Investigation of the influence of Hydrothermal Carbonisation (HTC) hydrochar on soil improvement and plant growth aspects

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Means for soil improvement...

VS

Biochar - Pyrolysis

- Closed system, limited O_2, dry conditions
- 400 - 850˚C
- Various source feedstocks

- Carbon- rich ➔ highly recalcitrant
- Increased net C stocks
- Improves soil fertility, soil aggregate stability, water holding capacity, nutrient use efficiency

- Enhance biochar properties pre and/ or post-processing

Hydrochar - Hydrothermal Carbonisation

- Thermochemical conversion method[2]
    - Closed, water - saturated system
    - 180 - 230˚C, 20 - 60 bar
    - Typically 4 - 12 hour reaction time

- Results depend on:
    - Feedstock/ source material
    - Process conditions
    - Application rate
    - Environmental conditions
    - Plant species

No general consensus

Pyrolysis - biochar	HTC - hydrochar
Releases GHG's (50% C)[1]	Carbon neutral
Restricted to dry biomass	Converts wet (& dry) biomass[3]
Energy for intensive pre-drying	Minimal additional energy

Project Aim

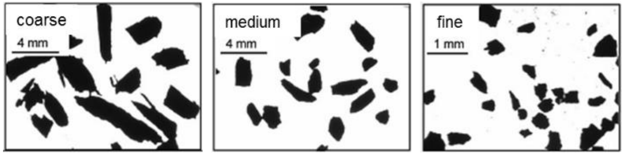
- Hydrochar differs in physical and chemical structure from biochar[2, 4, 6]
- Despite differences, hydrochar is similarly suitable for soil amelioration (as for biochar)
- HTC is relatively novel… Majority research focused on pyrolysis
- Research gaps:
  - Hydrochars suitability for soil amendment
  - Effects of hydrochar on soil properties and plant growth

To analyse the influence of hydrochar grain size (digestate feedstock) on soil improvement, germination success and biomass production.

Methodology

Hydrochar:

- Digestate feedstock (Grenol GmbH)
- ~ 200 ˚C, 18-20 bar, ~ 6 hr
- 5% addition
- coarse (6.3 - 2 mm), medium (2 mm - 630 µm), fine (< 630 µm)



Adapted from Liu et al. (2017)

Soils:

- Three soil types (dissimilar properties and agricultural value)
- Pot experiments
- Homogenously mixed with char
- Controls (no hydrochar)

Soil type	Sand	Silt (%)	Clay	Texture (USDA)
Chernozem	22.5	55.8	21.7	silty loam
Podzol	69.5	26.1	4.4	sandy loam
Gleysol	1.3	36.5	62.2	clay

Soil property analysis:

germination success, biomass production, pH, water holding capacity, cation exchange capacity, plant available nutrients (Nmin, K and P), aggregate stability.

Methodology:

standard pedological methods; Kruskal-Wallis H Test and Independent t-test (SPSS, ver. 25)

T_0 = controls at beginning | T_1 = shortly after HC addition | T_2 = end of experiment

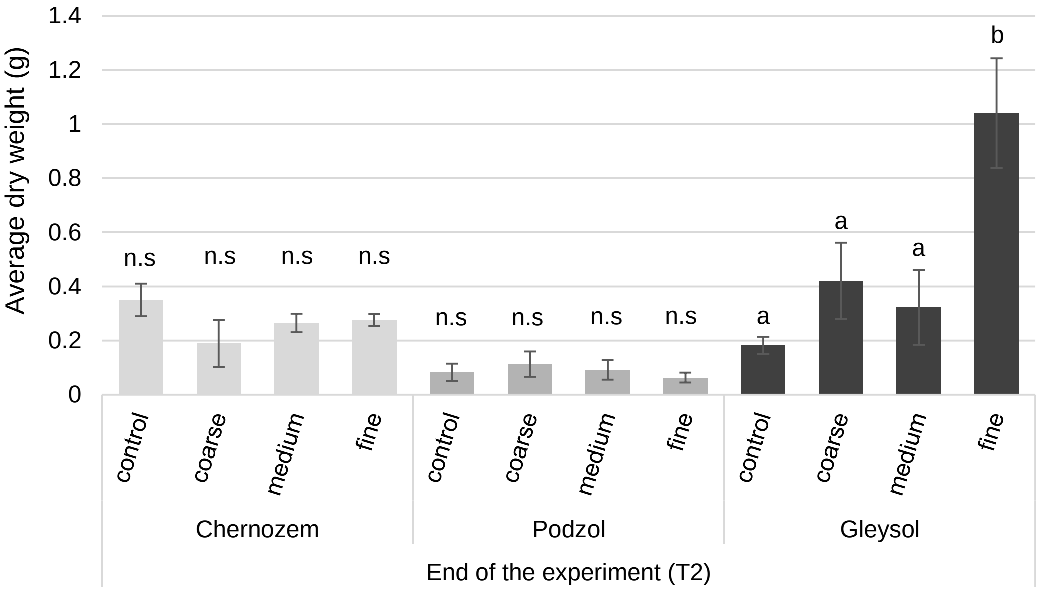
Results and Discussion: Germination Success

Percentage germinated seeds for the controls and hydrochar amended soils over two rounds of the germination experiment.

Soil	Control			Hydrochar amended soil		
	Round 1	Round 2	Average	Round 1	Round 2	Average
	%					
Chernozem	94	12	53	85	28	56
Podzol	95	73	84	84	66	75
Gleysol	73	78	76	34	86	60

The addition of hydrochar did not inhibit seed germination (of Chinese cabbage) in any soils

Biomass Production



Significant differences (Scheffe-Test) between means ($p \leq 0.001$) are indicated by different letters.

"n.s" indicates no significance

The addition of hydrochar showed no positive or negative influence on plant growth (of Chinese cabbage) in any soils

Water Holding Capacity

Minimum and maximum range in WHC for controls and HC amended soils over the course of the study in a Chernozem, Podzol and Gleysol. WHC of hydrochar = 1.47 g/g.

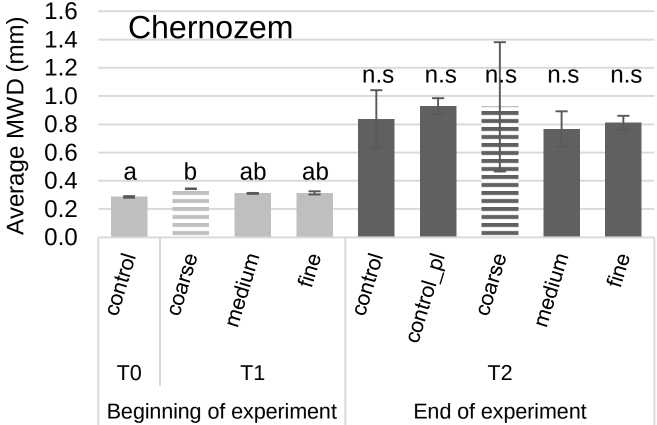
Soil	Beginning of experiment (T_0 & T_1)				End of experiment (T_2)				
	Control	Coarse	Medium	Fine	Control	*Control_pl	Coarse	Medium	Fine
	%								
Chernozem	0.88 - 0.97	0.94 - 0.97	0.89 - 0.97	0.96 - 1.03	0.85 - 1.1	0.86 - 0.94	0.86 - 0.9	0.85 - 0.87	0.86 - 0.87
Podzol	0.63 - 0.73	0.74 - 0.84	0.74 - 0.84	0.74 - 0.8	0.7 - 0.7	0.68 - 0.73	0.72 - 0.75	0.68 - 0.74	0.67 - 0.73
Gleysol	1.14 - 1.27	1.16 - 1.22	1.28 - 1.29	1.19 - 1.20	1.07 - 1.12	1.13 - 1.22	1.03 - 1.06	1.07 - 1.12	1.09 - 1.12

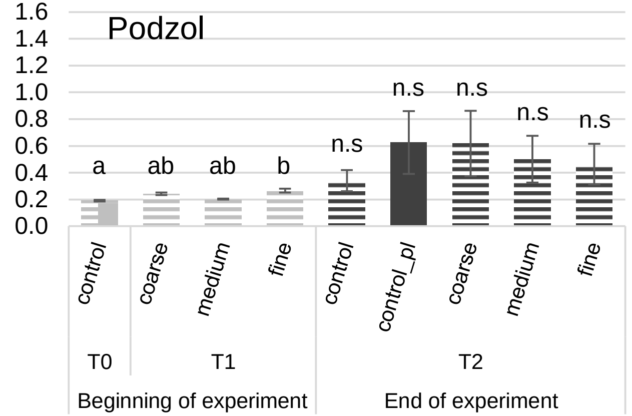
*Control_pl: control with plant

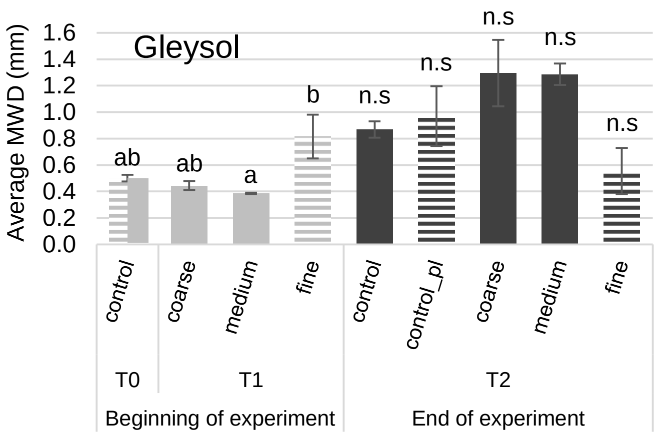
Tendential increase at the beginning did not persist.

Hydrochar addition had little to no effect the WHC of any soils.

Aggregate Stability



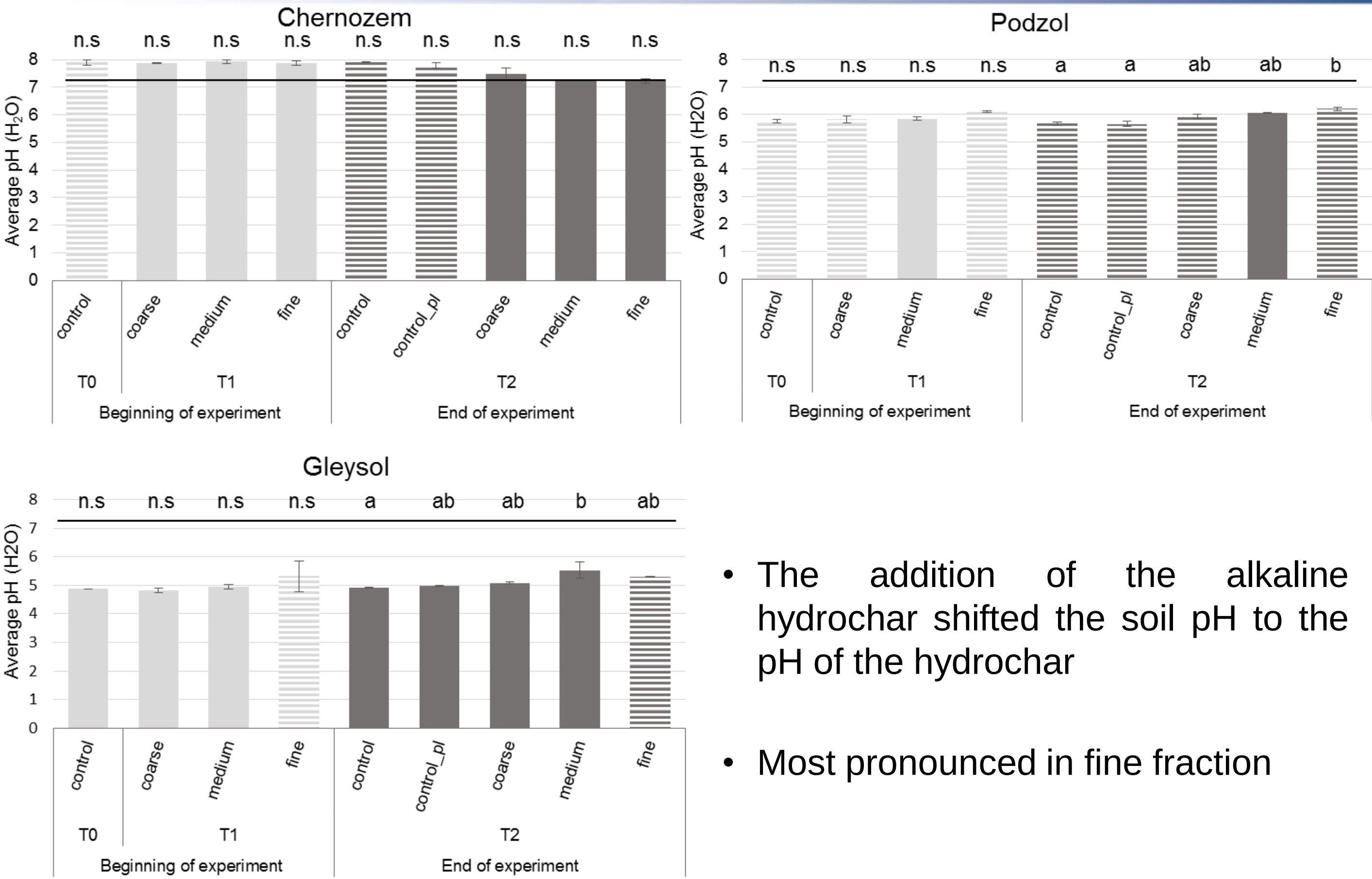




- No clear effect of hydrochar addition
- Increase over time likely not due to hydrochar

Significant differences between means ($p \leq 0.05$) are indicated by different letters. Significant difference Not significant (n.s)

pH



- The addition of the alkaline hydrochar shifted the soil pH to the pH of the hydrochar

- Most pronounced in fine fraction

Significant differences between means ($p \leq 0.05$) are indicated by different letters. Significant Not significant (n.s) Hydrochar pH (7.2)

Cation Exchange Capacity

Minimum and maximum range in CEC for controls and HC amended soils over the course of the study in a Chernozem, Podzol and Gleysol. CEC of hydrochar = 28.2 cmol kg^{-1}.

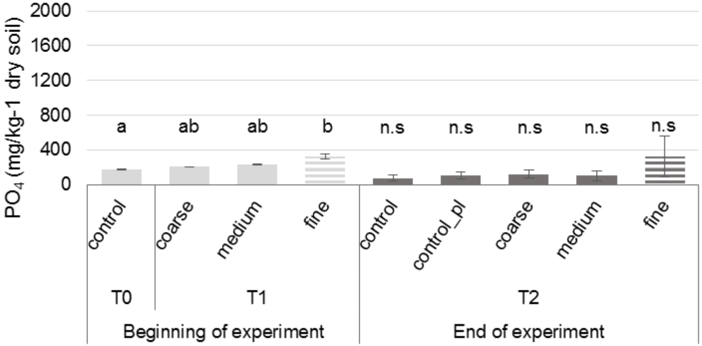
Soil	Beginning of experiment (T_0 & T_1)				End of experiment (T_2)				
	Control	Coarse	Medium	Fine	Control	*Control_pl	Coarse	Medium	Fine
	%								
Chernozem	38 – 40.9	38.8 – 39.7	39.9 - 40	38.4 – 39.6	40 – 40.6	40.2 – 43.2	40.9 – 41.4	41 - 43	42.6 – 46.6
Podzol	17.3 – 20.2	20.3 – 21.8	22 – 22.2	18.6 – 19.9	19.5 – 20.7	20 – 20.6	20.1 – 21.3	24.2 – 24.3	19.6 – 20.2
Gleysol	85.5 – 86.1	84 – 79.9	84.4 – 85.3	85.7 – 89.7	91.9 – 95.4	94.9 – 95.2	83.1 – 85.7	82.6 – 86.7	87.7 – 87.7

*Control_pl: control with plant

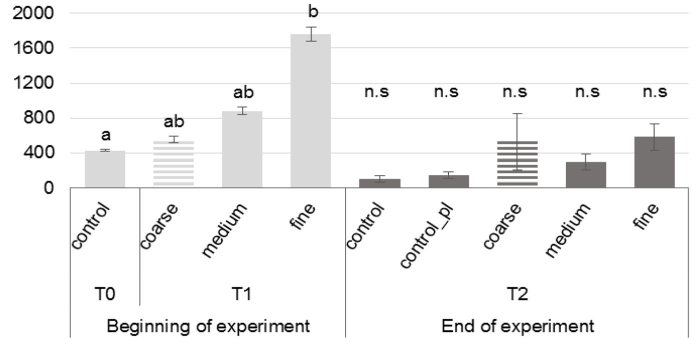
Hydrochar addition had little/ no effect on CEC of any soil

Phosphorous

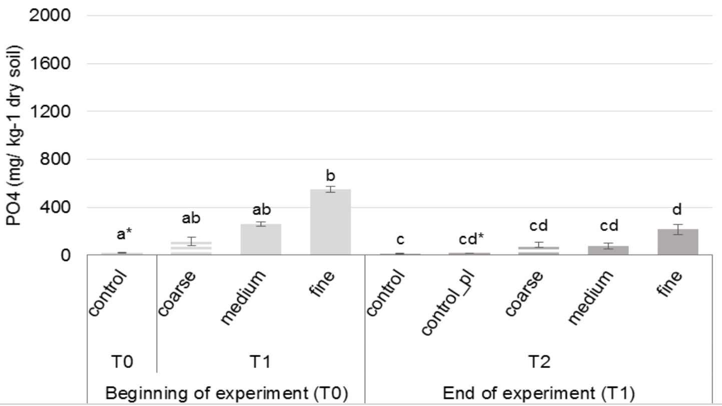
Chernozem



Podzol



Gleysol

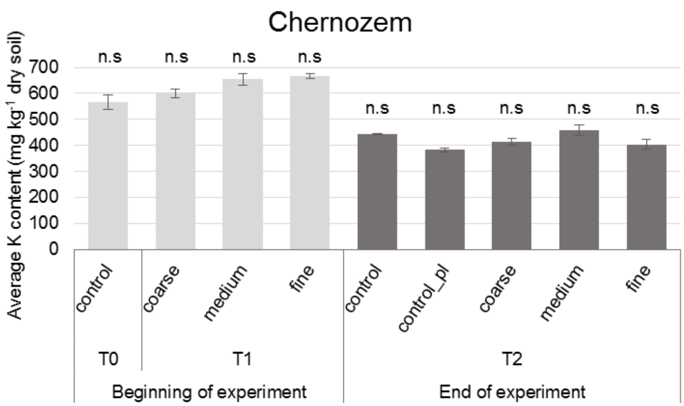


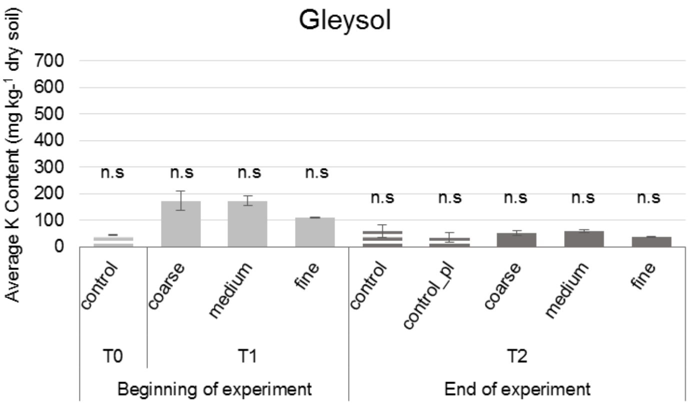
PO_4 of hydrochar = 2034.6 mg kg^{-1}

- Hydrochar acts as short-term source of PO_4
- Most pronounced in fine fraction

Significant differences between means ($p \leq 0.05$) are indicated by different letters. Significant difference Not significant (n.s)

Potassium (K)



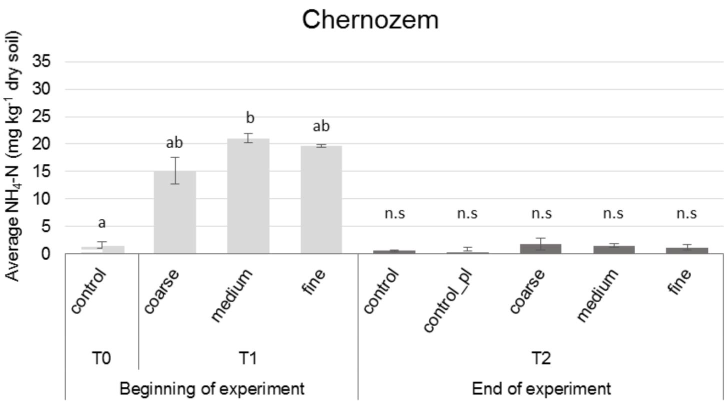


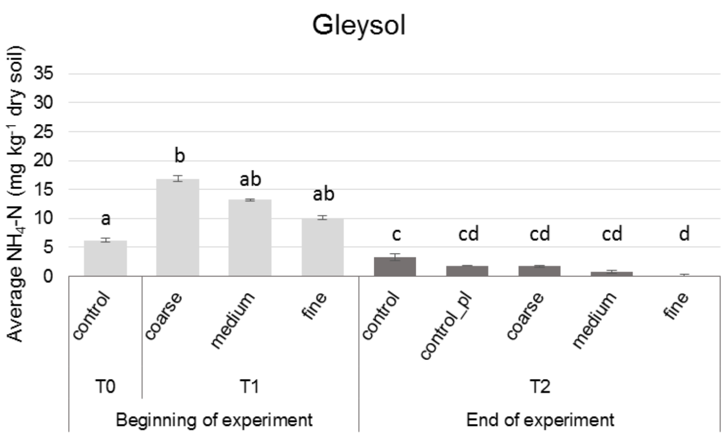
K of hydrochar = 2612.5 mg kg^{-1}

- Initial short-term increase
- Hydrochar as source of K
- Effect is not sustainable over time

Significant differences between means (p ≤ 0.05) are indicated by different letters. Significant difference Not significant (n.s)

Ammonium (NH_4)





- Initial short-term increase
- Hydrochar as source of N

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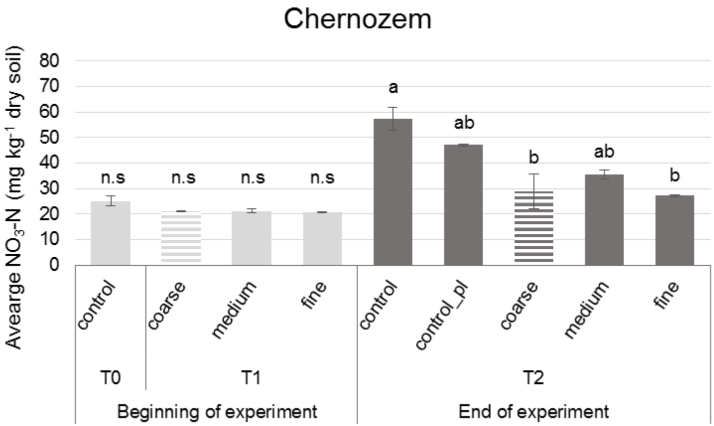
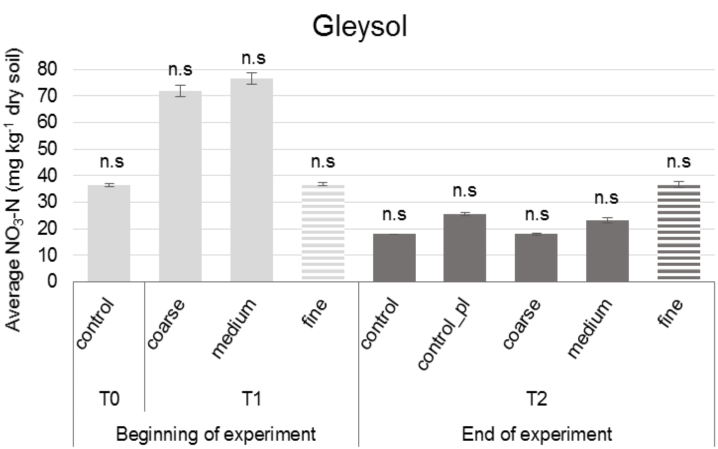
Nitrate (NO_3)





- Varied response by soils
- Relationship between hydrochar and NO_3^- is indeterminable.

Significant differences between means ($p \leq 0.05$) are indicated by different letters. Significant difference Not significant (n.s)

Conclusion

The addition of hydrochar:

1. Did not inhibit seed germination

2. Had little or no effect on biomass production, WHC, aggregate stability and CEC

3. Shifted the pH of the soil toward the pH of the hydrochar
    - Persisted over time
    - Most pronounced in fine grained fraction

4. Provided short-term supply of nutrients – P, K and N
    - Not sustainable over longer term
    - Most pronounced in fine grained fraction

5. The application rate of 5% (w/w) hydrochar may not have been sufficient to induce change or allow a sustainable release of nutrients, however, steadily influenced soil pH

Therefore, further research using higher application rates to improve soil properties may be worthwhile, particularly for use as a long-term fertiliser, while being vigilant of potential adverse impacts

Thank you for your attention

7. References

Title page image: Getty Images available on: The Economist. 2009. The virtues of biochar. A new growth industry? 27 August 2009, Colorado. https://www.economist.com/node/14302001

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