

Biochar stability in soil: Meta-analysis of decomposition and priming effects

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Abstract

© 2016 John Wiley & Sons Ltd. The stability and decomposition of biochar are fundamental to understand its persistence in soil, its contribution to carbon (C) sequestration, and thus its role in the global C cycle. Our current knowledge about the degradability of biochar, however, is limited. Using 128 observations of biochar-derived CO₂ from 24 studies with stable (¹³C) and radioactive (¹⁴C) carbon isotopes, we meta-analyzed the biochar decomposition in soil and estimated its mean residence time (MRT). The decomposed amount of biochar increased logarithmically with experimental duration, and the decomposition rate decreased with time. The biochar decomposition rate varied significantly with experimental duration, feedstock, pyrolysis temperature, and soil clay content. The MRTs of labile and recalcitrant biochar C pools were estimated to be about 108 days and 556 years with pool sizes of 3% and 97%, respectively. These results show that only a small part of biochar is bioavailable and that the remaining 97% contribute directly to long-term C sequestration in soil. The second database (116 observations from 21 studies) was used to evaluate the priming effects after biochar addition. Biochar slightly retarded the mineralization of soil organic matter (SOM; overall mean: -3.8%, 95% CI = -8.1-0.8%) compared to the soil without biochar addition. Significant negative priming was common for studies with a duration shorter than half a year (-8.6%), crop-derived biochar (-20.3%), fast pyrolysis (-18.9%), the lowest pyrolysis temperature (-18.5%), and small application amounts (-11.9%). In contrast, biochar addition to sandy soils strongly stimulated SOM mineralization by 20.8%. This indicates that biochar stimulates microbial activities especially in soils with low fertility. Furthermore, abiotic and biotic processes, as well as the characteristics of biochar and soils, affecting biochar decomposition are discussed. We conclude that biochar can persist in soils on a centennial scale and that it has a positive effect on SOM dynamics and thus on C sequestration.

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Keywords

Black carbon, C sequestration, Climate change, Priming effect, Pyrogenic organic matter, Soil respiration