Short Communication

The effect of young biochar on soil respiration

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**A B S T R A C T**

The low temperature pyrolysis of organic material produces biochar, a charcoal like substance. Biochar is being promoted as a soil amendment to enhance soil quality, it is also seen as a mechanism of long-term sequestration of carbon. Our experiments tested the hypothesis that biochar is inert in soil. However, we measured an increase in CO2 production from soils after biochar amendment which increased with increasing rates of biochar. The 13C signature of the CO2 evolved in the first several days of the incubation was the same as the 13C signature of the biochar, confirming that biochar contributed to the CO2 flux. This effect diminished by day 6 of the incubation suggesting that most of the biochar C is slowly decomposing. Thus, aside from this short-term mineralization increasing soil C with young biochar may indeed be a long-term C storage mechanism.

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Recently there has been increasing interest in low temperature pyrolysis of organic materials to produce a charcoal product termed biochar. It has been postulated that biochar is an inert substance that could be a beneficial soil amendment for increasing soil quality and a permanent mechanism for carbon (C) sequestration to reduce CO2 enrichment of the atmosphere from anthropogenic activities (Laird, 2008; Novak et al., 2009). Biochar is not a precisely defined material since process conditions and feedstocks can influence the characteristics of the final biochar product, where slow pyrolysis properties tend to be similar, fast pyrolysis chars are a more chemically heterogeneous group (Amonette et al., 2008). Beyond pure chemistry biochar is thought to have some common features regardless of feedstock source or synthesis, in particular, potential soil quality benefits which include increases in the water holding capacity, cation exchange capacity, and C content of amended soils (Lehmann et al., 2008). In addition, biochar may enhance soil fertility (Van Zwieten et al., 2010) and soil aggregation (Novotny et al., 2009). An auxiliary benefit may be the suppression of N2O production from biochar amended soils (Singh et al., 2010). Generally, biochar additions to soil may increase the soil C and N pools but the accompanying N addition may have little added benefit for plant nutrition (Granatstein et al., 2009). Several questions remain to be addressed: what is the influence of biochar on biological activity (Kolb et al., 2009) or soil processes (Granatstein et al., 2009) and is biochar truly inert in soil?

We hypothesized that biochar is not totally inert in soil and thus contributes to CO2 flux when added to soil. A C4 biochar and historically C3 soils were used to follow soil organic matter decomposition to CO2.

The young biochar was produced from a switchgrass (Panicum virgatum) feedstock that was processed at a pyrolysis temperature of 500 °C in a low oxygen environment for 2 h. The biochar product had the following chemical characteristics: pH 9.7, 52% C, 1.6% N and 13C of −12.57‰. Typically, switchgrass loses 45% of the original C and 65% of original N during pyrolysis (Granatstein et al., 2009). The young biochar contained 40% volatile (low vapor pressure compounds) (Spokas et al., 2010) matter and was dominated by aromatic ring structures followed by aliphatic and to a lesser extent carbonylic functional groups as determined by NMR (Amonette et al., 2008). The soluble C concentration of the water extracted biochar was 3.4 mg-C/g biochar and the N .075 mg-N/g biochar (0.03 NH4 and 0.15 NO3 mg-N/g biochar). By FTIR analysis the soluble C and N were dominated by aromatic (amide and methyl), aliphatic and carboxylate groups.

We used two Washington State, USA soils to test our hypothesis, a Shano silt loam (Coarse-silty, mixed, superactive, mesic Xeric Haplocambids) and a Walla Walla silt loam (Coarse-silty, mixed, superactive, mesic Typic Haploxerolls). The soils were collected from the 0–5 cm depth, put through a 2 mm sieve and used field
moist (adjusted to −0.03 MPa where needed). The Shano silt loam has a pH of 5.4, 0.64%C, 0.08%N and a δ13C of −21.4 ‰. The Walla Walla silt loam has a pH of 7.1, 1.27%C, 0.12%N and a δ13C of −21.2 ‰. We amended 25 g aliquots of each soil with biochar at rates equivalent to 0, 11.2, 22.4 and 44.8 Mg/ha. Biochar plus sand was used as a secondary control. The amended soils were incubated at −0.03 MPa moisture potential in closed containers with a 1 N NaOH trap for collecting CO2. Total CO2 was determined by titration of these traps at 2, 6, 10, 17, 28, 35, 42, 49 days. Before the titration trapped CO2 was precipitated with SrCl2 to form a precipitate that combusts at a temperature less than 1100 °C. The residual Sr13CO3 left after the titration was dried and the δ13C of the 13CO2 evolved was determined by isotope ratio mass spectrometry (IRMS).

The cumulative CO2 evolved after biochar addition is shown in Fig. 1. Both soils showed an increase in CO2 production with increased biochar additions. The Walla Walla soil experienced larger increases (Fig. 1b) than the Shano soil. CO2 production in the Shano soil (Fig. 1a) did not differ significantly at the 2 intermediate rates of biochar addition. In contrast these biochar amendment rates in the Walla Walla soil (Fig. 1b) did generate significantly different rates of CO2 evolution, and the lowest rate was not significantly different than the control. However, in both soils the increases were mostly during the first few days of incubation, thereafter the rates of CO2 production were similar (slopes of the lines from 10 to 50 days).

The CO2 signature of the evolved CO2 from decomposition is shown in Fig. 2. After 2 days the CO2 evolved from the highest biochar addition had a similar signature to that of pure biochar, approximately −13 ‰. After 4 days both soils continued to show a significant biochar influence in the CO2 evolved from decomposition. By day 6 there was no significant difference in the CO2 signature between the control soil (0 biochar additions) and the other 3 biochar soil additions (Fig. 2). This was consistent from day 6 to day 50 of the incubation (data not shown).

These experiments provide strong evidence that young biochar is not inert but provides significant amounts of labile C that is readily available to soil microorganisms for use as an energy source within a relatively short timeframe. The soluble C concentration of the biochar was 3.4 mg-C/g biochar. The rates applied would equal 350–1250 µg soluble C/g soil which could easily account for the difference between the highest rate of biochar addition and the control (Fig. 1).

We conclude that there is a distinct labile C pool associated with young biochar that may be significant in the short-term. It is likely that a fraction of the condensates from the bio-oil formed during pyrolysis absorbed to the biochar during cooling. These condensates are likely the source of the labile C pool and thus do not originate from the stable carbonized components of the biochar. Since only about 10–20% of the soluble component is mineralized to CO2 it is probable that the aromatic and aliphatic compounds may precipitate forming larger more complex molecules. In the long-term, we suggest these materials would be resistant to decomposition and would become part of the slow to resistant C pools in soils. Thus the claims in the literature and popular press that the greenhouse effect of increased CO2 could be reduced by converting organic material to biochar and used as a soil amendment may have merit.

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