



Influence of select bioenergy by-products on soil carbon and microbial activity

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Introduction

Fermentation by-product (FBP) and biochar are common organic C rich substances produced from converting biomass to bioenergy. The production processes are different; hence, the C characteristics and impacts in soil are expected to be different. The portion of soil organic carbon (SOC) that decays rapidly is defined as labile SOC and the portion that does not is considered as recalcitrant soil C. Increased labile C has been related to increased energy source in the soil food web, increasing soil quality and soil organic matter quality (Debusk and Reddy, 2005). Characterizing labile SOC by chemical extractant and ^{13}C NMR spectroscopy would provide comprehensive information on labile SOC. The objective of this study was to investigate the impacts of biochar and FBP on soil labile and recalcitrant C.

Experimental

Solid-state ^{13}C nuclear magnetic resonance (NMR) spectroscopy was used to characterize the C functional groups in SOC. Replicate samples from soil treated by low nitrogen (LN), high (HN), FBP and the biochar (BC) were composited into one sample for NMR spectroscopy analysis. ^{13}C NMR spectra were acquired using an Avance III spectrometer manufactured by Bruker Bio-Spin operating at a field strength of 14 T (600 MHz) with a 51 mm bore. Spectroscopy data were collected using TopSpin software (version 3.2 pl5), and imaging data were collected with ParaVision 6. Solid State NMR studies utilized Magic Angle Spinning (MAS) in which samples were spun at the magic angle ($\theta_m = \sim 54.74^\circ$) at speeds from 5 to 15 kHz that drastically decreases line broadening (Knicker, 2011).

Results and Discussion

The NMR spectroscopy analysis clearly indicated that the alkyl functional group dominated the NMR spectra of LN (100% of total C) and LN + N (86%), as well as LN + BC (41%) soils. In LN soil, no other groups were detected. In LN + N soil, 14% of total C was identified O-alkyl. C-NMR spectra showed that O-alkyl regions were dominant for soil amended with FBP (55%), followed by biochar (27%), but absent in LN and only 14% in LN + N soil treatments. The highest aromatic-C was identified in LN + BC soil (27%), followed by LN + FBP soil (19%). Similar to aryl-C, carboxyl-C was only detected in LN + FBP (1.4%) and LN + BC (5.2%) soils. ^{13}C NMR spectroscopy also provided the relative stability of SOC in terms of HI and aromaticity. Lower HI and aromaticity of LN + FBP (0.8 and 19, respectively) indicated short-term stability of FBP amended soil compared to biochar amended soil.

Generally, the extractable C (water and acid) was related to alkyl, O-alkyl and carboxylic C (0–110 and 165–200 ppm) while the recalcitrant C was mostly linked with aryl C (165–220 ppm) and to a lesser extent with O-alkyl C. The extractable C includes mostly carbohydrates, proteins and amino acids while the recalcitrant C includes lignin, lipids, waxes and anomeric cellulosic C (Silveira et al., 2008). The analogous C functional group composition of SOC in LN and LN + N suggested insignificant change in extractable C and microbial response due to mineral N fertilizer.

Conclusions

Bioenergy by-product application unsurprisingly improved SOC content compared to either LN or LN + N. The increase in SOC by LN + BC was 270% greater than LN alone. LN + FBP had greater soil microbial biomass, labile C and soil respiration compared to LN. Biochar increased the aromatic and lignin (recalcitrant forms of) C in soil, whereas FBP increased aliphatic, methoxyl and cellulosic (labile forms of) C in soil, as compared to LN. Depending on the type of bioenergy by-product, influences on labile and recalcitrant C contents will differ in soil. FBP application can increase soil C, mostly in the labile fraction, facilitating soil microbial activity and nutrient bioavailability. Biochar will also increase soil C, mostly in the recalcitrant fraction, facilitating increased C storage in the soil over time.

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References

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