Effect of hydrochar on soil physical and chemical properties

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Introduction

The process of hydrothermal carbonization (HTC) converts biomass into a carbonaceous product named hydrochar. It is hypothesized that application of hydrochar can maintain/enhance soil fertility (aggregate formation and stability, water infiltration and storage, soil aeration, nutrient storage and buffering), due to its humus similar properties such as high carbon content, large active surface area, and porous structure. The objective of our study was to quantify the effects of hydrochar on soil physical and chemical properties.

Material and Methods

- A variety of hydrochars (*N* = 3) differing in production conditions (sugarbeet pulp (S) & draff (D); processing temperature 190 °C, processing time 4 or 12 h) was tested in two laboratory experiments (L_1, L_2). The hydrochars ($S_{4/190}$, $S_{12/190}$, $D_{12/190}$) were applied to soil in a rate equivalent to 30 t ha^{-1}, and tested against an untreated control treatment. The pH of the hydrochar was 4-5, the electrical conductivity (EC) was 2-7 mS cm^{-1}.

Experiment L_1

- Incubation trial over 100 days (22 °C, 60% WHC_{max})
- Cambisol (50% sand, 42% silt, and 8% clay)
- Soil analyses:
  - pH via $CaCl_2$ extraction (1:2.5)
  - EC via H_20 extraction (1:5)
  - effective cation exchange capacity (ECEC) via $BaCl_2$
  - aggregate stability (AS) via wet sieving of 1-2 mm soil fraction (mesh 0.25 mm)

Experiment L_2

- Laboratory trial over 10 days
- Sandy soil (83% sand, 14% silt, and 3% clay)
- Soil analyses:
  - total pore volume (TPV) was calculated from the bulk and particle density
  - water holding capacity at pF 1.8 (field capacity (FC))
  - air capacity (AC) was calculated as difference between TPV and FC

Results

- In comparison to the untreated control soil, pH increased whereas, EC decreased (Tab. 1).
- The ECEC of the soil was increased especially by hydrochar from sugarbeet pulp (Tab. 1).
- The % of water-stable aggregates increased from 75 in the control to 80-88% in the hydrochar treatments (not significant) (Fig. 1: L_1).
- The soil field capacity increased whereas, air capacity decreased significantly (Fig. 1: L_2).
- Increasing hydrochar processing time from 4 to 12 h decreased water holding capacity (Fig. 1: L_2).

Tab. 1. Effect of hydrochar on soil chemical properties (pH, EC = electrical conductivity, ECEC = effective cation exchange capacity).

Hydrochar	pH [ ]		EC [µS cm^{-1}]		ECEC [$cmol_c$ kg^{-1}]	
	MV	SD	MV	SD	MV	SD
Control	5.7^a	0.02	213^c	10.91	7.59^a	0.70
$S_{4/190}$	6.6^c	0.02	177^b	11.12	10.92^b	0.50
$S_{12/190}$	6.4^b	0.04	125^a	2.94	10.18^b	0.84
$D_{12/190}$	6.4^b	0.06	194^{bc}	6.40	8.45^a	0.19

Hydrochar: S = sugarbeet pulp, D = draff; subscripted numbers refer to processing time (4 or 12 h) and processing temperature (190 °C). ANOVA: Treatment mean values (MV) labeled with the same letter are not significantly different (p ≤ 0.05). SD = standard deviation.

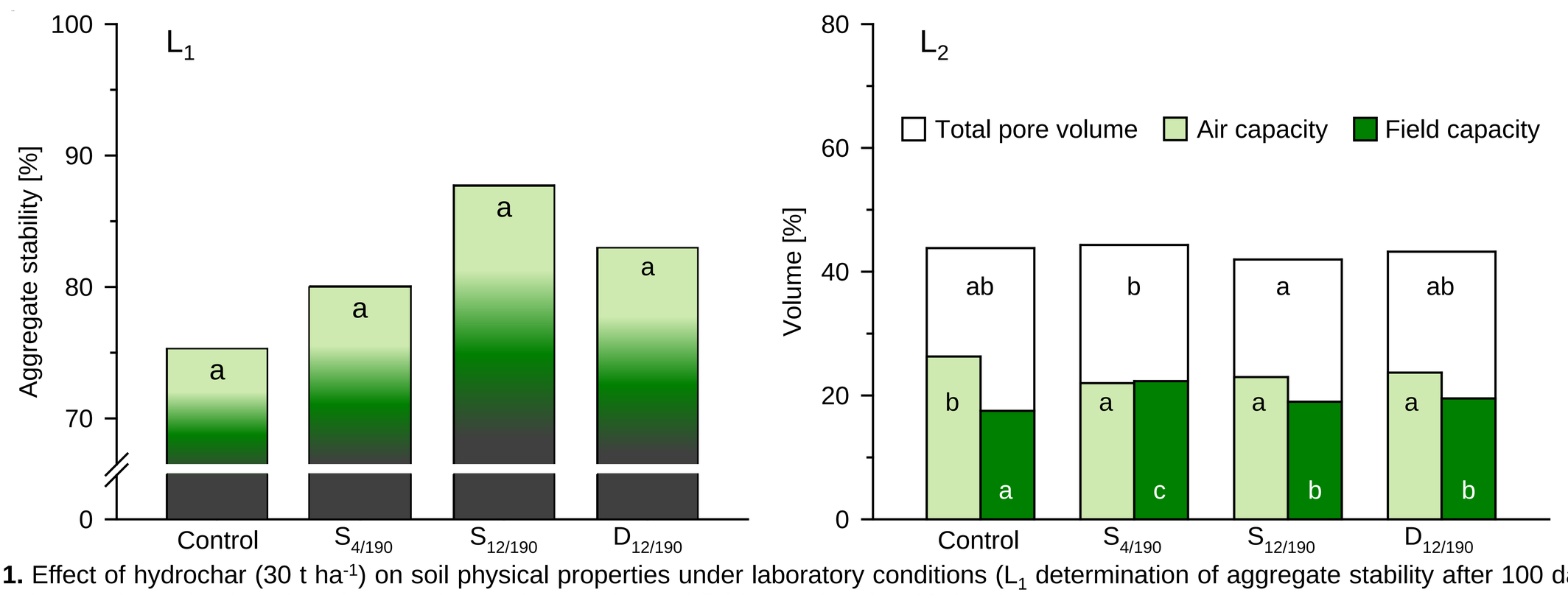

Fig. 1. Effect of hydrochar (30 t ha^{-1}) on soil physical properties under laboratory conditions (L_1 determination of aggregate stability after 100 days of incubation; L_2 determination of total pore volume, air capacity, and field capacity after 10 days).
Hydrochar: S = sugarbeet pulp, D = draff; subscripted numbers refer to processing time (4 or 12 h) and processing temperature (190 °C). ANOVA: Within each parameter treatments with the same letter are not significantly different (p ≤ 0.05).

Conclusions

A hydrochar application to soil may enhance nutrient buffering and water holding capacity. Increase of pH value combined with decrease of soil air capacity suggests soil reduction processes. More studies, particularly under field conditions are urgently needed.