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Microbial utilisation of organic carbon as affected by biochar application

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Introduction

Biochar has become an area of intensive research for soil biogeochemists in recent years. Little is known about its rates of degradation and the mechanisms behind this. Recent interest has had two main objectives: a) its indirect or direct effects on soil quality; and b) its potential for terrestrial carbon sequestration. Much research has been carried out to investigate processes by which chars may remain stable, and whether their presence may affect the degradation of recalcitrant indigenous carbon pools such as humic-carbon [1].

Organic acids such as citrate may be exuded by plant roots through a multitude of mechanisms in response to a number of well-defined environmental stresses (e.g. Al, P and Fe stress) [2]. Sorption of organic acids to the soil solid phase, and mineralisation by the soil's microbial biomass greatly affect the efficacy of these compounds in most rhizosphere processes. Charcoal in soil is known to be sorbent in soil systems, has the potential to reduce the efficacy of exudate-derived organic acids by binding them to its surface. In addition, these organic acids are routinely turned over by the soil microbial community at extremely high rates ($t_{1/2}$ 2-3 h). The potential sorption of organic acids to charcoal may affect the microbial community, reducing the availability of this carbon source, and possibly favouring K-strategists who grow at a slower rate and prefer a stable environment, but degrade more recalcitrant carbon – as discussed in [1].

Possible implications of this may be that biochar application may lead to a shift in the microbial community from one mainly utilising low molecular weight organic carbon (LMWOC) to one more suited to degrading recalcitrant portions of the soil carbon stock.

A counter-argument to this is presented by [3]. In a study investigating effect of glucose on black carbon, it was found that biochar enhanced glucose mineralisation. However, it should be noted that glucose does not bind strongly to solids, whereas significant sorption is observed by organic acids [2].

Outline and Hypotheses

We plan to investigate the effect of biochar on the microbial uptake and degradation of the organic acid citrate in a mesocosm experiment, with the overarching hypothesis: Biochar sorbs compounds, making them less available to the soil microbial community. Our secondary hypotheses are:

a. Bound compounds will be utilised more readily by fungi as these microbes are generally more capable of degrading recalcitrant material
b. Soils containing more fungi will take up the compounds much faster than those which are dominated by bacteria
c. Soils which have had greater exposure to charcoal will contain microbial communities which are more readily able to assimilate organic compounds which may be bound to biochar.

This experiment will be conducted in conjunction with another mesocosm experiment by Thomas Kuhn, which investigates the bioavailability of labile compounds in biochars through ^{13}C-labelling, quantitative and isotopic analyses of microbial respired CO_2, and compound-specific isotope analyses (CSIA) of microbial phospholipid fatty acids (PLFAs)

Proposed methods

An initial study will be carried out using [U]^{14}C-citrate to quantify the capacity of the biochar used in this study to sorb citrate by fitting a sorption curve to the Langmuir isotherm [4]. Soils from long-term biochar field trials are being sought, and will be used in a destructively-sampled incubation experiment to investigate the effect of biochar on the microbial uptake and degradation of [U]^{13}C-citrate.

Treatments will be:

- Soil only (control)
- Field soil and biochar (aged)
- Soil + new biochar
- Field soil and aged biochar + new biochar

Gas will be captured and analysed for CO_2 concentration and $^{13}CO_2$ release. In addition we plan to use CSIA to allow us to investigate uptake of the ^{13}C label and incorporation into microbial biomass by different groups of microbes. This will involve the extraction of the PLFA biomarkers and analysis by gas chromatography – combustion – isotope ratio mass spectrometry (GC-C-IRMS) to determine how much ^{13}C has been incorporated into each group of microbes. This technique will enable us to elucidate much more specific results than if just the $^{13}CO_2$ data were used, or if just microbial community structure were analysed by either PLFAs or DNA-based analyses.

Outcomes

This work should enable us to delve into microbial degradation of organic compounds to a level of much finer detail than that offered by either bulk isotope studies, or by general community profiling techniques. It will enable us to identify which microbial groups are utilising labelled substrates, and should react much quicker to these additions than the time taken for actual shifts in community structure to be observed, hence affording us a more accurate picture of rapid changes in the rhizosphere. In the context of this experiment, we hope to be able to demonstrate a more rapid utilisation of the ^{13}C tracer by the microbial community that has been previously exposed to biochar.

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