Effect of HTC-biochar on crop growth

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Introduction

The process of hydrothermal carbonization converts plant biomass into a carbon rich product named HTC-biochar (Fig. 1). The properties of HTC-biochar are greatly affected by the type of material being carbonized and the process management; namely temperature, pressure, and reaction time. It is hypothesized that an application of HTC-biochar can positively affect plant growth and therefore increase the yield of crops through an enhancement of soil physical, chemical, and biological properties. The aim of this research was to investigate effects of HTC-biochar on plant growth.

Material and Methodology

- a greenhouse pot experiment was conducted with sugar beet (Beta vulgaris) as a test crop
- five treatments (control, HTC 1, HTC 2, HTC 3, HTC 4) replicated six times were performed on two soil substrates:
  - pure sand (conditioned with a nutrient solution and adjusted to pH 7 with addition of $CaCO_3$)
  - loess topsoil from an arable field (dried, sieved at < 2 mm)
- HTC-biochar was mixed with a substrate in concentration 0,44 % (w/w, dry matter), equivalent to 10 t ha^{-1} mixed into 15 cm soil depth (basic properties of the HTC-biochars used in this research are given in Tab. 1)
- ten seeds of sugar beet were planted in each pot and thinned to five plants after emergence
- above ground plant material was harvested after four weeks, processed to dry matter, and analyzed for total N, P and K
- sand substrate was analyzed for plant available N, P and K

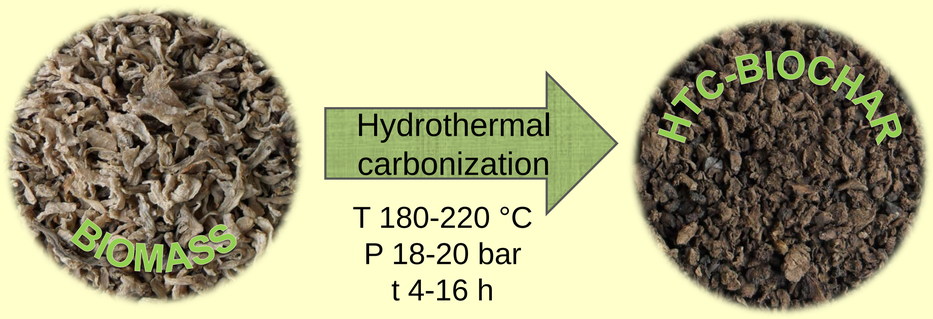

Fig. 1: *Hydrothermal carbonization (e. g. sugar beet pulp)*

Tab. 1: *Properties of the investigated HTC-biochars*

HTC-biochar	Feedstock	T* [°C]	N [%]	C [%]	C/N	pH	EC** [mS cm^{-1}]
HTC 1	beer draff	200	3.3	61.1	18.6	4.3	5.7
HTC 2	beer draff	220	3.4	53.4	15.7	4.4	7.0
HTC 3	sugar beet pulp	200	1.6	56.4	35.8	4.0	6.0
HTC 4	sugar beet pulp	220	2.2	54.8	24.4	4.2	7.4

** processing temperature; ** electrical conductivity*

Results

- addition of HTC-biochar did not affect seedling emergence (Fig. 2)
- on sand substrate, sugar beet yield was reduced by 50 % compared to the control treatment, while on loess soil no yield reduction occurred (Fig. 3 and Fig. 4)
- severe stunting of plant growth on sand substrate appeared in the cotyledon stage and was accompanied by a necrosis of the cotyledon tips
- symptoms of macro-nutrient deficiency were not detectable, and contents of total N, P, and K in plants were similar between HTC-biochar treatments and the untreated control (Tab. 2)

Fig. 3: *Sugar beet grown on sand and loess, with (+) and without (-) addition of HTC-biochar (e. g. HTC 4)*

Tab. 2: *Content of plant available nutrients in sand substrate, and total nutrients in sugar beet grown on sand substrate*

Treatment	- Sand substrate [mg 100 g^{-1}] -				- Sugar beet [% dm] -		
	NO_3-N	NH_4-N	P_{CAL}	K_{CAL}	N	P	K
Control	22.7	1.6	24.2	36.5	6.7	1.5	2.8
HTC 1	22.5	1.4	20.2	40.7	6.5	2.0	3.6
HTC 2	24.7	1.8	21.6	41.5	6.5	1.5	2.9
HTC 3	25.6	2.9	20.7	49.0	6.5	1.8	2.9
HTC 4	25.8	2.4	20.7	46.5	6.3	1.9	3.2

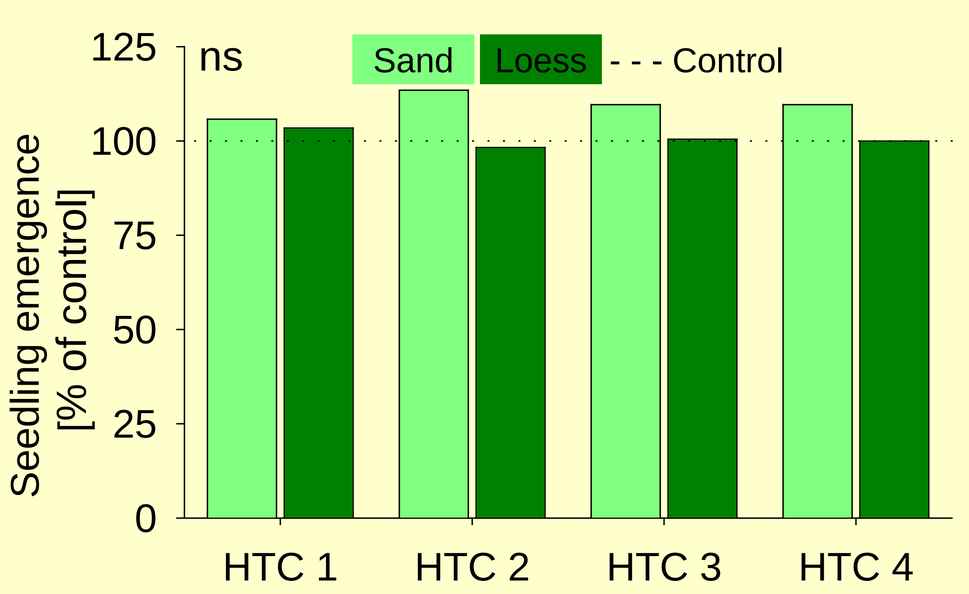

Fig. 2: *Effect of different HTC-biochar additives to sand and loess substrate on seedling emergence of sugar beet plants relative to an untreated control (ns no significantly different from the untreated control (Tukey))*

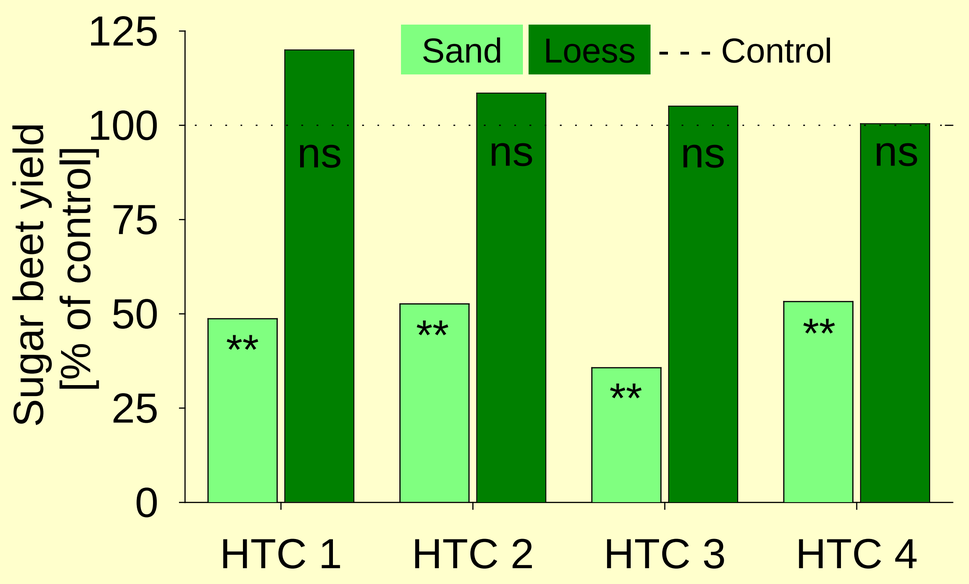

Fig. 4: *Effect of different HTC-biochar additives to sand and loess substrate on yield of 4 weeks old sugar beet plants relative to an untreated control (** significantly different from the untreated control (Tukey, $p \leq 0.01$))*

Conclusions

The addition of HTC-biochar on loess soil resulted in identical or slightly higher yields, but differences were small and insignificant. Stunted sugar beet growth on sand substrate may have been caused by toxic HTC-biochar compounds which might have been immobilized on loess substrate. Differences between different types of HTC-biochars were relatively small. In future, the complex interaction between HTC-biochars, soils, and plants needs to be elucidated in detail.