Biochar addition rate controls GHG fluxes, soil priming, and microbial activity in temperate soils

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Introduction

Biochar application to soils may have several environmental benefits including making bio-energy production C negative, soil C sequestration, reduction in greenhouse gas (GHG) emissions, and enhancement of soil fertility (Lehmann, 2007).

Our aims were:

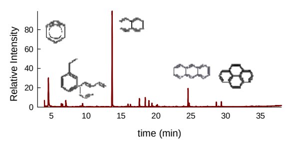
1) **To quantify the potential environmental benefits of a fast-pyrolysis biochar to temperate soil C sequestration, GHG emission reduction, and microbial community size and structure.**

2) **To determine biochar-C versus native soil organic C (SOC) contribution to the CO_2 efflux and incorporation into microbial biomass using natural abundance $\delta^{13}C$.**

Long-term Laboratory Incubation

Biochar characteristics

- Fast-pyrolyzed, oak (550ºC) (Natural Renewable Energy Lab, Golden)



C %	55.80
N %	0.22
O %	0.70
$\delta^{13}C$	-27.10
IC (mg/g)	3.12
pH	10.50
Ash %	41.93
Volatile matter %	4.42

Figure 1: Biochar characterization by pyrolysis-gas chromatography-mass indicated a recalcitrant chemical nature, (single, double, triple and quadruple C rings). Products of ligno-cellulose and sugars were absent.

Experimental Design

Soils	Textural class	C	N	pH	$\delta^{13}C$
Colorado	Sandy Clay Loam	1.03%	0.12%	8.95	-12.66
Minnesota	Sandy Clay Loam	1.86%	0.19%	6.34	-19.25
Iowa	Sandy Loam	1.14%	0.10%	7.27	-21.64
Michigan	Clay	1.48%	0.18%	8.21	-15.98

- Complete factorial design
  - 4 soils
  - 5 biochar addition rates
  - 0, 1, 5, 10, 20% w.w.
- No nutrient additions
- 60% water holding capacity (for every soil+BC combination)

Measurements

- CO_2 analyzed by IRGA
- $\delta^{13}C$ GC-IRMS
- CH_4 and N_2O analyzed by GC
- Microbial biomass via phospholipid fatty acid (PLFA).

SOC priming

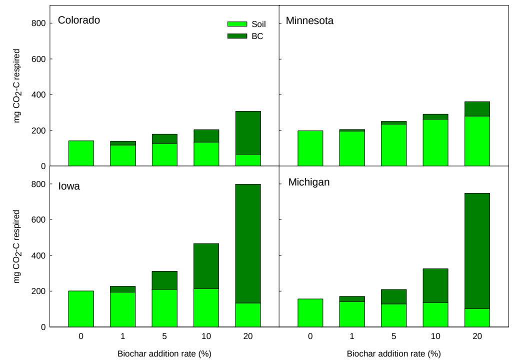


Figure 2: Cumulative SOC-derived and biochar-derived respiration over the 2 years of laboratory incubation for the 4 soils and the 5 biochar addition rates.

CO_2

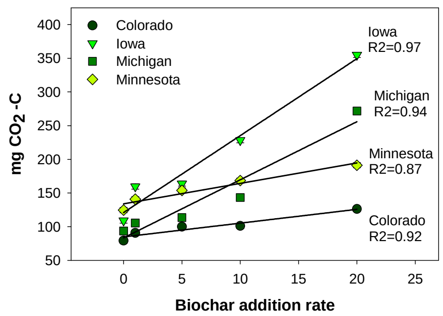


Figure 3: Cumulative CO_2 over 2 years of laboratory incubation for the 4 soils and the 5 biochar addition rates.

GHG Balance

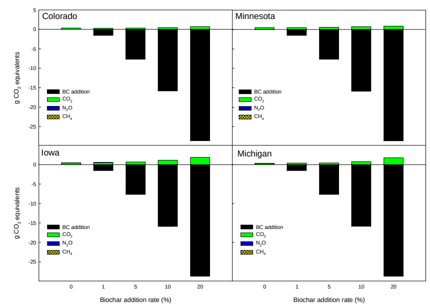


Figure 5: Soil C sequestration *versus* GHG emissions expressed as CO_2 equivalents, for the 4 temperate soils after 2 years of incubation.

N_2O

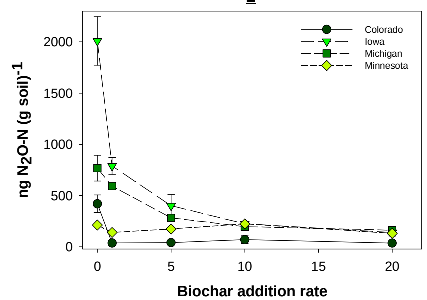


Figure 4: Cumulative N_2O over 2 years of laboratory incubation for the 4 soils and the 5 biochar addition rates.

Microbial effects

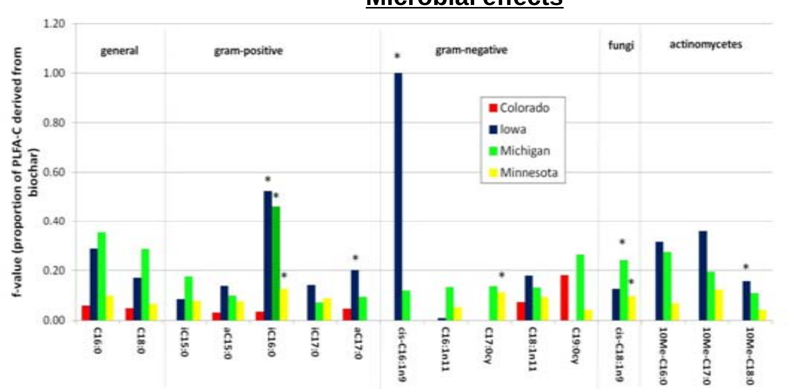


Figure 6: Biochar-derived PLFA-C (f-value from $\delta^{13}C$) for biomarkers of microbial groups after 1 year of incubation for the 4 soils and 5 biochar additions.

Results & Conclusions

1. Fast-pyrolysis produced an ash-rich, alkaline, chemically recalcitrant char (Fig 1).
2. Nevertheless, biochar was used as a substrate for microbial respiration, more so in the soils with low SOC content, where it suppressed native SOC respiration at most sites (Fig 2).
3. Increasing biochar addition rate stimulated CO_2 emissions, proportionally (Fig 3).
4. Increasing biochar addition exponentially reduced N_2O emissions over the 2 years of incubation (Fig 4).
5. Only a small fraction of BC-C was respired after 2 years--likely corresponding to the volatile fraction (4%) (Fig 2).
6. The remaining C fraction accumulated in soils and completely offset any stimulation of CO_2 emissions (Fig 5).
7. Increasing biochar addition proportionally increased microbial biomass (data not shown). Biochar-C was actively used by several microbial groups including gram-positive, gram-negative bacteria and fungi (Fig 6).

References

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