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Short communication

Impact of quality and quantity of biochar and hydrochar on soil Collembola and growth of spring wheat

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ABSTRACT

The effects of biochar (maize biochar – MBC, wood biochar – WBC) and unfermented or fermented hydrochar (HTC) on the euedaphic Collembola *Protaphorura fimata* and on spring wheat were investigated in greenhouse experiments. The impact of char type, amount of fermented HTC, and MBC-Collembola interactions were assessed. Generally, shoot and root biomass as well as abundance of *P. fimata* were not affected by the different chars. However, with increasing amounts of fermented HTC the abundance of *P. fimata* declined, whereas shoot biomass of wheat increased. Moreover, MBC altered root morphology and resulted in thicker roots with higher volume. The latter was not apparent when Collembola were present.

Applying carbon-rich biochar to soils can improve soil fertility and sequester carbon (Lehmann et al., 2006; Lehmann, 2007; Laird, 2008; Sohi et al., 2010; Lehmann et al., 2011). Biochar results from the pyrolysis of organic material (e.g., plant residues, organic debris), whereas hydrochar is produced by hydrothermal carbonization (Libra et al., 2011). Compared to biochar, hydrochar decomposition in soil is generally faster due to the less aromatic structure and higher content of labile C fractions (Steinbeiss et al., 2009; Cao et al., 2010; Libra et al., 2011). Thereby hydrochar provides often more accessible C and N resources to microorganisms (Bargmann et al., 2014), which also may affect their animal grazers.

To date biochar research has mainly focused on plant growth and soil properties, generally revealing small benefits for crop productivity (Jeffery et al., 2011; Jones et al., 2012). In contrast, soil animals have received little attention, with research mainly performed on earthworms (Noguera et al., 2010, 2012; Salem et al., 2013b), but less on soil microarthropods such as Collembola (Lehmann et al., 2011; Marks et al., 2014). As Collembola feeding activity promotes decomposition and mineralisation, and further alters root morphology and growth (Theenhaus et al., 1999; Cole et al., 2004; Endlweber and Scheu, 2006), related effects on plant performance may be an important factor modulating the impact of char amendments in cropping systems.

This study investigates the impact of different chars on Collembola and spring wheat. Three experiments were performed to determine the effects of: *(i)* maize biochar (MBC), wood biochar (WBC) and fermented or unfermented hydrochar (HTC, HTC_ferm) on the abundance of *Protaphorura fimata*; *(ii)* different amounts of fermented HTC on the abundance of *P. fimata*; *(iii)* interactions between MBC and Collembola on plant growth and root morphology.

Ensiled crop maize and screenings from wood chip production were processed by pyrolysis for MBC (600 °C, 30 min) and WBC (850 °C, 30 min), respectively. Hydrothermal carbonization of maize silage resulted in HTC (210 °C, 23 bar, 8 h), which was mixed with digestate (ratio 1:2) and subjected to methanogenic fermentation for HTC_ferm. Detailed production processes and chemical characteristics of the chars are reported elsewhere (Mumme and Diakité, 2013; Reibe et al., 2014b). Soil was obtained from arable land (71% sand, 22% silt, 7% clay, pH ($CaCl_2$) 6.2, 0.73% (DM) C_{org},

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0.79% C_t, 0.07% N_t, 0.10 g kg^{-1} P, 0.12 g kg^{-1} K), where the assortment of chars tested here is evaluated under field conditions (http://www2.atb-potsdam.de/biochar/biochar_start_en.htm).

Soil was defaunated (three cycles of 5 days at −21 °C followed by defrosting), filled into glass pots (volume 2650 ml) and adjusted to 60% water holding capacity. Three pre-germinated (5 days old) spring wheat (*Triticum aestivum L.*, cv. Chamsin) seedlings were planted per pot and two weeks later 150 individuals of the euedaphic Collembola *P. fimata* (Gisin, 1960) were added. Plants were grown in a greenhouse (mean temperature 18 °C; humidity 50–60 %, day length 12 h), regularly watered, and arranged in a randomised block design.

Experiment 1 investigated the effects of char type, using soil mixed with crushed chars (particle size ≤3 mm) to increase C_{org} from 0.73% (Control) to 1.0% (i.e. 9.8 g MBC, 13.6 g WBC, 16.4 g HTC, 36.1 g HTC_ferm in 2.5 kg soil, respectively). C_{org} amended with char to 1% was also used in other studies (Reibe et al., 2014a,b). Exp. 2 tested different amounts of HTC_ferm. Soil C_{org} levels were 0.73% (Control), 1, 2, and 4% with HTC_ferm addition, i.e. for 30.3, 142.5 and 367 g char in 2.5 kg soil, respectively. For Exp. 3 on char-Collembola interactions, soil C_{org} was increased from 0.73 % to 1.0 % by mixing 2 kg with 7.8 g MBC. Treatments (n = 5) comprised no manipulation (CON), Collembola (COLL), maize biochar (MBC), char and Collembola (MBC + COLL), with one spring wheat seedling per pot and, 50 individuals of *P. fimata* per pot in treatments COLL and MBC + COLL.

Wheat shoots and roots were harvested at flowering (BBCH-code 65 (Meier (1997), experiment 1 + 2) or main shoot elongation (BBCH 33, experiment 3), i.e. 7.5 and 5 weeks after planting, respectively. Roots and soil were soaked in a tray with tap water, and Collembola picked with a brush and counted; shoots and washed roots were then dried at 60 °C for 48 h. Roots from experiment 3 were scanned prior to drying (600 dpi, flat-bed HP Scanjet 2400), and scans were analysed with WinRHIZO 2012b Software (Regent Instruments, Quebec, Canada). Statistical analyses (SAS Version 9.4, SAS Institute, Cary, NC) used ANOVA followed by Tukey's HSD test at $P \le 0.05$. Block effects were not significant and were removed from analyses.

In experiment 1, shoot and root biomass of wheat were not significantly affected by any of the char amendments (Fig. 1a, b). Similarly, the abundance of *P. fimata* was not altered; however, population tended to decline from 171 to 126 Ind. kg^{-1} DW in control compared to HTC_ferm soils, respectively (Fig. 1c, $P = 0.089$). Based on this, varied amounts of HTC_ferm were compared in experiment 2. Shoot biomass in plants grown with HTC_ferm 4% was markedly higher compared to control plants

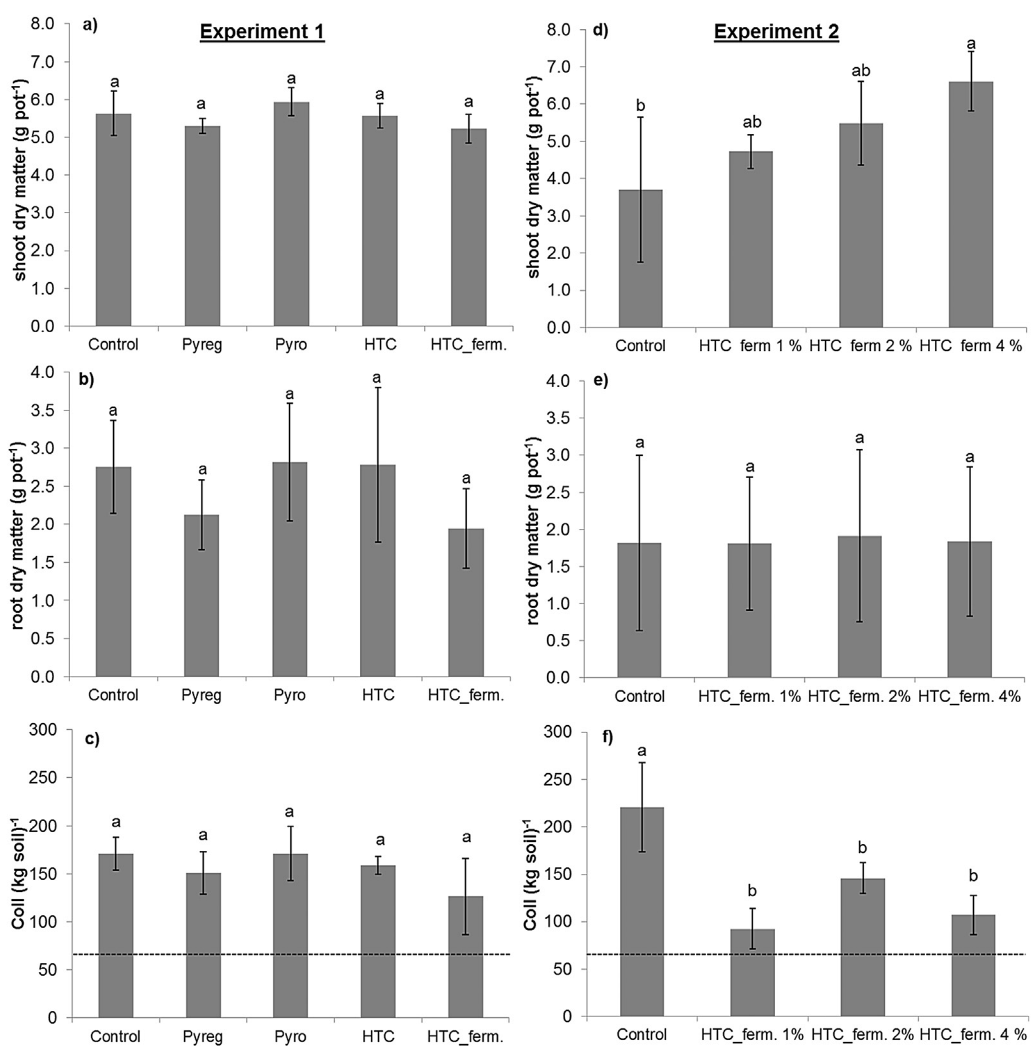

Fig. 1. Spring wheat and Collembola in the first experiment testing different chars (a, b, c) and the second experiment assessing effects of increasing amounts of fermented hydrochar (HTC_ferm added to increase the C_{org} to 1, 2 and 4%) (d, e, f). Given are the responses in shoot dry matter (g pot^{-1} ± s.d.), root dry matter (g pot^{-1} ± s.d.) and Collembola per kg soil (individuals kg^{-1} soil ± s.d.). The dashed lines in c) and f) show the initial rate of Collembola added (60 Coll (kg soil)$^{-1}$). (Pyreg – WBC, Pyro – MBC). Different letters indicate significant differences between the treatments according to Tukey's HSD test at $P \le 0.05$.