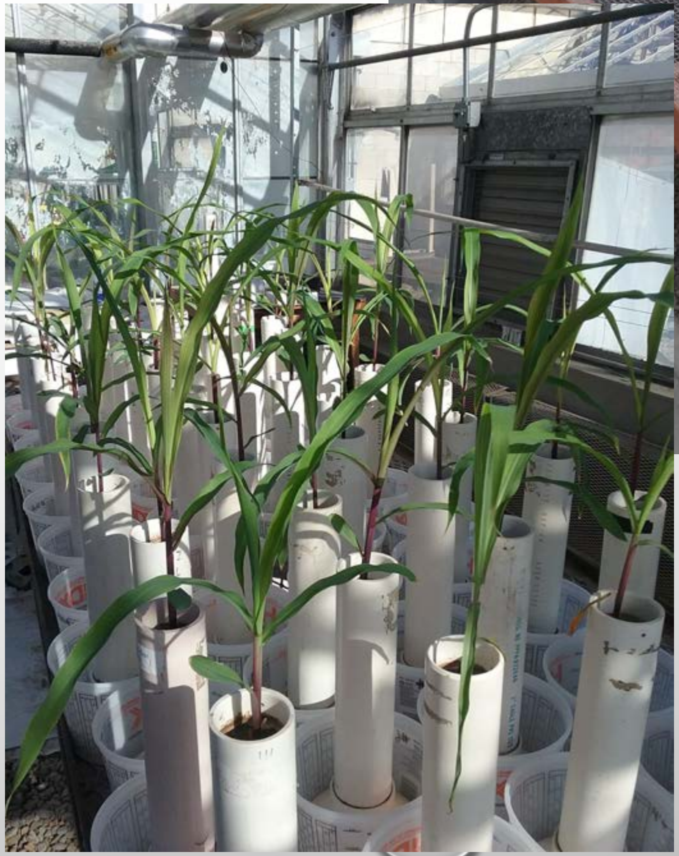
- ❑Evaluate the relationship between sorption and bioavailability

Hypotheses

- Biochar won't decrease plant growth
  - Increased water holding capacity, porosity, etc.
  - Raises soil pH
  - Increased nutrient retention capacity
- Biochar will reduce plant PPCP uptake
  - Reduction in uptake due to sorption to biochar
  - Leaf concentrations: sand > soil > sand/soil+biochar
- Sorption will correlate to bioavailability
  - Sorption function of physical/chemical properties

Experiment Overview

- Corn grown for 28 days in soil or sand mixtures
  - Biochar mixed at 5% by mass
  - Perlite used as soil aeration control
- Corn watered with a 1 mg/L PPCP spike
- Corn leaves were analyzed (LC/MS)
- Column sorption experiments
  - Determined sorption coefficients (Kd's)
- Hydroponic study
  - Relate leaf uptake to exposure concentration



Materials

Hyrum Sewage Plant

- ❑Reclaimed water from Hyrum Wastewater Treatment Plant
  - pH 7.7
- ❑Corn seeds
  - Syngenta 8590 GT 2006
- ❑Soil (clay loam, organic matter 2.7%, pH 7.7 – slightly alkaline)
- ❑PVC columns used to grow corn

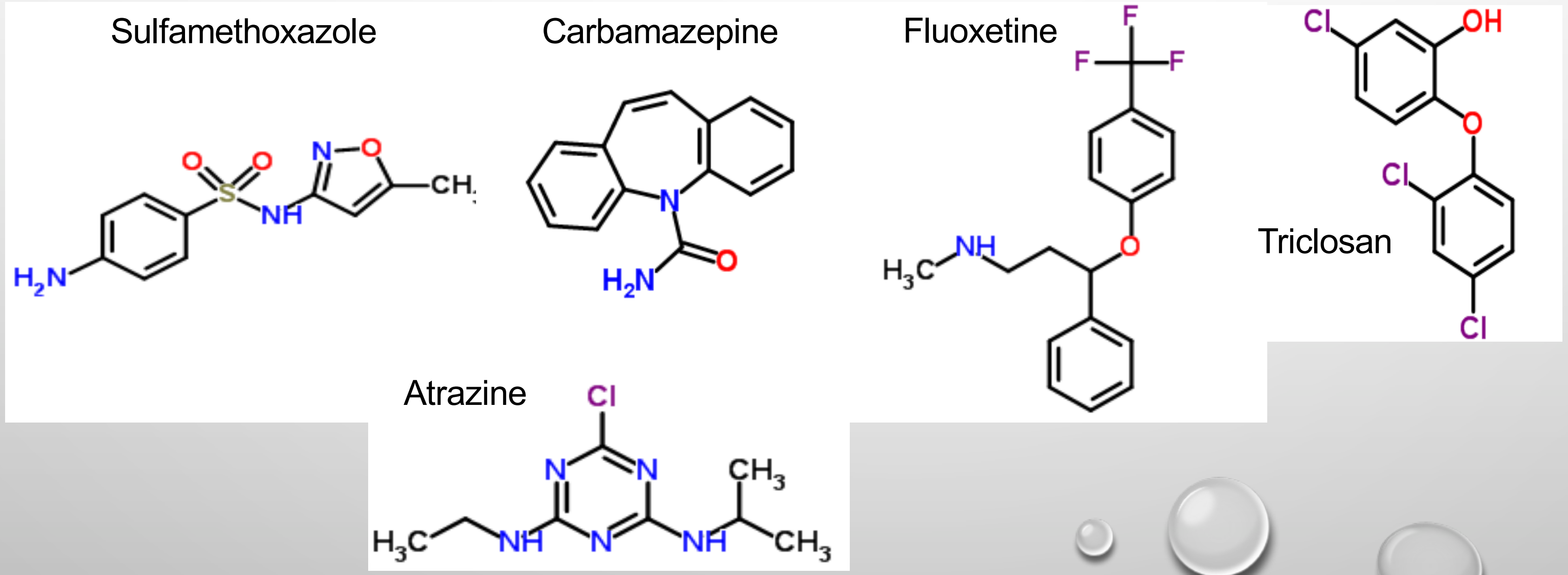
Biochar

- ❑ Reduction of forest fire fuel

- ❑ Biochars from invasive or infested tree species in Intermountain West
  - Lodgepole pine infested with beetles
  - Pinyon juniper is an invasive species
- ❑ Pinyon juniper biochar (@ 500 C)
  - pH 9.4 with 62.4% carbon
- ❑ Lodgepole pine biochar (@ 550 C)
  - pH 9.2 with 62.3% carbon
  - Higher metal concentrations

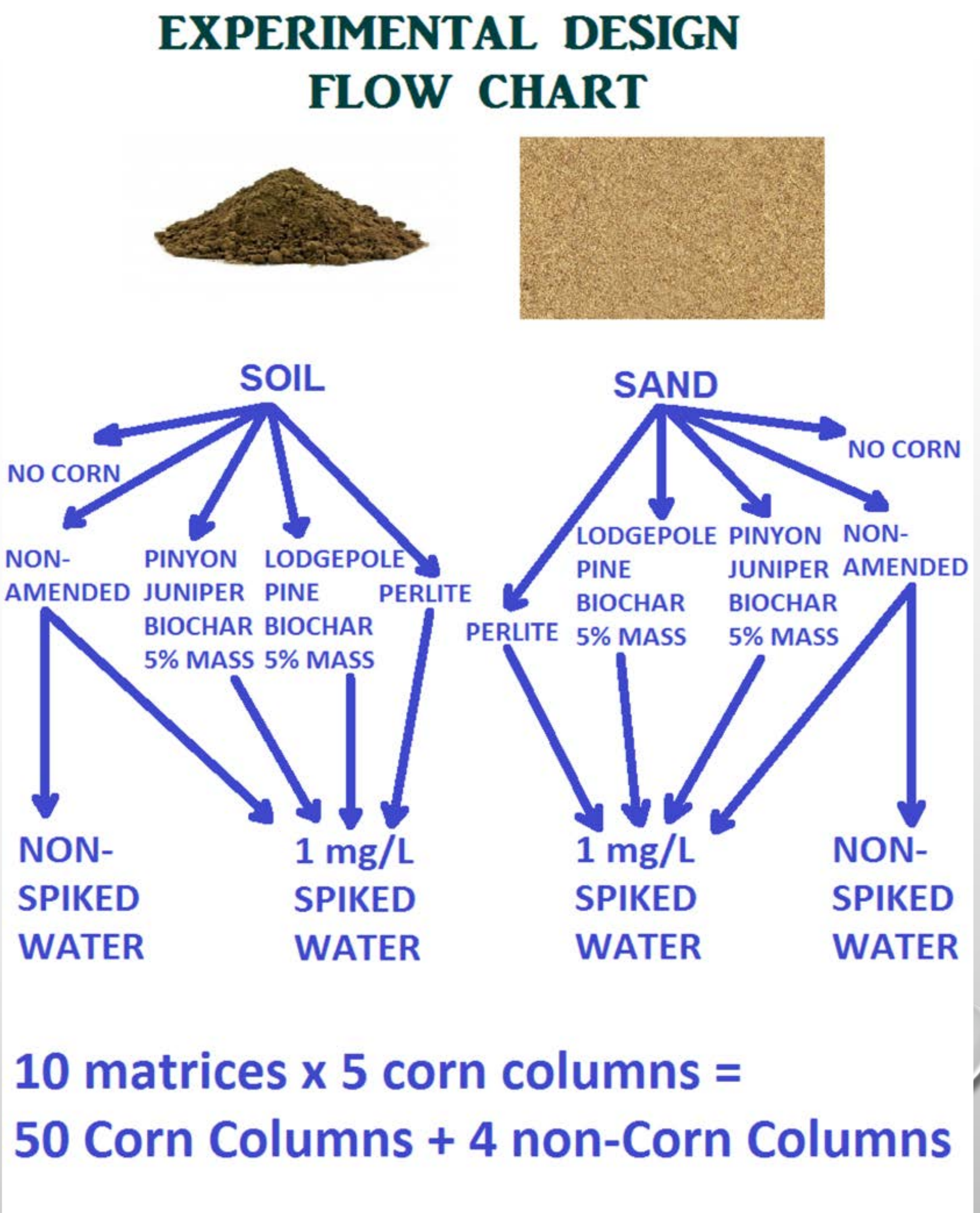
Target Compounds

Compound	Molecular Wt	pK_a	Log K_{oc} (L/kg) EPI suite calc (MCI)	log K_{ow}	Solubility (mg/L) 25ºC	Class/Use	Charge at pH 8
Sulfamethoxazole	253	1.6, 5.7	2.41	0.89	610	Antibiotic	-
Carbamazepine	236	13.9	3.12	2.25	112	Antiseizure	Neutral
Fluoxetine HCl	346	9.8	4.97	2.45	14000	Antidepressant	+
Atrazine	216	1.6	2.35	2.61	35	Herbicide	Neutral
Triclosan	290	7.9	4.37	4.76	10	Antimicrobial	- /Neutral



Column study (corn)

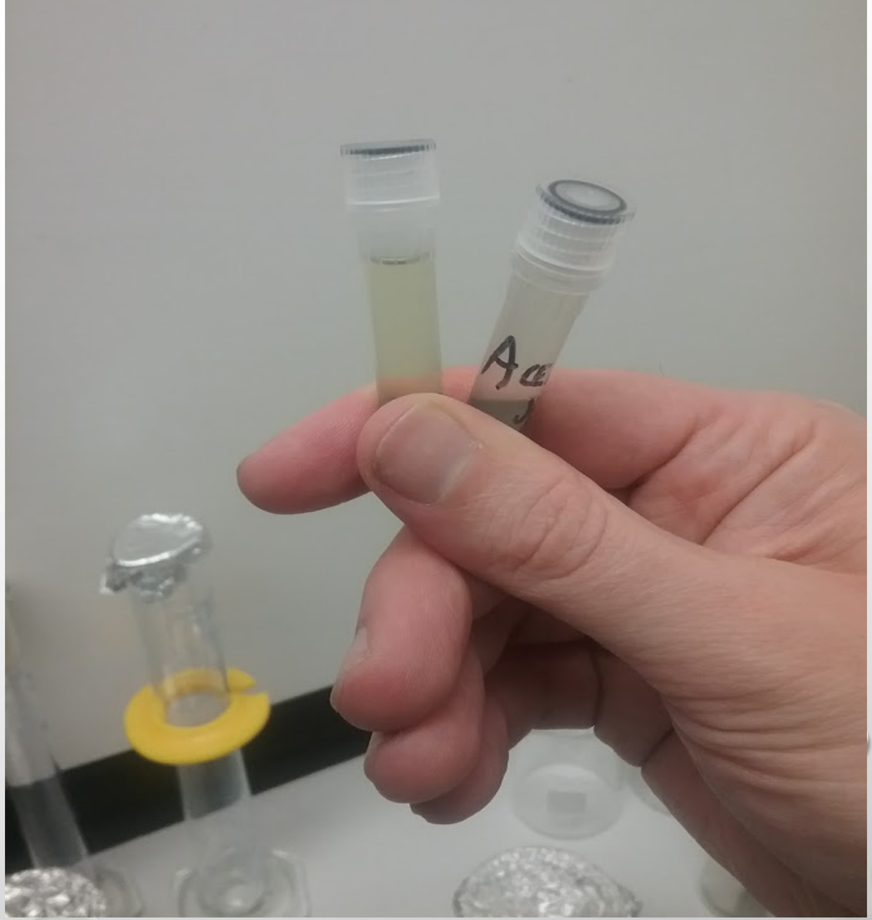
- Began October 2017 at USU Greenhouse
- Variables:
  - Soil vs. sand
  - Non-amended media vs. biochar mixture
  - Nonspiked vs. spiked irrigation water
  - 4 columns w/no corn used for evaporation
- 5 replicates for each matrix:
  - Only triplicates grew the entire 28 days
- Greenhouse conditions:
  - 28 days growing
  - Avg. temp 75.4 F, avg. relative humidity 26.5%, avg. light at noon 280 μmol/m2sec
  - 700 g soil, 950 g sand



Leaf Tissue Analysis

- **Leaf extraction**
  - Air dried and crushed with liquid Nitrogen
  - Triple extraction with methanol
  - 30 minute centrifuge at 5000 rpm
  - Clean up with Quechers™
- **Analysis**
  - Agilent 1290 Infinity LC with Agilent 6490 Triple Quadrupole MS
  - Agilent Eclipse Plus C18 (2.1 x 50 mm, 1.8 µm I.D, 0.45 mL/min)
- **Quality assurance/quality control**
  - Deuterated compounds spiked into dry leaves

QUECHERS USED FOR SAMPLE CLEANUP



Sorption column study

❑Determine sorption coefficients (Kd):

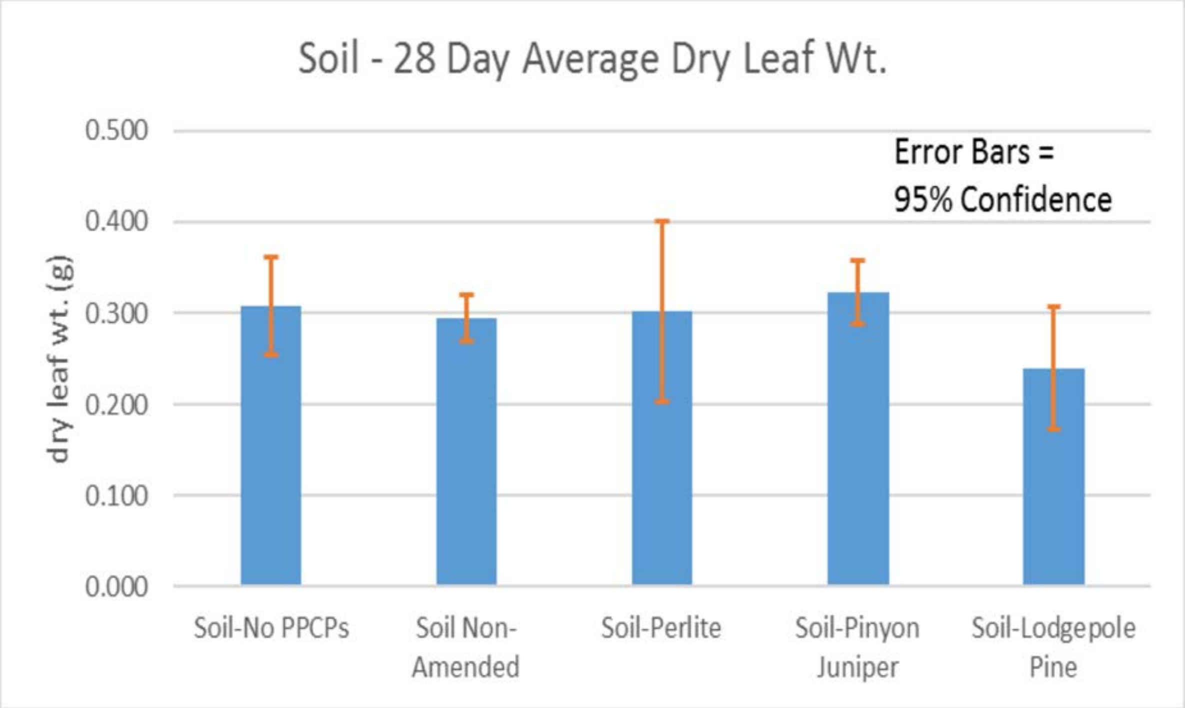
- 0.5 g growth media mixtures were tested
- Glass columns
- Reclaimed water with 1000 ug/L spike was added until leachate reached >90%
- Activated carbon was tested to compare
- Extraction with methanol

Hydroponic study

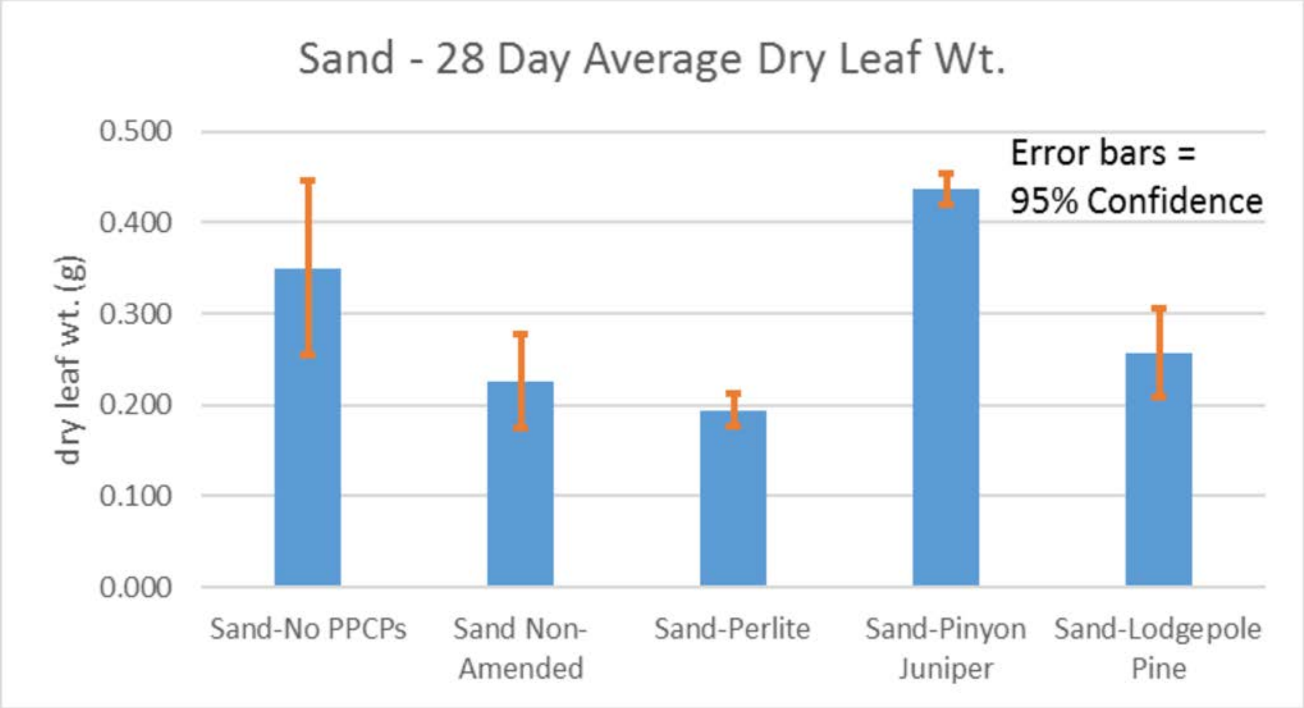
- Compare leaf uptake to exposure concentration and transpiration volume:
  - 6 spiked vs. 6 unspiked corn plants
  - PPCP concentrations (approx. 200 ug/L)
  - Transpiration volumes measured daily
- Does compound spike impact growth?
  - Experiment is ongoing

Results column study: dry leaf weight

CORN GROWN IN SOIL

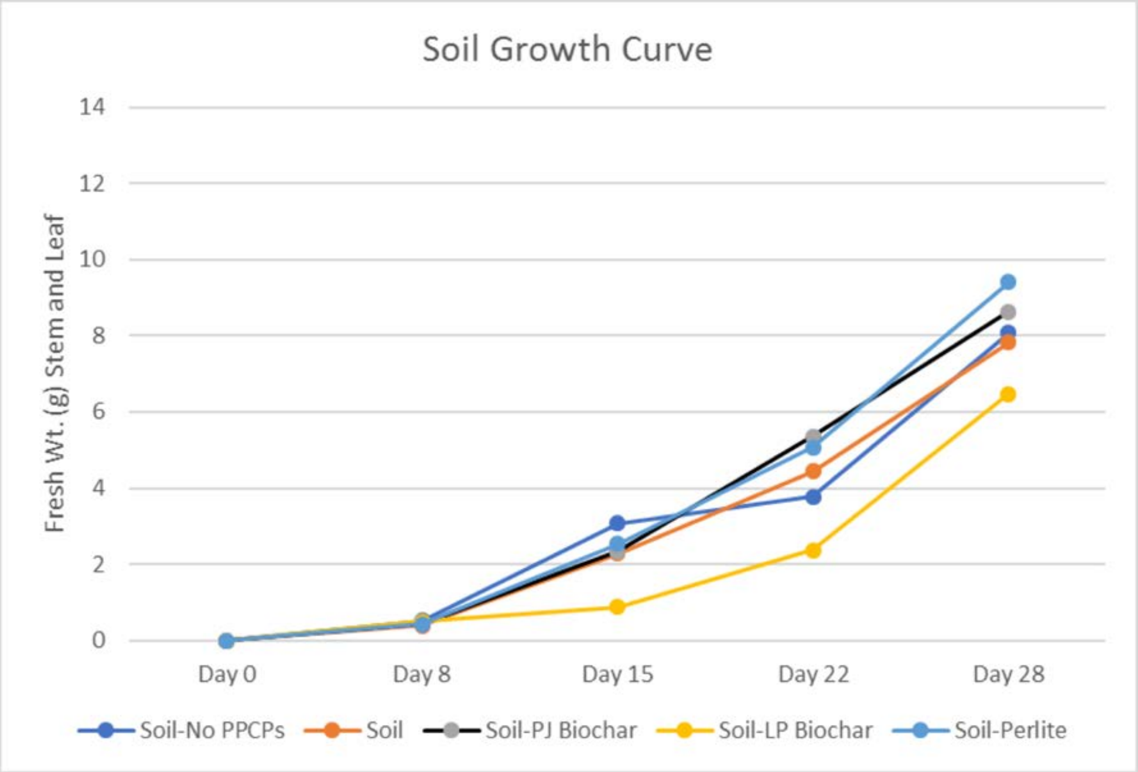


CORN GROWN IN SAND

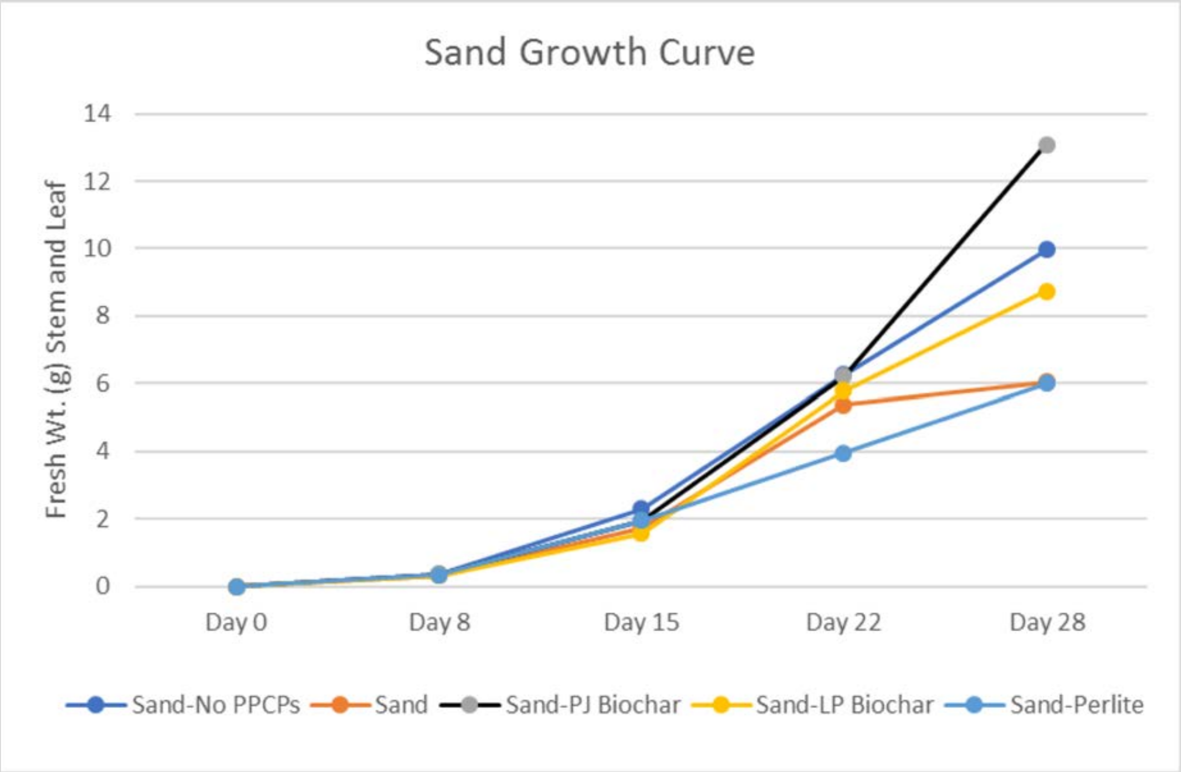


Results column study: growth curves

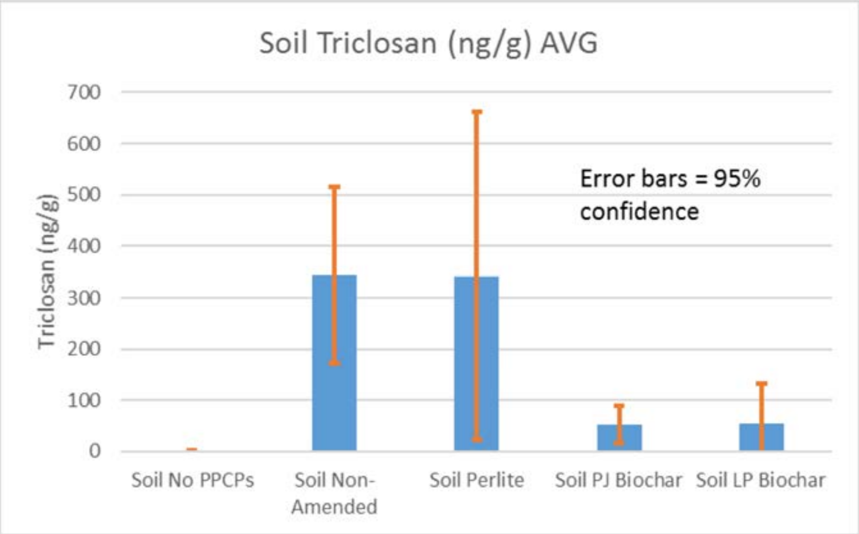
CORN GROWN IN SOIL

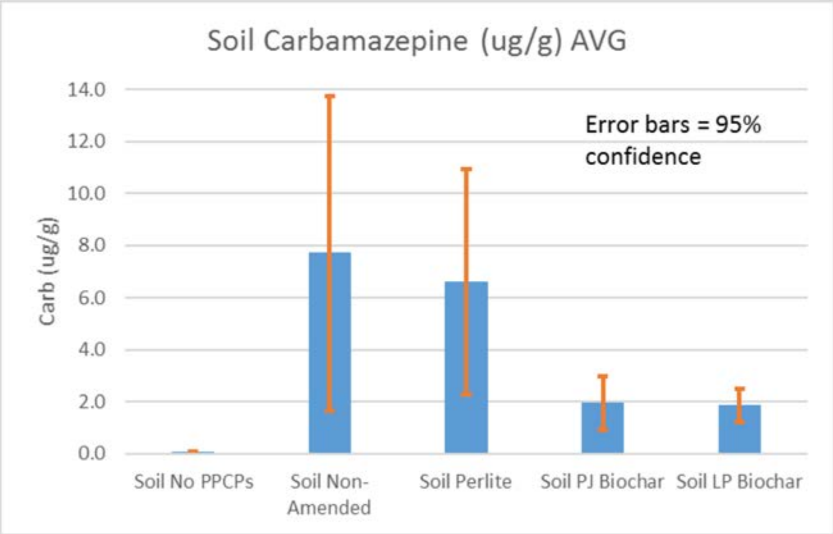


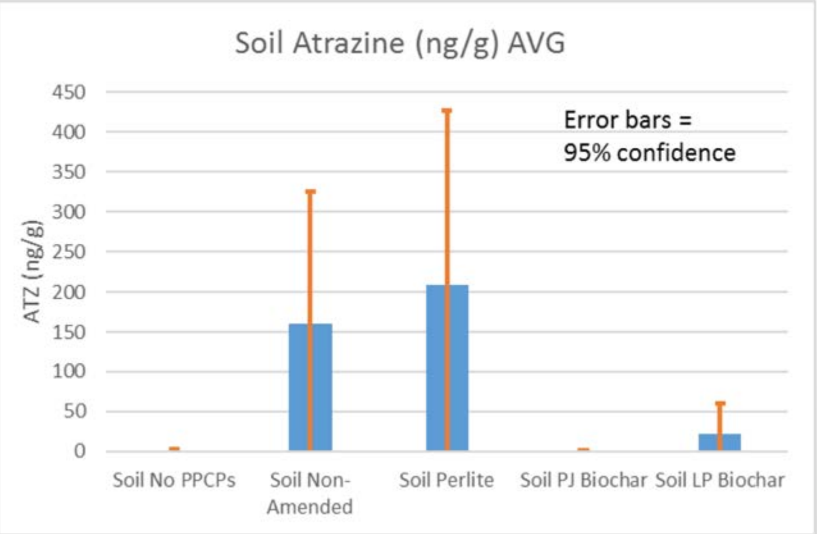
CORN GROWN IN SAND



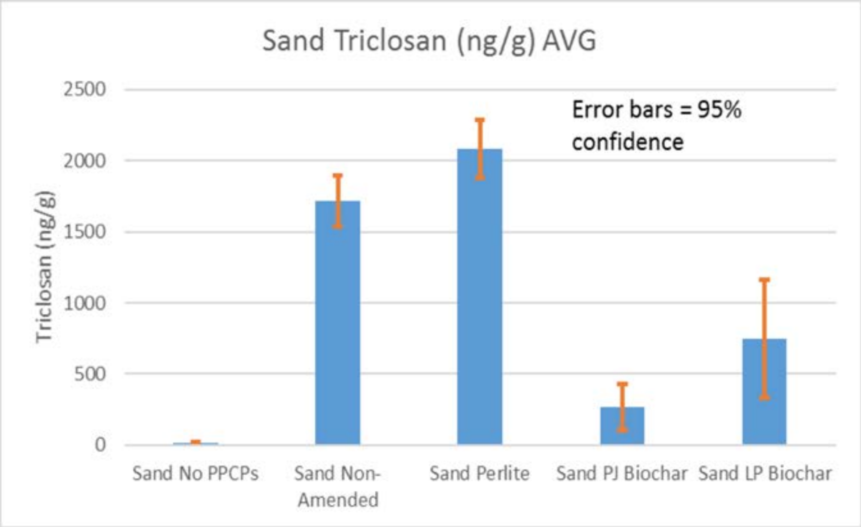
Results column study: leaf uptake (soil)

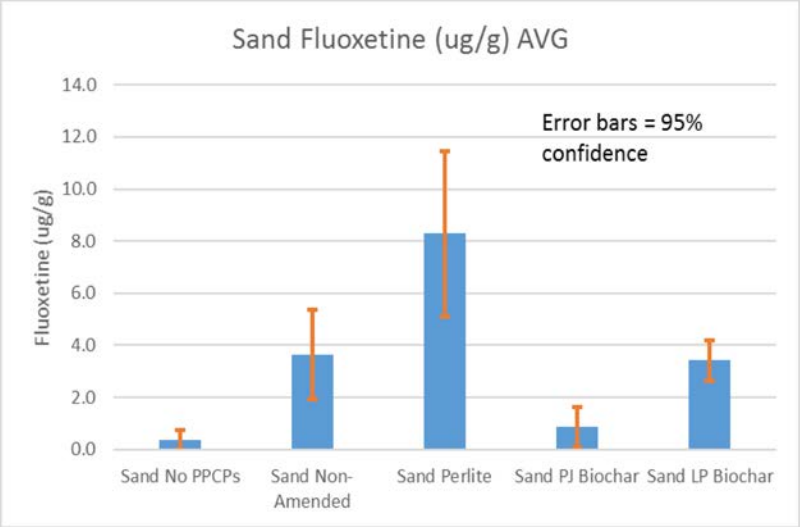


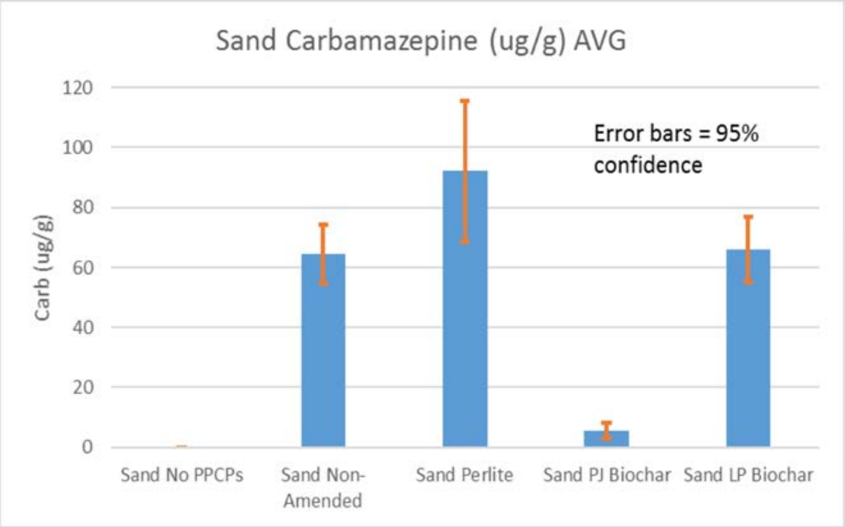




Results column study: leaf uptake (sand)







Results sorption study: Kd values (L/kg)

SOIL

Kd Soil	ATZ	CBZ	FLX	SMZ	TCS
L/kg	**4.78** ± 0.48	**5.62** ± 0.56	**497.65** ± 49.8	**5.90** ± 0.59	**118.30** ± 11.8
Recovery	101.6%	102.4%	98.8%	96.5%	93.9%

SAND

Kd Sand	ATZ	CBZ	FLX	SMZ	TCS
L/kg	**0.091** ± 0.01	**0.182** ± 0.02	**21.2** ± 2.12	**0.069** ± 0.01	**1.44** ± 0.14
Recovery	100.1%	100.5%	92.6%	101.0%	91.0%

SOIL W/PINYON JUNIPER BIOCHAR (5%)

Kd Soil-Pinyon BC	ATZ	CBZ	FLX	SMZ	TCS
L/kg	**23.1** ± 2.31	**40.6** ± 4.06	**480.2** ± 48.0	**11.3** ± 1.13	**185.9** ± 18.6
Recovery	103.5%	103.6%	104.3%	101.1%	97.1%

SAND W/PINYON JUNIPER BIOCHAR (5%)

Kd Sand-Pinyon BC	ATZ	CBZ	FLX	SMZ	TCS
L/kg	**24.6** ± 2.46	**30.8** ± 3.08	**143.9** ± 14.4	**12.2** ± 1.22	**88.6** ± 8.86
Recovery	101.0%	102.4%	85.9%	100.4%	82.8%

SOIL W/LODGEPOLE PINE BIOCHAR (5%)

Kd Soil Lodge BC	ATZ	CBZ	FLX	SMZ	TCS
L/kg	**6.55** ± 0.66	**8.74** ± 0.87	**611.0** ± 61.1	**3.19** ± 0.32	**272.6** ± 27.3
Recovery	97.7%	96.0%	87.3%	96.6%	87.0%

SAND W/LODGEPOLE PINE BIOCHAR (5%)

Kd Sand-Lodge BC	ATZ	CBZ	FLX	SMZ	TCS
L/kg	**5.90** ± 0.59	**7.97** ± 0.80	**182.1** ± 18.2	**6.06** ± 0.61	**51.8** ± 5.18
Recovery	101.1%	98.3%	93.7%	98.5%	89.8%

Results: correlation Kd to uptake

- Hypothesis: inverse relationship between Kd and leaf uptake
- Correlation was highest for triclosan

Matrix:	TCS (ng/g) ± st. dev.	Kd (L/kg)
Sand Control Leaf Uptake	1717.8 ± 157	1.4
Sand PJ Biochar Leaf Uptake	267.2 ± 144	88.6
Sand LP Biochar Leaf Uptake	748.5 ± 369	51.8
Soil Control Leaf Uptake	342.8 ± 152	118.3
Soil PJ Biochar Leaf Uptake	52.7 ± 32	185.9
Soil LP Biochar Leaf Uptake	55.8 ± 67	272.6

Conclusion

- ❑ Biochar didn't negatively impact growth
  - Pinyon juniper biochar mix had the most growth in both soil and sand
- ❑ Biochar reduced uptake of target compounds
  - High variability in leaf concentrations - need more replicates
  - Pinyon juniper biochar was more effective than lodgepole pine biochar
- ❑ Leaf concentrations:
  - sand > soil > soil + biochar (except atrazine)
  - carbamazepine > fluoxetine > triclosan > atrazine > sulfamethoxazole
- ❑ Ongoing research and experiments:
  - Analyze correlation between Kd's and bioavailability
  - Continue with hydroponic study

QUESTIONS AND COMMENTS

Engineering Significance: importance of climate change and carbon sequestration

- "Paleoestimate for the range of surface air temperature difference between 2100 CE and preindustrial period: 4.78 to 7.36 C."
  - Tobias Friedrich, Axel Timmermann, Michelle Tigchelaar, Oliver Elison Timm and Andrey Ganopolski, *Science Advances*, Nov 2016

- "It is certainly consistent with other studies, so there is reason to pay attention. In science, confidence in results builds when independent lines of investigation converge on a consistent conclusion."
  - Dr. Robert Davies, Utah State University

Engineering Significance: importance of climate change and carbon sequestration

- "The last time the planet was 5C degrees above mean was 55 million years ago. Though when it happened, it occurred over 10,000 years, while change now will be in a matter of a few decades: a pace of warming much too rapid for substantial adaptation either by natural ecosystems or human civilization." - Mark Lynas, National Geographic
- "With 5C degrees of global warming, an entirely new planet is coming into being - one largely unrecognizable from the Earth we know today":
  - Inland areas may see temperatures rise ten or more degrees C
  - Rain forests will disappear
  - Inundated coastal cities; decreasing zones of habitation due to drought and flood
  - Decreasing arable land area
- 55 million years ago at 5-8C degrees warmer:
  - Alligators in Alaska
  - Palm trees in Wyoming
  - No ice sheets at either poles

Engineering Significance: importance of climate change and carbon sequestration

- "If this sounds apocalyptic, it is. This is why we need to reduce emissions dramatically." - Dr. James Hansen, Head of the NASA Goddard Institute for Space Studies(81'-13'), *New York Times*, May 2012

- "Production of biochar and its storage in soils could reduce CO2 emissions by 12% without endangering food security, habitat or soil conservation."
  - Dominic Woolf, James E. Amonette, F. Alayne Street-Perrott, Johannes Lehmann & Stephen Joseph, August 2010, *Nature Communications*

- FUTURE STUDIES SHOULD ANALYZE COMPOUNDS BASED ON CHARGE, LOG KOW, PKA, AND OTHER IMPORTANT PROPERTIES

BIOCHAR ADVANTAGES/DISADVANTAGES

- REPORTED ADVANTAGES
  - IMPROVED SOIL FERTILITY
  - REDUCED NUTRIENT LOSS
  - REDUCED HERBICIDE LEACHING
  - LIMING PROPERTIES FOR ACID SOILS
  - CARBON SEQUESTRATION
- REPORTED DISADVANTAGES
  - REDUCTION IN HERBICIDE EFFICIENCY
  - PAHS, DIOXINS, METALS (DEPENDS ON FEEDSTOCK)
  - CHANGES IN SOIL MICROBIAL COMMUNITY
  - REDUCED NUTRIENT AVAILABILITY
- SHORT TERM VS LONG TERM IMPACTS?

Fluoxetine leaf concentrations normalized to water transpired