Thermochemical Characterization of a Biochar in Relation to its Biodegradation in Soil

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Introduction

The impact of rising atmospheric carbon dioxide (CO_2) levels is a real concern for our generation. Biochar (Bc) technology is emerging as a plausible solution for sequestering carbon in soils. One of the critical issues facing Bc research is the lack of analytical techniques that not only characterize Bc but also link the analytical properties to its environmental functionality. The goal of this study was to evaluate the biodegradation rate of Bc in a mixed biochar-soil system in relation to the native soil organic carbon (SOC) using a ^{13}C tracer technique. We then linked the biodegradation behavior to the thermochemical nature of the Bc.

Methods

Switchgrass (*Panicum virgatum*) biochar (Bc) was generated at 400°C via slow pyrolysis in a furnace flushed with nitrogen gas. A multi-element scanning thermal analysis (MESTA) technique was used to characterize the thermochemical properties of the Bc. Respired CO_2 was collected for $^{13}CO_2$ analysis from the following soil incubation conditions: control forest soil (0% Bc), 1% Bc (1g Bc in 100g of soil, dry weight), 3% Bc, and raw feedstock (4% switchgrass). $^{13}CO_2$ was measured using wavelength-scanned cavity ring-down spectroscopy (Picarro, Inc $^{13}CO_2$ analyzer). A two-end member mixing model with ^{13}C tracers was used to measure the biodegradation rates of the native SOC and Bc in the mixed biochar-soil system.

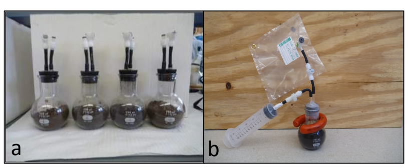

Fig 1. (a) Soil respiration jars capped with two-port stopper.
(b) These air-tight connectors and air bags were used to sample the head space gas without changing the pressure conditions in the jars.

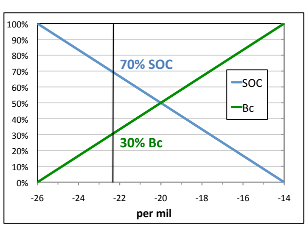

Fig 2. Two-end member mixing model based on ^{13}C signature of forest soil (-26 per mil, 100% SOC) and switchgrass (-14 per mil, 100% Bc).

Acknowledgments

We wish to thank our lab team, Dr. Glynnis Bugna and Djanan Nemours for their technical assistance, Ms. Hatakka's committee members Dr. Onokpise, Dr. Milla, and Dr. Minogue, and Dr. Mbuya and the School of Graduate Studies at FAMU for their financial assistance.

Results

Soil Respiration Rate

The total respiration rates (Fig 3a) of the 1% and 3% Bc treatments were only significantly different from the control during the first 12 weeks (initial priming period). The biodegradation rate of native SOC in the 1% and 3% treatments was not significantly different from the control (Fig 3b), suggesting that Bc application did not accelerate native soil organic matter decomposition. As such, the initial short-term increase in total respiration rate appears to be from the decomposition of Bc in the mixed biochar-soil treatments (Fig 3a). The biodegradation rate of Bc-carbon (mgCO2-C/g Bc-C/day) in both the 1% and 3% treatments was very low (Fig 3c) and contributed very little to the total respiration rate (Fig 3a).

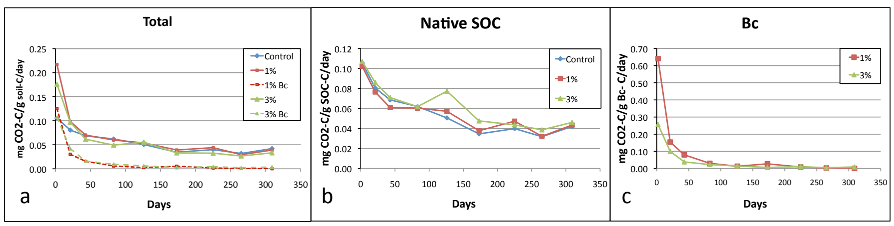

Fig 3. (a) Total respiration rate of the control, 1% and 3% Bc treatments, and the Bc fraction of the total respiration rate. (b) Biodegradation rate of native SOC in the control and Bc treatments. (c) Biodegradation rate of Bc in the 1% and 3% biochar-soil treatment.

MESTA Characterization

The MESTA thermogram indicates that the carbon in the control soil can be divided into two peaks, corresponding to a low temperature region (<425°C) and a high temperature region (> 425°C). Switchgrass Bc contains a higher proportion of high-temperature, stable carbon than low-temperature, less stable carbon (Fig 4a). The carbon thermogram of the 1% mixed Bc-soil treatment is additive indication that no interaction occurred between the SOC and Bc-C (Fig 4b).

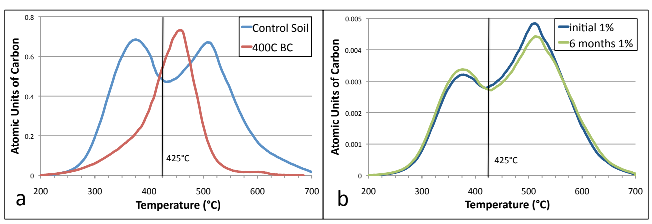

Fig 4. MESTA thermogram of 400°C switchgrass Bc and the control forest soil (a), and the 1% Bc treatment initially and after 6 months incubation (b).

^{13}C Analysis

Initially, the 1% BC treatment consisted of 6.00% BC carbon in the low temperature region and 10.25% in the high temperature region. After 6 months of incubation the percentages of BC carbon increased to 9.30% and 27.99%, respectively, indicating the differential biodegradation rates between Bc and the native SOM carbon. The results from the ^{13}C analysis are consistent with our CO_2 soil respiration results.

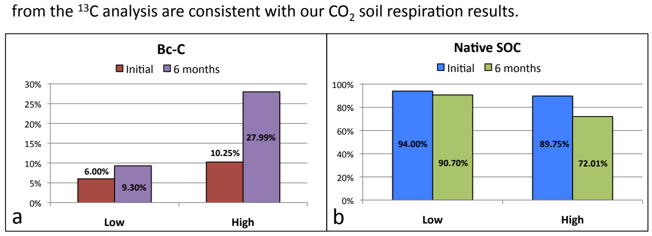

Fig 5. Changes in the proportion of Bc-carbon (a) and native SOC (b) in the low-temperature and high-temperature regions of the 1% Bc-soil treatment after 6 months of incubation (based on the ^{13}C signature of the carbon).

Summary

- priming effect in Bc-soil treatments was short-lived and solely due to Bc carbon mineralization
- decomposition of SOM was not accelerated with Bc application
- biodegradation of Bc was not proportional to the application rate (3% not significantly higher than 1%)
- Bc degradation (mineralization) was minimal during the 310 day incubation period
- switchgrass biochar contains a higher proportion of thermally stable carbon than labile carbon
- the two pools of carbon in Bc and native SOC degrade at different rates

Future Research

This short term study suggests that we are able to link the biodegradation behavior to the thermochemical properties of Bc in a soil system. By continuing with this study we hope to confirm this relationship, which may enable us to predict the mean resident time of a given Bc in soils using MESTA rather than through a lengthy incubation study.

References

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