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A survey of biochars:

Interactions with dissolved ammonia, nitrate,
and phosphate



Biochar for Agriculture

Primary Research Motivation:

1. ↑ crop production
2. ↓ nutrient leaching



Additional Benefit of Biochar:

3. Potentially sustainable
 - CO₂ sequestration
 - reuse of organic waste



The problem with Biochar

- Currently no consensus in BC protocol
who, what, when, where, and how of BC
- A result of a more fundamental question
having yet to be answered:
 - **How does BC work?** / What is the mechanism for
 - ↑ crop production?
 - ↓ nutrient leaching?

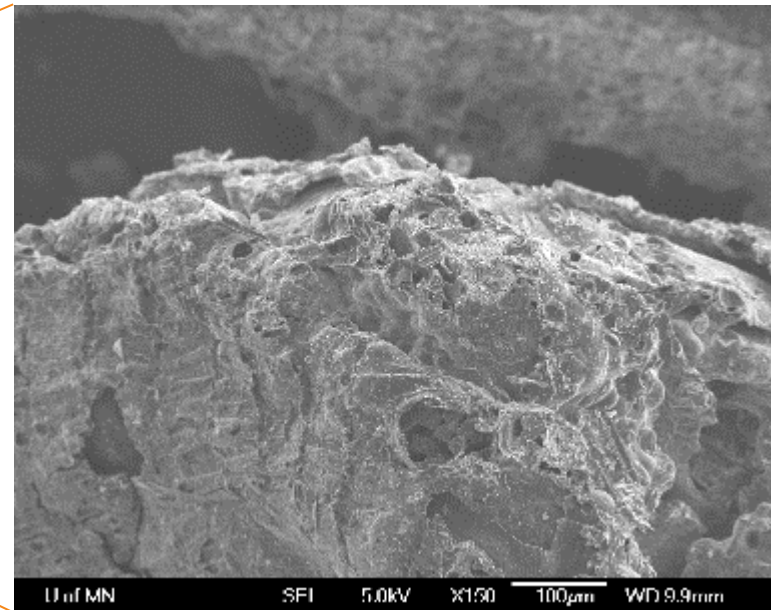
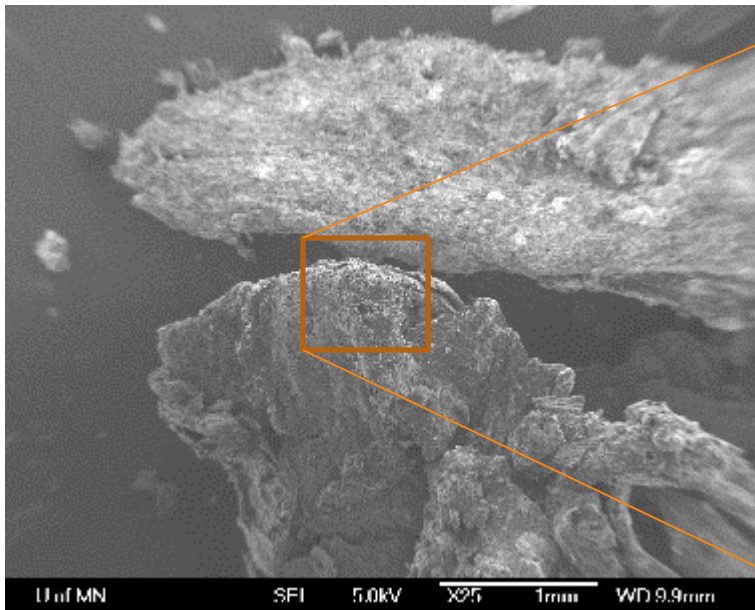


What is biochar?

Biochar is:

- 1) black carbon
- 2) carbon sequestration

The physical and chemical properties of the biochar (black carbon structure) will dictate the use of biochar in agricultural applications



What do we know?

- BC (biochar/black carbon) affects soil-nutrient-plant dynamics
 - “*Terra Preta*” soils of Amazon Basin (Glaser et al., 2002)
 - Observational studies
 - Crop enhancement (Lehmann et al. 2003, Major et al. 2010, Yamato et al. 2006)
 - Nutrient Leaching (Laird et al., 2010; Lehmann et al., 2003; Liang et al., 2006)
 - Not all biochars have positive effects (Atkinson et al., 2010; Lehmann et al., 2003; Lehmann et al., 2011; Major et al., 2010; Novak et al., 2009)



Suggested reasons for observed effects

1. Increase soil carbon content
2. Alter soil Cation Exchange Capacity
3. Affect soil microbial populations/diversities
4. Interacting with soil nutrients directly

We focus on the direct nutrient interaction with
Biochar - #4



Direct Nutrient Interaction

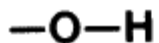
- Biochar shows capacity to sorb nutrients and maintain plant availability (Taghizadeh-Toosi et al., 2011; Yao et al., 2012)
 - Results indicate a chemical interaction, likely surface chemistry
 - However, surface chemistry was not investigated in these studies



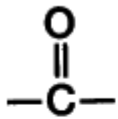
Sorption Chemistry

Two parameters needed for sorption:

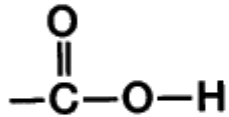
1) Sorption sites
(functional groups)



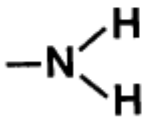
Hydroxyl group



Carbonyl group



Carboxyl group



Amino group



Sulfhydryl group

2) Sorptive chemicals

Nutrients!!!

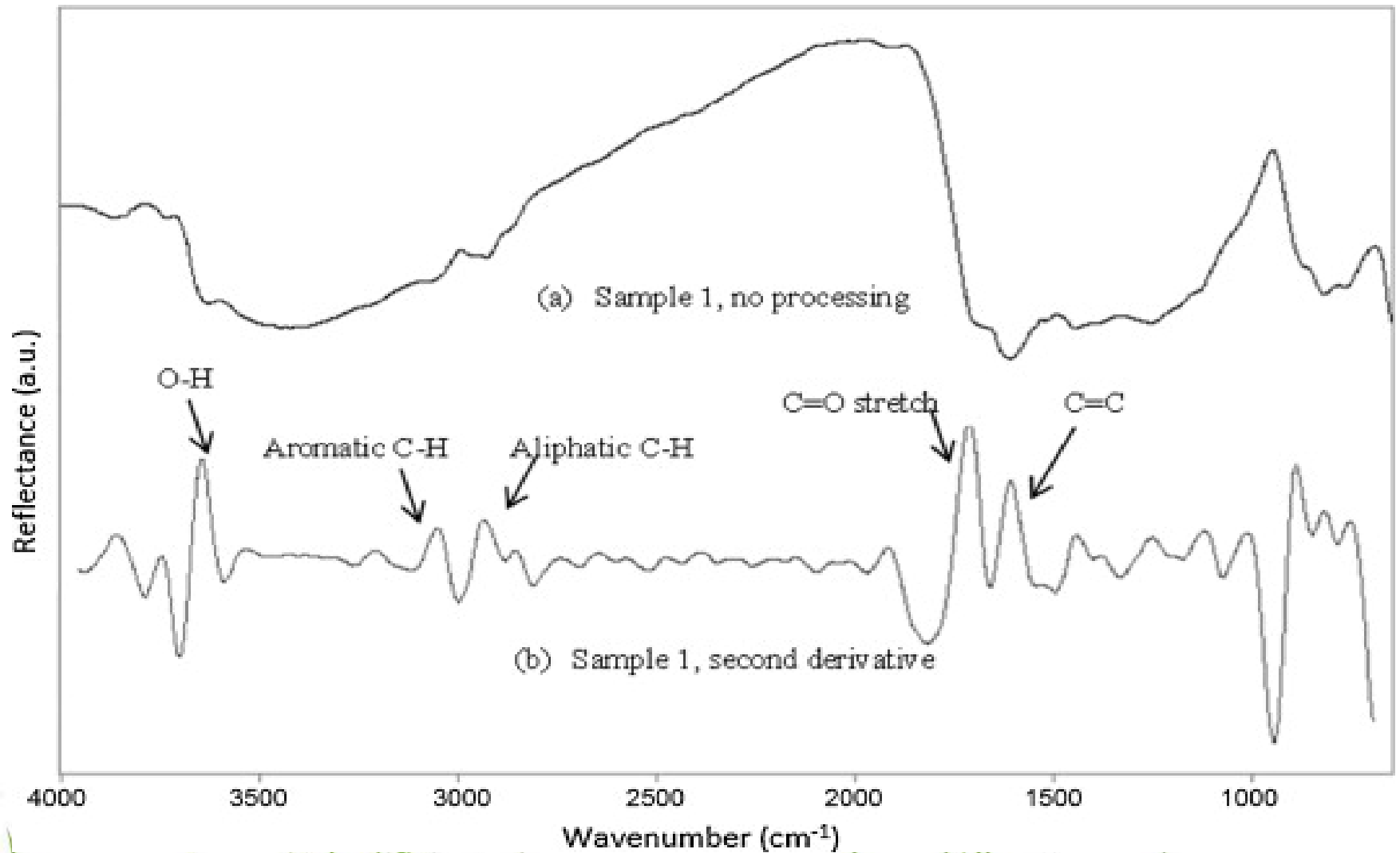


Biochar has Sorptive Sites

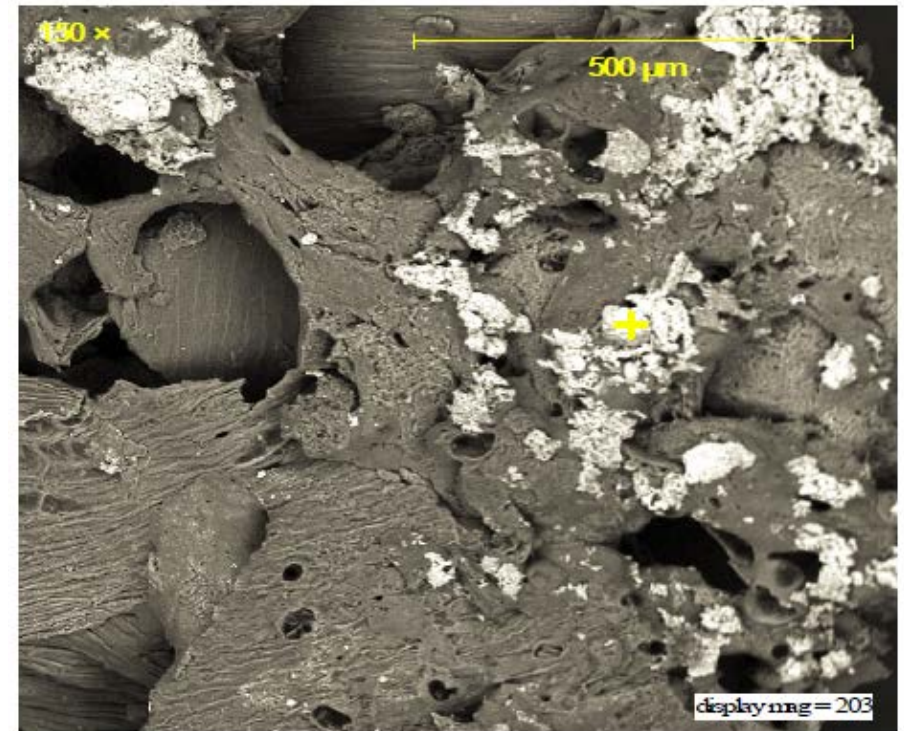
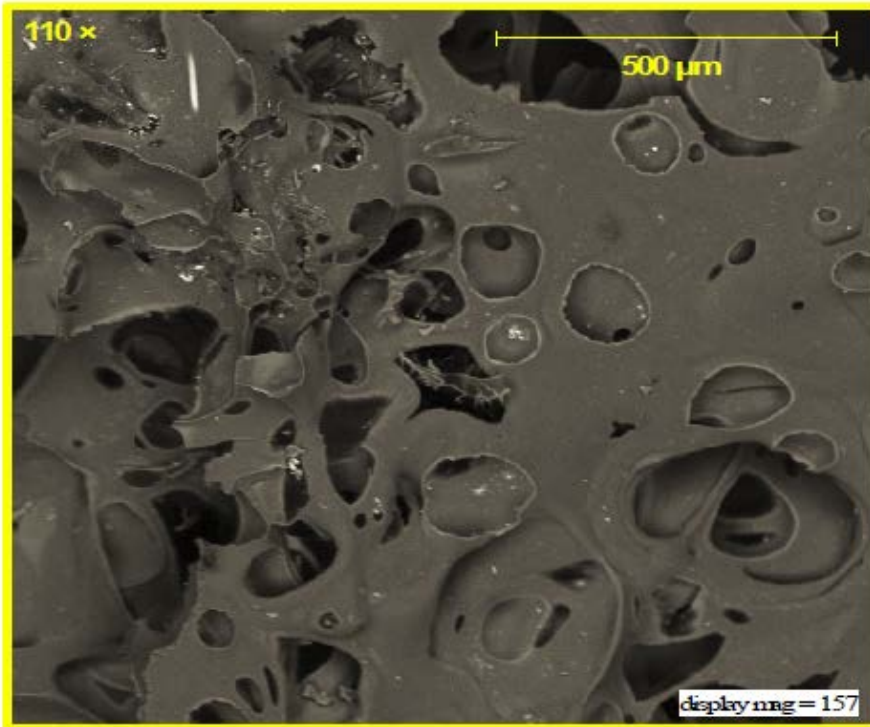
- Preliminary data indicates that functional groups exist on the Biochar surface.



FT-IR Spectra



SEM-EDS Spectra



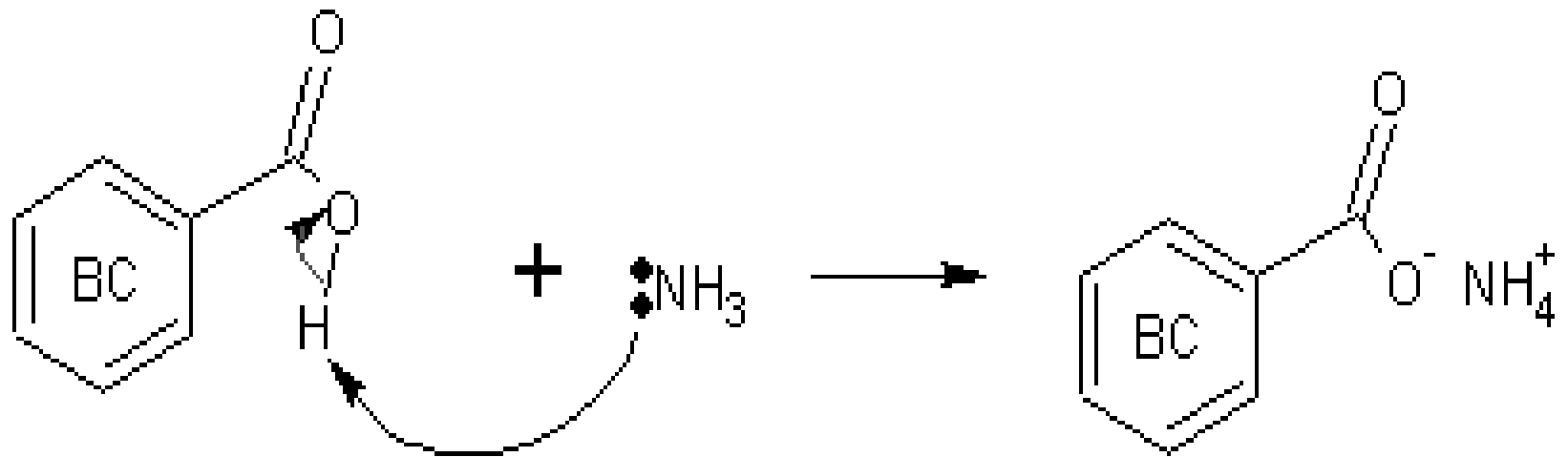
Notice Differences:

- Color
- Porosity
- Surface area

Precipitation formation

- Before and After examination

Example Potential Interaction with Ammonia



Big Picture Recap

- Investigating BC for Agricultural applications
 - ↑ Crop production
 - ↓ Nutrient leaching

- Refined investigation from
Field Study to Lab Study

BC in agriculture – to – BC sorptive properties



Focusing On Surface Chemistry

Experimental Premise: Different Biochars have different and varying amounts of functional groups

Hypothesis: Sorption by functional groups on BC is the mechanism by which biochars interact with nutrients.



Research Goal and Theoretical Test

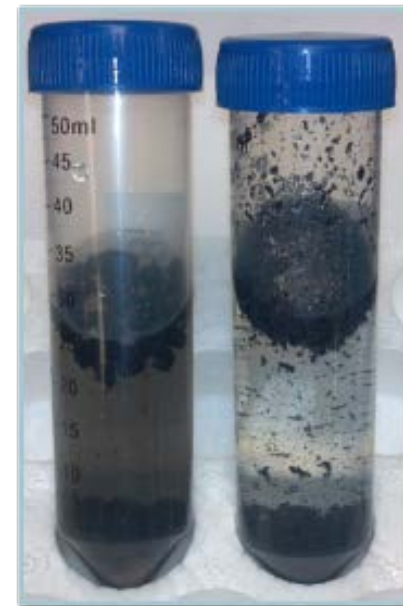
- **Goal:** find determining characteristics for biochar-nutrient interaction (Hypothesis: Functional Groups)

Theoretical Test:

- Test Biochars for sorbtion of:
Nutrients: NO_3^- PO_4^{3-} NH_4^+
- Characterize Biochar surface functional group chemistry

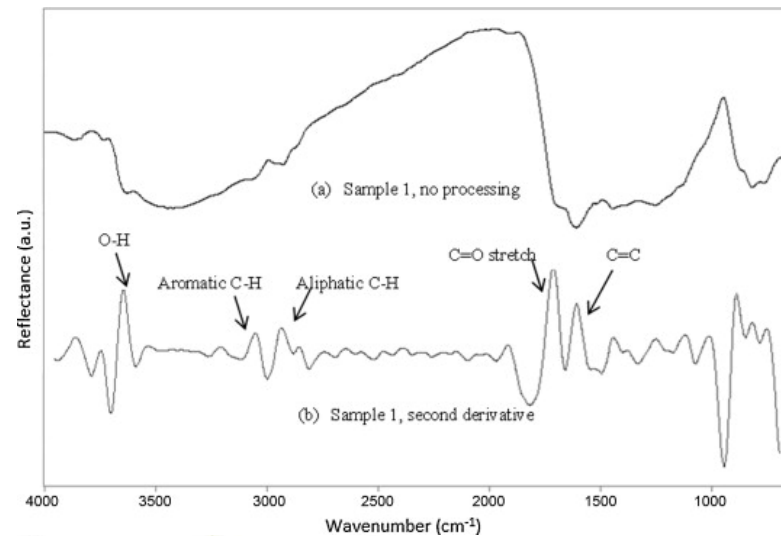
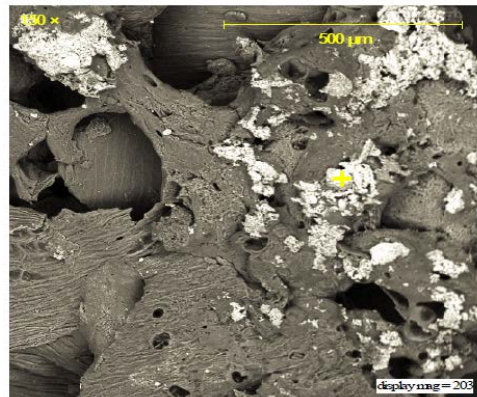
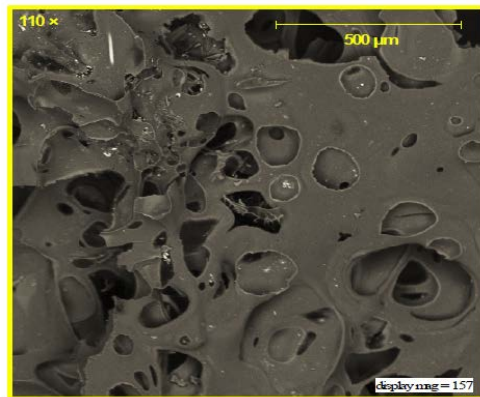
Experimental Design

- Batch equilibrium:
 - Global collection of biochars
 - 20ppm NH_4^+ , 20 ppm NO_3^- , and 2ppm PO_4^-
 - Triplicate replicates
 - 24 hours agitation

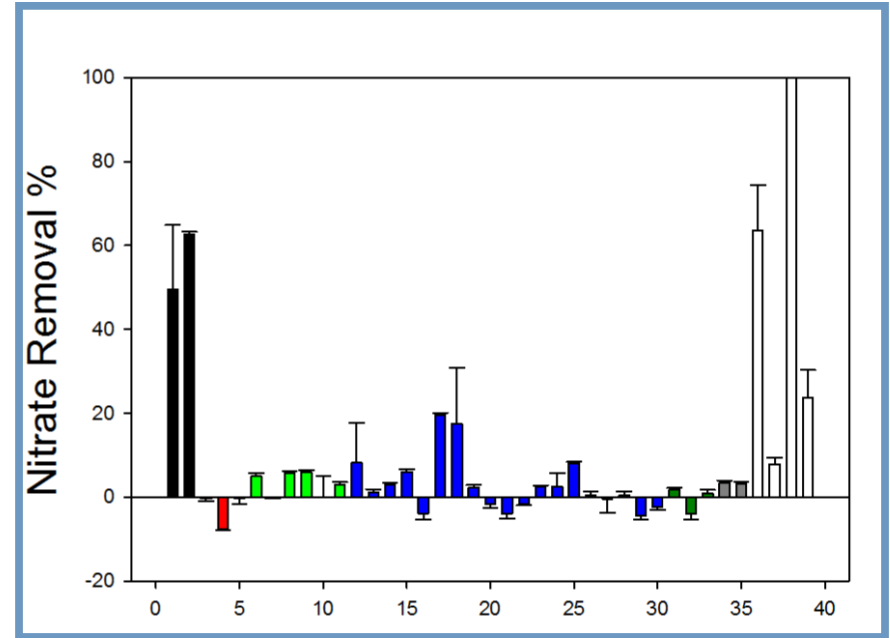
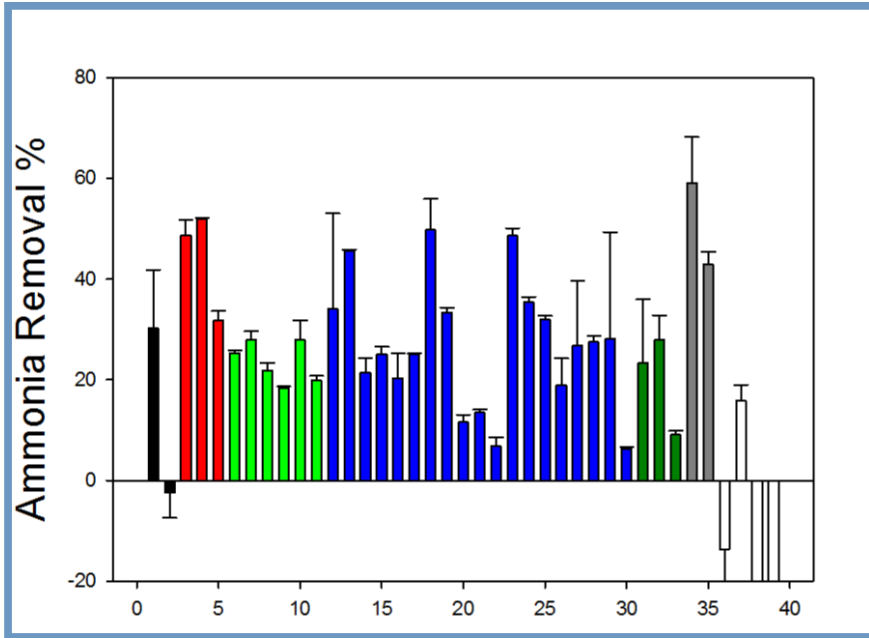


Experimental Design

- Biochar CEC determination
- Biochar characterization
 - XPS, SEM, FT-IR (provide us with surficial analysis and functional group data)



Preliminary data



■ Activated Charcoal ■ Fast Pyrolysis ■ Microwave Assisted Pyrolysis ■ Slow Pyrolysis ■ Hydrothermal ■ Wood Ash □ Raw Feedstock

Conclusions

- Biochars are different
- Biochars interact with nutrients differently
- Currently conducting research on BC functional group interaction with Nutrients





Thank You

Questions?

