Effects of biochar on soil microbial communities and nitrogen cycling in two California nutrient management systems.

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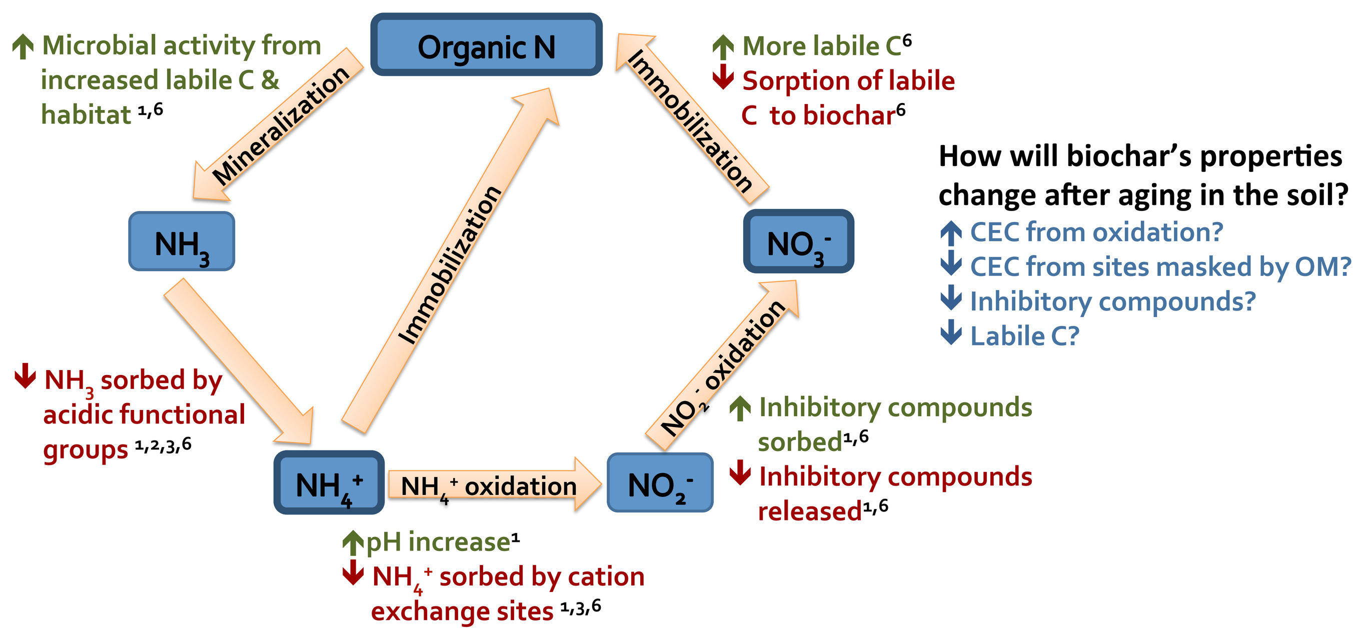
Introduction

- There are still knowledge gaps concerning short- and long-term effects of biochars on soil microbial abundance and microbially-driven processes, such as N cycling.
- Impacts of biochars and other pyrogenic C products on soil microbes and N transformations have been well-studied in low input systems, such as forests or highly weathered tropical soils.
- Some studies have found:
  - ↑ N mineralization rates[5,6]
  - ↑ Nitrification rates[1,4,6]
  - ↑ Ammonium-oxidizing bacteria (AOB) abundance[1,4]
- But effects of biochars depend on the properties of the system to which they are being added.

In what ways could biochar affect microbes in the N cycle?



- More long-term, field studies on biochars' effects in intensively-managed, agricultural systems are needed.
- Soil N cycling dynamics will differ based on the nutrient management system used. Therefore, we need to explore biochar's impacts in conjunction with both mineral and organic N fertilizers.

We hypothesize that in agricultural systems, biochar can change the abundance of ammonia-oxidizing and total microorganisms, affect N mineralization and nitrification dynamics, thus influencing crop yields.

Objectives

- To assess how amendment of walnut shell biochar influences the abundance of specific microbial groups in agricultural soils.
- To determine whether potential changes in microbial groups, such as ammonia-oxidizing bacteria (AOB) and archaea (AOA) are reflected in soil N transformations.

Materials and Methods

Location

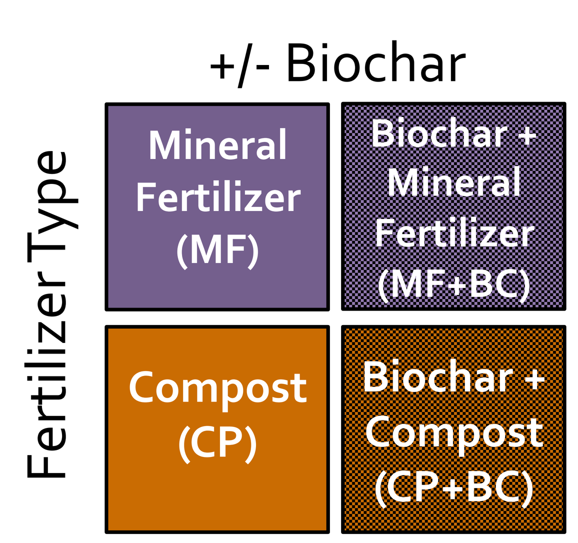
- UC Davis's Russell Ranch Sustainable Agriculture Facility provides a unique opportunity for long-term field research.

Materials:

- Walnut shell biochar: produced at 900°C, pH= 9.7, Surface Area = 221.7 m² g⁻¹
- Yolo silt loam soil: $pH_{MF, CP}$= 7.7, pH_{MF+BC} = 7.9, pH_{CP+BC}= 7.8

Experimental Setup:

- Biochar applied at 10 t ha⁻¹ (~0.5% w:w) once in May 2012.
- RCBD with 4 blocks, 1 treatment rep/block; 2 x 2 factorial treatments
- Planted in tomato-corn rotation since Summer 2012



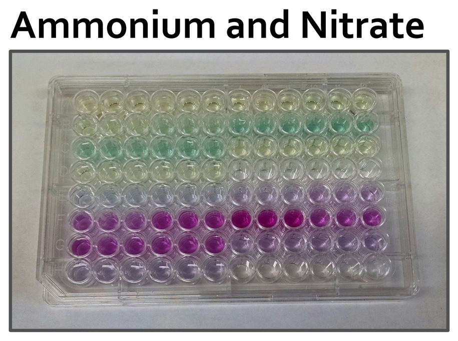
Mineral fertilizer: UAN
Compost: Poultry manure compost

Sampling and Processing:

- 0-30 cm cores sampled from each plot throughout the summer and winter seasons
- Subsamples extracted immediately in 0.5 M K2SO4 for NH_4^+ and NO_3^- concentrations
- Subsamples frozen at -20 °C for DNA extraction

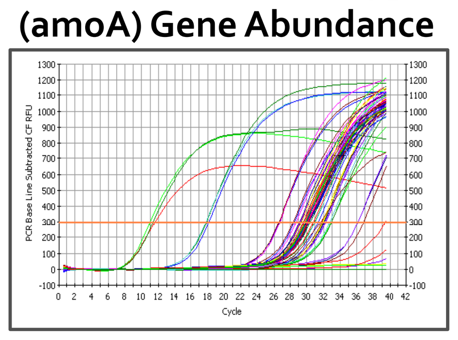
Methods:

Ammonium and Nitrate



Ammonium-N and nitrate-N concentrations measured colorimetrically from 0.5 M K_2SO_4 extracts[7]

16S & Ammonia Monooxygenase (amoA) Gene Abundance



Bacterial and Archaeal 16S and amoA gene copy numbers measured using quantitative PCR (qPCR)

Potentially Mineralizable N

PMN determined from an anaerobic incubation of samples collected 7/9/14. NH_4^+-N concentration measured after 7 days.[8]

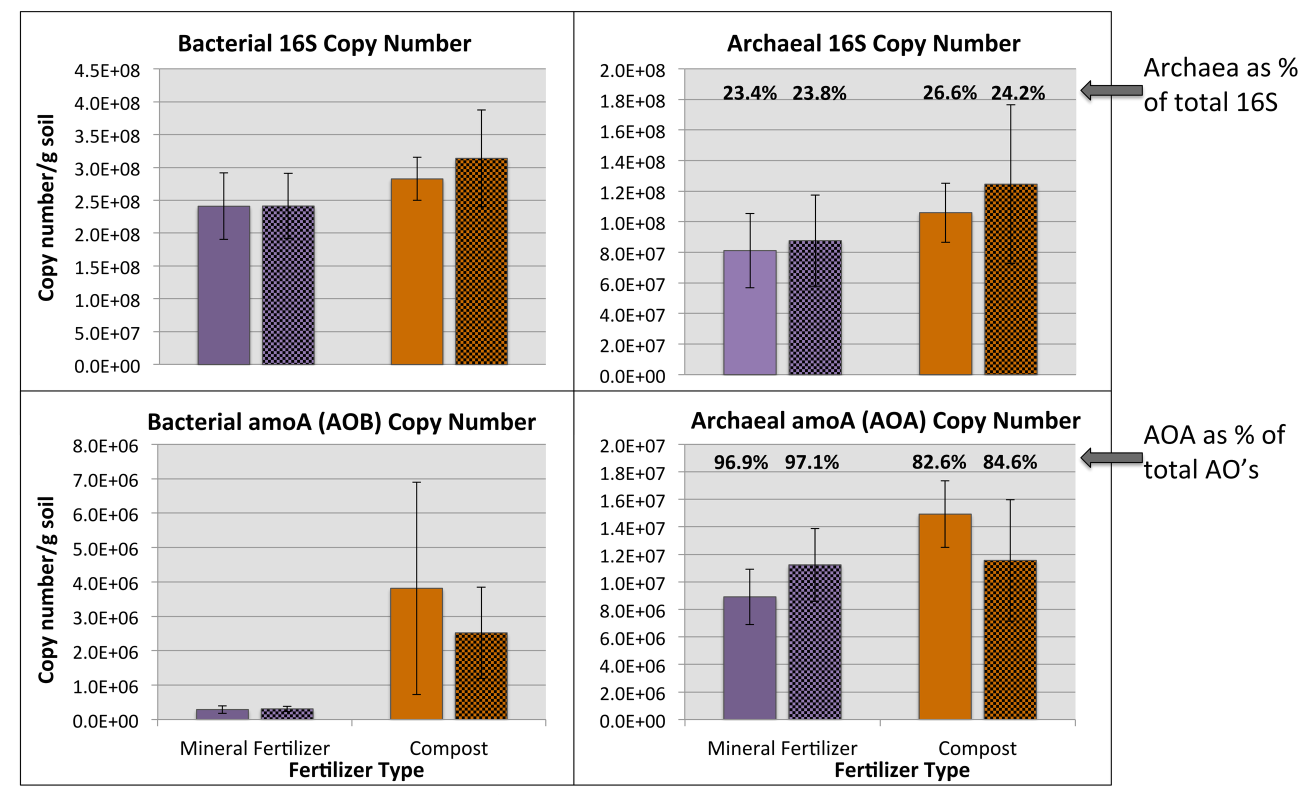
Crop Yields

Crop yields were measured on a dry weight basis from hand and machine harvests of fruit/grain and biomass.

Results

qPCR

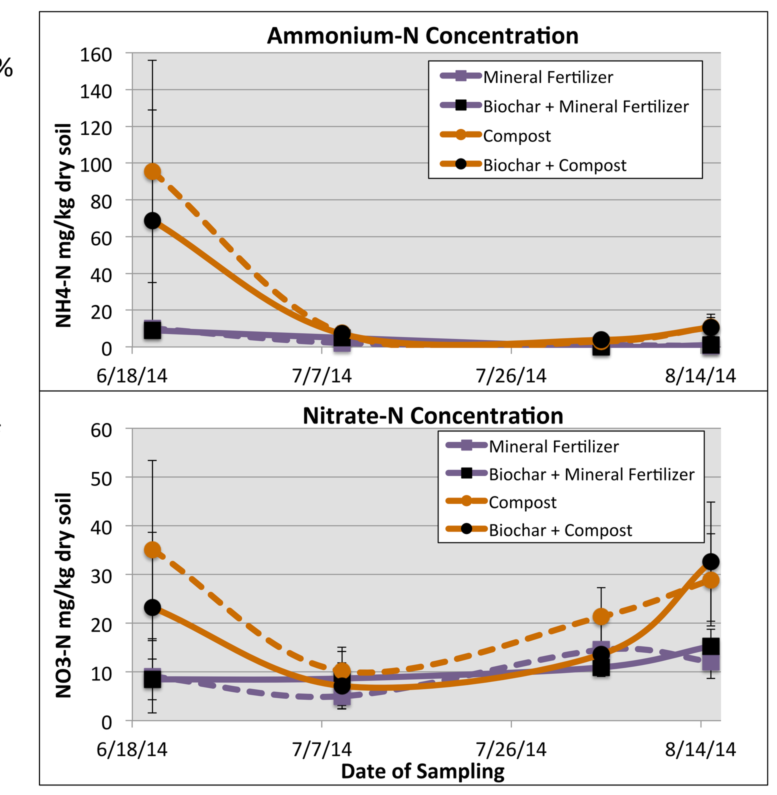
- Total microbial biomass (16S) was slightly higher (NS) in CP+BC plots, perhaps due to labile C availability.
- CP plots had the highest AO organisms (NS), with slightly reduced numbers in CP+BC, possibly due to sorption of NH_3 and NH_4^+.
- Biochar addition increased AOA slightly in MF, but decreased them with CP. Potential explanations include the higher pH in MF+BC and availability of NH_3 from organic sources, which AOA may prefer.[9]



Figures 1-4. Gene copy numbers gram⁻¹ from samples collected 6/20/14. Samples from other time points followed similar trends. Graphs show mean ± SE.

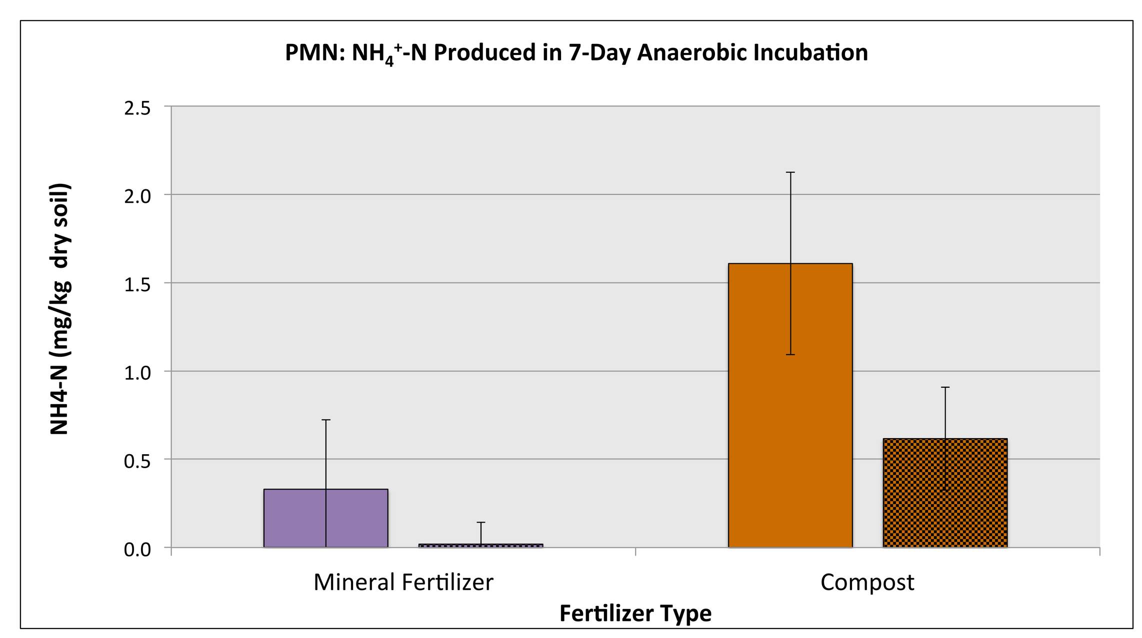
Ammonium & Nitrate

- Plots with biochar added did not show significant differences in extractable NH_4^+-N and NO_3^--N concentrations compared with plots without biochar.
- However, CP+BC did tend to have lower inorganic N compared to CP alone, particularly at the beginning of the season.



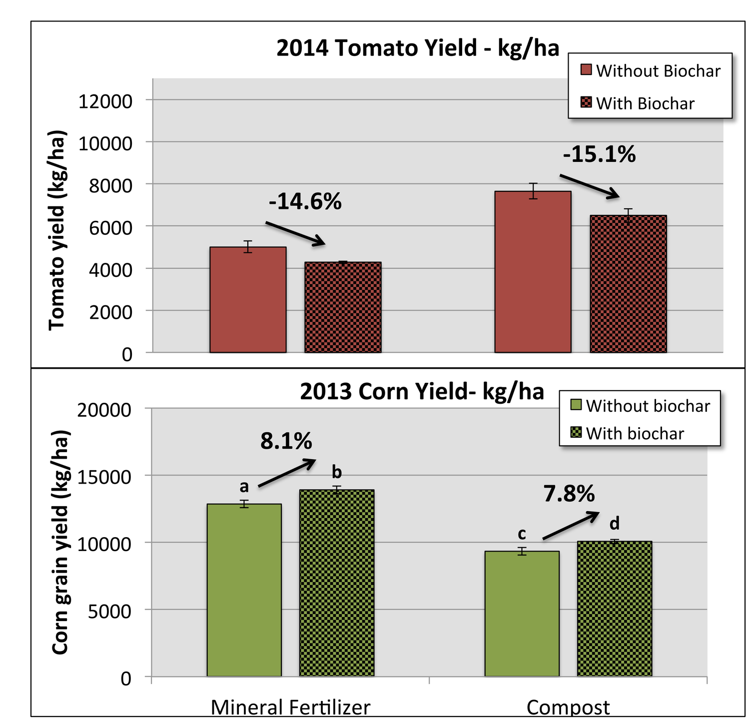
Potentially Mineralizable N

- +BC treatments showed lower values (NS) of PMN compared with soils with the same fertilizer –BC.
- This may be due to NH_3 and NH_4^+ adsorption onto biochar surfaces, reducing availability of NH_3 to microbes and the concentrations of extractable NH_4^+.



Yield – 2013 and 2014

- Tomato yields in 2014 were significantly lower in plots with biochar. However, 2013 corn yields showed ~8% increase in yield with biochar.



Conclusions

- Though some trends are present, biochar amendment did not significantly alter the abundance of ammonia-oxidizing (AO) or total bacteria & archaea over the 2014 growing season.
- Biochar did not significantly change inorganic N concentrations over the growing season.
- However, + BC plots showed lower PMN, potentially due to sorption of NH3 and NH4+ onto biochar surfaces.
- Biochar also decreased tomato yields by ~15% in both fertilizer regimes. This showed the opposite trend to the 2013 season, where corn yields increased by ~8% with biochar. There may be interactions with differing nutrient and water uptake and management patterns between these two crops.
- **Overall, biochar amendment to agricultural soils does not appear to significantly change microbial abundance or N transformations in the field. However, it is still having a significant effect on crop yield.**

Next Steps

- Our long-term study will continue, and in Nov. 2014, walnut shell biochar will be reapplied at a rate of 10 tonnes ha⁻¹.
- We will continue to explore potential explanations for yield differences, including NH_3 and NH_4^+ sorption.
- Other planned measurements include:
  - Phospholipid Fatty Acid Analysis (PLFA)
  - Ca^{2+}, K^+, Mg^{2+}, SO_4^{2-} ion concentrations to further assess fertility differences with biochar addition.

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