Environmental implications of interactions between biochar and the nitrogen cycle

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Outline

- Short-term effects of competition for N in the soil
- Benefits of biochar–N interactions in the field
- Effects of biochar on N cycle processes in the soil
**Biochar pot experiment with microlysimeters:**

Seepage water collection and N$_2$O measurements

**Introduction**

Biochar-N-effects on plants  
Benefits  
Soil microbial processes

**Cropping pattern:**
- Mustard
- Barley
- Red clover
Introduction

Biochar-N-effects on plants

Benefits: Soil microbial processes

First crop after start: yield depressions

Effects of different N-levels on crop yield (total above-ground d.m.)

- After 7 months: N0 and N0 + BC similar

- After 12 months: no significant difference

1st crop: mustard

2nd crop: Barley

3rd crop: Clover

mit 3 % Biokohle
Barley yield in dependence on biochar and nitrogen supply

N-release slowly starting at lowest N level

<table>
<thead>
<tr>
<th>0 % biochar</th>
<th>3 % biochar</th>
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</thead>
<tbody>
<tr>
<td>20 g/m² N ohne BC</td>
<td>20 g/m² N + 3 % BC</td>
</tr>
<tr>
<td>10 g/m² N ohne BC</td>
<td>10 g/m² N + 3 % BC</td>
</tr>
<tr>
<td>5 g/m² N ohne BC</td>
<td>5 g/m² N + 3 % BC</td>
</tr>
<tr>
<td>0 g/m² N ohne BC</td>
<td>0 g/m² N + 3 % BC</td>
</tr>
</tbody>
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Woodchip-based biochar.
Soil: Planosol

100 % = 764 g/m²
Cumulative N-losses in seepage water with and without biochar

- N addition: 12 g N m\(^{-2}\)
- N-retention is dependent on soil type
- Acidic, sandy soil: 80 % reduction of N-losses
- Other soil types: 25-40 % reduction
N₂O-emissions with and without biochar

- 35 – 50 % N₂O emission reduction
- 24 und 72 t biochar per ha cause a similar degree of reduction
- At high N-level (120 kg N/ha) without biochar:
  - 1.9 % loss of added N
- At high N-level (120 kg N/ha) with biochar:
  - 1.2 % loss of added N
Installation of a field experiment with biochar plots (0, 24, 72 t ha$^{-1}$)
Overview of the N cycle in agricultural soils

DNRA: dissimilatory nitrate reduction to ammonium,
DON: dissolved organic N
PON: particulate organic N
SMB: soil microbial biomass

Source: Prommer et al., PLOS ONE, e86388, 2014
Soil C and N pool sizes for control and biochar treatments

Open bars: control treatment
(0 t biochar, 120 kg N ha\(^{-1}\))

Grey bars: biochar treatment
(72 t biochar, 120 kg N ha\(^{-1}\))

Units in mg C g\(^{-1}\) dry soil and µg N g\(^{-1}\) dry soil.

Extractable N pool was nitrate-dominated

Source: Prommer et al., PLOS ONE, e86388, 2014
Soil N transformation rates

Left panels: gross influx rates into the target pools (production rates)

Right panels: gross efflux rates (consumption rates).

Units in µg N g⁻¹ dry soil d⁻¹, equivalent to mg N kg⁻¹ d⁻¹.

Open bars: control treatment (0 t biochar, 120 kg N ha⁻¹)

Grey bars: biochar treatment (72 t biochar, 120 kg N ha⁻¹)

Source: Prommer et al., PLOS ONE, e86388, 2014
Soil microbial community size and ammonia oxidizers

DNA: soil DNA content
AOA: archaeal amoA copy numbers
AOB: bacterial amoA copy numbers

Microbial community and ammonia oxidizers were stimulated by biochar!

Open bars: control treatment
(0 t biochar, 120 kg N ha\(^{-1}\))
Grey bars: biochar treatment
(72 t biochar, 120 kg N ha\(^{-1}\))

Source: Prommer et al., PLOS ONE, e86388, 2014
Relationship of ammonia oxidizer abundance (AOA, AOB) with gross soil nitrification rates

Source: Prommer et al., PLOS ONE, e86388, 2014

0 t biochar, 120 kg N ha\(^{-1}\)

72 t biochar, 120 kg N ha\(^{-1}\)
Introduction

Biochar-N-effects on plants  Benefits

Soil microbial processes

Biochar in the electron microscope

Porous structure of biochar may provide a protected microhabitat for soil microbes

Photo: Martin Brandstetter
Nitrogen cycling in soil

Introduction

Source: Hoyle et al., GRDC, 2013

Nitrous oxide
(N₂O)

Atmospheric nitrogen (N₂)

Nitrogen inputs

Plant uptake

De-nitrification

Nitrate (NO₃⁻)

Nitrification

Nitrite (NO₂⁻)

Leaching

Immobilisation

Mineralisation

Exchangeable and fixed in soil

NH₃

Source: Hoyle et al., GRDC, 2013
N cycling in soil with biochar

Introduction

Biochar-N-effects on plants

Benefits

Soil microbial processes

Source: Hoyle et al., GRDC, 2013 modified
Conclusions

- Biochar decouples the inorganic and organic N cycles in soil

- Deceleration of organic N cycling → increase of soil organic N pool

- Stimulation of nitrification but decrease of nitrate levels in soil

- Decrease of nitrate losses in seepage water by 40-80 % and decrease of N₂O losses by 35-50 %

- Increase of soil microbial pool, and increase of microbial nitrate utilization

- Potential for increase of non-biochar derived soil organic matter

- Potential for financial compensation for the protection of the natural resources air and groundwater with biochar
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Thanks for your attention

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