Application of Fast Pyrolysis Biochar to a Loamy soil - Effects on carbon and nitrogen dynamics and potential for carbon sequestration - DTU Orbit (04/10/2019)

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Thermal decomposition of biomass in an oxygen-free environment (pyrolysis) produces bio-oil, syngas, and char. All three products can be used to generate energy, but an emerging new use of the recalcitrant carbon-rich char (biochar) is to apply it to the soil in order to enhance soil fertility and at the same time mitigate climate change by sequestering carbon in the soil. In general, the inherent physicochemical characteristics of biochars make these materials attractive agronomic soil conditioners. However, different pyrolysis technologies exist, i.e. slow pyrolysis, fast pyrolysis, and full gasification systems, and each of these influence the biochar quality differently. As of yet, there is only limited knowledge on the effect of applying fast pyrolysis biochar (FP-biochar) to soil. This PhD project provides new insights into the short-term impacts of adding FP-biochar to soil on the greenhouse gas (GHG) emissions and on soil carbon and nitrogen dynamics. The FP-biochars investigated in the thesis were generated at different reactor temperatures by fast pyrolysis of wheat straw employing a Pyrolysis Centrifuge Reactor (PCR). The carbohydrate content ranged from more than 35 % in FP-biochars made at a low reactor temperature (475 ºC) down to 3 % in FP-biochars made at high temperatures (575 ºC). The relative amount of carbohydrates in the FP-biochar was found to be correlated to the short-term degradation rates of the FP-biochars when applied to soil. Fast and slow pyrolysis of wheat straw resulted in two different biochar types with each their distinct physical structures and porosities, carbohydrate contents, particle sizes, pH values, BET surface areas, and elemental compositions. These different physicochemical properties obviously have different impacts on soil processes, which underscores that results obtained from soil studies using slow pyrolysis biochars (SP-biochar) are not necessarily applicable for FP-biochars. For example, the incorporation of FP-biochar (10 wt%) in a sandy loam soil improved the water holding capacity (WHC) by 32 %, while the SP-biochar reference only increased it moderately. Moreover, soil amendment of FP-biochar caused immobilization of considerable amounts of soil N, whereas SP-biochar resulted in a net mineralization of N after two months of soil incubation. Nitrogen immobilisation can be detrimental to crop yields, as shown in a Barley pot trial in this thesis, but may, on the other hand, constitute an advantage during e.g. fallow periods by preventing N leaching. Moreover, when it comes to the mobility of biochar in soil, FP-biochars acted considerably differently to SPbiochar. FP-biochar contained highly mobile carbon components (nm-scale), which followed the downward movement of water. By contrast, C components from slow pyrolysis biochar were retained in the topsoil. In summary, the research of this thesis shows that, compared to its more inert ‘traditional biochar counter-part’ made by slow pyrolysis, FP-biochar, in a number of ways, acts more like the original organic matter feedstock when added to soil. Yet, on the longer term the effects are likely a transient phenomenon, as the labile part is used up after a few months, leaving a much more recalcitrant FP-biochar. It is still too early to recommend - or discourage - FP-biochar for agronomic use, since field trials are needed in order to verify potential benefits or drawbacks on soil fertility and crop yields. However, this thesis has improved the mechanistic understanding of the effects of applying FP-biochar to soil, and shows that wheat-straw FP-biochar has properties beneficial for agricultural soil, e.g. it improves soil WHC, adds minerals, enhances microbial activity/biomass, and increases the N and C turnover dynamics.

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