

PYROGENIC CARBON APPLICATION AND NATIVE SOIL ORGANIC MATTER DECOMPOSITION IN A SANDY SOIL MATRIX

TATIANA F. RITTL¹, ETELVINO H. NOVOTNY², FABIANO C. BALIEIRO³, ELLIS HOFFLAND⁴, THOMAS W. KUYPER⁵, BRUNO J.R. ALVES⁶, ALINE F. RODRIGUES⁷

¹Environmental manager, Ph.D. candidate, Wageningen University, Wageningen 6700 AA (Netherlands), tatiana.rittl@wur.nl; ²Agronomic engineer, Researcher, Embrapa Solos, Rio de Janeiro 22460-000 (Brazil), etelvino.novotny@embrapa.br; ³Agronomic engineer, Researcher, Embrapa Solos, Rio de Janeiro 22460-000 (Brazil), fabiano.balieiro@embrapa.br; ⁴Biologist, Professor, Wageningen University, Wageningen 6700 AA (Netherlands), ellis.hoffland@wur.nl; ⁵Biologist, Professor, Wageningen University, Wageningen 6700 AA (Netherlands), thom.kuyper@wur.nl; ⁶Agronomic engineer, Researcher, Embrapa Agrobiologia, Seropedica 23890-000 (Brazil), bruno.alves@embrapa.br; ⁷Student of geography, Student, Embrapa Solos, Rio de Janeiro 22460-000 (Brazil), line_frodrigues@hotmail.com

ABSTRACT: Pyrogenic carbon (C) is produced from different biomass and by different pyrolysis processes. These two factors may not only affect the decomposition of pyrogenic C in soil but also the decomposition of the native soil organic matter (SOM). There are some studies on the decomposition rate of pyrogenic C and native SOM, however their results are conflicting. This study aimed to investigate the effect of biomass type on pyrogenic C and native SOM decomposition rate in a sandy soil. For that three feedstocks were pyrolysed by the low-temperature conversion (LTC) pyrolysis process and their pyrogenic C characterized for elemental (CHN) and structural (¹³C nuclear magnetic resonance (NMR) spectroscopy) composition. The decomposition rate was measured by CO₂ evolution and each source of CO₂ released was distinguished by the CO₂-¹³C signatures. Our results showed (i) differences in the C:N ratio and chemical groups of the three pyrogenic C; (ii) differences in CO₂ evolution between treatments and control; (iii) preferential decomposition of compounds present in the pyrogenic C against the native SOM in soil and; (iv) samples richer in amorphous alkyl groups presented a higher decomposition rate of pyrogenic C than samples richer in aryl groups, indicating a preferential decomposition of these aliphatic compounds. As a main conclusion the application of pyrogenic C in this sandy soil resulted in an early negative priming effect in the decomposition of native SOM.

KEY WORDS: Priming effect, sandy soil, isotope (¹³C) fractionation, biochar

INTRODUCTION: Pyrogenic carbon (C) has a potential to improve soil quality (Lehmann et al., 2003) and increase C sequestration (Whitman

and Lehmann, 2009). Depending on the biomass and pyrolysis process used, the quality of the pyrogenic C may vary. Differences in chemical and physical properties may affect the decomposition rate of pyrogenic C and of native soil organic matter (SOM). On one hand studies have shown that pyrogenic C application can lead to stabilization of labile organic matter (Keith et al., 2011). On the other hand, it was shown that addition of pyrogenic C may promote SOM decomposition and that this effect may be even more significant in soils with low C content (Wardle et al., 2008). Thus, the effect of pyrogenic C addition on SOM needs to be better understood. This study aimed to investigate the relation between the chemical composition of pyrogenic C and its impacts on pyrogenic C and SOM decomposition.

MATERIALS AND METHODS: Three cakes from oil extraction (*Glycine max* - i.e. Soybean; *Ricinus communis* - castor bean and; *Jatropha* sp.) were pyrolysed by low-temperature conversion (LTC), in nitrogen atmosphere (N₂), during 3 h at 380 °C (Vieira et al., 2009). The produced pyrogenic C were characterized by elemental analysis (CHN by Dumas method, CHN analyzer) and ¹³C NMR spectroscopy. They were mixed with a sandy soil incubated in sealed jars in a Biochemical Oxygen Demand incubator at 28 °C during 30 days (700 h). All pyrogenic C sources were C₃ and the SOM in the sandy soil was mainly C₄. To evaluate the decomposition rate and importance of each source on the CO₂-C released the CO₂-C efflux was determined and the variations in ¹³C isotopic signatures were determined by ¹³C natural abundances and compared to controls without pyrogenic C addition. The CO₂ evolution was estimated by the respiration product CO₂ trapped in NaOH

and titrated with HCl (Fernandez and Cadisch, 2003). The C isotope signature was measured by C contents and ^{13}C natural abundances in two moments. First time, in the pyrogenic carbons and soil matrix. In the second time, on the respiration product CO_2 trapped in NaOH and precipitated as CaCO_3 . A simple mixing of two ^{13}C pools was used to estimate the breakdown of the pyrogenic C and of soil organic matter. Principal component analysis was carried out using the full spectra obtained by ^{13}C NMR. The differences between CO_2 -C efflux treatments were analysed by ANOVA.

RESULTS AND DISCUSSION: The *Ricinus communis* and *Jatropha* sp. cake had higher C:N ratio than the *Glycine max* pyrogenic C. The *Glycine max* and *Ricinus communis* pyrogenic C were more enriched with alkyl groups, which is saturated hydrocarbon. All pyrogenic C were rich in aromatic groups. Total amount of CO_2 after 30 days of incubation was 0.0263 g of CO_2 -C for *Jatropha* sp. cake, 0.0664 g of CO_2 -C for *Glycine max* and 0.1112 g of CO_2 -C for *Ricinus communis*. Relative to the initial C content in the soil, the C lost as CO_2 was larger for the control (14.5%) than for the treatments with pyrogenic carbons (11.37 - 2.53%). The ^{13}C signatures of C_4 soil matrix was -15.11‰ and of C_3 pyrogenic carbons were -26.51‰ for *Glycine max*; -26.60‰ for *Ricinus communis*; and -27.03‰ for *Jatropha* sp. After the time of incubation, the ^{13}C abundance for the CO_2 -C emitted from all treatments were around -22‰, despite large differences in total CO_2 -C flux. The final ^{13}C signal was closer to that of pyrogenic carbon than to SOM and suggests preferential C degradation of 54 to 68% of the C_3 pyrogenic carbons against the 31 to 39% of SOM of the C_4 soil. Matching the CO_2 -flux with the ^{13}C signal indicated that the decomposition of pyrogenic C and of soil organic matter were not simple independent additive processes, but that pyrogenic C reduced the decomposition of soil organic matter (negative priming). This effect was strongest for *Jatropha* sp. and weakest for *Ricinus communis*. This may be due to the preferential substrate utilization and/or to the inhibition of microbial activity (Zimmerman et al., 2011). The differences in negative priming suggest that the pyrogenic C that is richer in amorphous alkyl groups results in less negative priming (and higher substrate utilization of that pyrogenic C) than the pyrogenic C that is richer in aromatic groups (*Jatropha* sp.).

Other studies previously reported that pyrogenic C contain substantial amounts of compounds that degrade after a short period of weeks to months (Cheng et al., 2008), and that is related with the type of biomass and pyrolysis. The inhibition of microbial activity can be physical or chemical. Pyrogenic C could sequester native SOM within its pores network, protecting it from degradation. This mechanism has been observed in other studies and seems to be more relevant to soils with low C content and in the later incubation stage (Zimmerman et al., 2011). The toxicity of the pyrogenic C to microorganisms is another possible inhibitor of microbial activity. Biomass combustion products may contain toxic compounds, such as phenols, polyaromatic hydrocarbons or ethylene, which may reduce microbial activity.

CONCLUSION: (i) The C:N ratio was not the main driver of pyrogenic C decomposition; (ii) The amorphous alkyl compounds seemed to decompose faster than aromatic groups; (iii) A preferential decomposition of the compounds that are present on the pyrogenic C was observed against the decomposition of the SOM; (iv) The application of pyrogenic C in a sandy soil matrix resulted in an early negative priming effect in the decomposition of the SOM.

ACKNOWLEDGEMENTS: This work was supported by grant from the National Council for the Improvement of Higher Education (CAPES).

REFERENCES

- CHENG CH, LEHMANN J, THIES JE AND BURTON S. Stability of black carbon in soils across a climatic gradient. **Journal of Geophysical Research (Biogeosciences)** 113, 2008.
- FERNANDEZ, I.; CADISCH, G. Discrimination against ^{13}C during degradation of simple and complex substrates by two white rot fungi. **Rapid Commun. Mass Spectrom.** (17) 2614–2620, 2003.
- LEHMANN, J.; DA SILVA JR, J. P.; STEINER, C.; NEHLS T.; ZECH, W.; GLASER, B. Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. **Plant and Soil** (249) 343–357, 2003.



VIEIRA, G.E.E.; ROMEIRO, G.A.; SELLA, S.M.; DAMASCENO, R. N; PEREIRA, R.G. Low temperature conversion (LTC) – An alternative method to treat sludge generated in an industrial wastewater treatment station – Batch and continuous process comparison. **Bioresource Technology** (100) 1544–1547, 2009.

WARDLE, D. A.; NILSSON, M. C.; ZACKRISSON, O. Fire-Derived Charcoal Causes Loss of Forest Humus. **Science** (320) 629-, 2008.

WHITMAN, T.; LEHMANN, J. Biochar—One way forward for soil carbon in offset mechanisms in Africa? **Environmental Science & Policy** (12) 1024 – 1027, 2009.

ZIMMERMAN, A. R.; GAO, B.; AHN, M. Positive and negative carbon mineralization priming effects among a variety of biochar-amended soils. **Soil Biology & Biochemistry** (43) 1169-1179.

