Plantation of sunflowers in elevated carbon dioxide concentration by the addition of biochar

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Contents

• Introduction

• Methodology

• Results and discussion
  • Effect of elevated CO$_2$ on sunflower growth
  • Effect of biochar on sunflower growth
  • Heavy metals in the growing substrates
  • Heavy metals in sunflower plants

• Conclusions
Introduction
• Global warming

GLOBAL AVERAGE SURFACE TEMPERATURE

CO₂
Greenhouse gas (GHG)
Risen by 0.18 °C per decade
Stimulate the plant’s photosynthesis and water use efficiency
Affect yield

• Sunflower

Production of four main kinds of vegetable oil in 2020

- Sunflower seed oil
- Soya bean oil
- Palm oil
- Rapeseed oil

20.58 million tons
11%
• Biochar

• Sequester carbon
• Mitigate atmospheric GHG
• Trap heavy metals in the soil
• Enhance water use efficiency
• Adjust pH
Methodology
• Biochar production

Trimming landscaping plants

Proposed Singapore biochar standard → Safe to use for agricultural purpose?
• **Growing substrate**

Biochar - compost mixture (500 g) • Soil (2500 g)

**Biochar ratios:** 0%, 15%, 30%, 45%

**Open area (OA)**

Ambient CO$_2$: ~420 ppm

**Greenhouse (GH)**

Elevated CO$_2$: ~740 ppm
Heavy metals analysis

Elevated CO₂ (740 ppm) → Seeds
Horticultural waste → Leaves
Gasification → Stems
Biochar → Roots
Compost → Mixed
Soil → Potting substrates

Heavy metal analysis:
- Cr
- Cu
- Pb
- Ni
- V
- Zn

Sunflower plant growth:

- Plant height (cm)
- Stem diameter (mm)
- Root mass (g)

As × Se × Cd
Results and discussion
Effect of elevated CO$_2$ on sunflower growth
**Effect of elevated CO₂ on sunflower growth**

Increasing ratio of sunflower characteristics from OA to GH.

<table>
<thead>
<tr>
<th>Sunflower characteristics</th>
<th>Biochar 0%</th>
<th>Biochar 15%</th>
<th>Biochar 30%</th>
<th>Biochar 45%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height</td>
<td>40.02%</td>
<td>29.30%</td>
<td>19.47%</td>
<td>19.45%</td>
</tr>
<tr>
<td>Stem diameter</td>
<td>14.49%</td>
<td>11.41%</td>
<td>1.26%</td>
<td>0.66%</td>
</tr>
<tr>
<td>Flower head diameter</td>
<td>–36.05%</td>
<td>–34.33%</td>
<td>–43.36%</td>
<td>–49.56%</td>
</tr>
<tr>
<td>(with ray florets)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Contents in each cell stands for: Average value*

Increasing ratio = \( \frac{\text{Characteristic of sunflower in GH} - \text{Characteristic of sunflower in OA}}{\text{Characteristic of sunflower in OA}} \)
• Effect of elevated CO$_2$ on sunflower growth – Seed

• Lower seed mass (0% to 25%) which their maternal plant matured at elevated CO$_2$ (Poorter and Navas, 2003)

• Seed crops was not suitable to planted in elevated CO$_2$ concentration

Immature seeds in GH
Effect of biochar on sunflower growth
• Effect of biochar on sunflower growth –
  (a) Plant height; (b) Stem diameter; (c) Flower head diameter

*The horizontal lines in the boxes represent the median; the square hollow points represent the mean; the individual dot represents outliers.
(a) Fresh weights of the vegetative, reproductive and root portions of the sunflower plant, and (b) their proportions in the GH-grown plants ($n = 5$).
Heavy metals in the growing substrates
• **Heavy metals in the growing substrates – Before and post-harvest**

<table>
<thead>
<tr>
<th>Biochar</th>
<th>Zn</th>
<th>Cu</th>
<th>Cr</th>
<th>V</th>
<th>Ni</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15%</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>30%</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>45%</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Unit: ppm

- Higher heavy metal increasing ratio manifests the lower take-up rate of heavy metals by plants compared with other substances.
• Heavy metals in the growing substrates – OA and GH

*Unit: ppm

• Vital plant activity in elevated CO₂

• Properties of growing substrates changed in elevated CO₂
Heavy metals in sunflower plants
• **Heavy metals in sunflower plants**

Most heavy metals would retain in sunflower roots and seeds.
**Heavy metals in sunflower plants – Food safety for seeds**

- Fulfill Singapore food regulations (Sale of food act, chapter 283, section 56(1)) in terms of As and Cd.
- Safe to eat within a certain amount (referenced Dietary Reference by IOM)

<table>
<thead>
<tr>
<th>Heavy metal</th>
<th>Tolerable upper intake level* (mg/day)</th>
<th>Safe consumption of sunflower seeds** (g/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr</td>
<td>Not determined***</td>
<td>N/A</td>
</tr>
<tr>
<td>Cu</td>
<td>10</td>
<td>787</td>
</tr>
<tr>
<td>Ni</td>
<td>1</td>
<td>3333</td>
</tr>
<tr>
<td>Zn</td>
<td>40</td>
<td>667</td>
</tr>
</tbody>
</table>

* Determined by Institute of Medicine in the United States (IOM).
** Sunflower seeds refer to the seeds produced in this study which their maternal plant matured at elevated CO₂ with addition of 15% biochar in the growing substrates.
*** Cr overdose from food hasn’t been linked to significant adverse effects (not including hexavalent chromium)
Conclusions
• Conclusions

• 740 ppm atmospheric CO$_2$ promoted the growth of the plant’s vegetative parts (stem and leaves) but hindered the growth of its reproductive parts.

• At both 420 ppm and 740 ppm atmospheric CO$_2$, plant growth was best using the 15% biochar growing substrate, but the positive effect of biochar to sunflower plants was muted at 740 ppm atmospheric CO$_2$.

• Studied heavy metals percentage (except for Pb) in the growing substrates rose after harvesting the plants.

• Seeds in the 15% biochar grown plants have the lowest concentration of heavy metals.
Thank you for your attention 😊