Effect of Charcoal Application to Early Growth Stage of *Acaia mangium*

Carbon Fixing Forests Management in Indonesia

Chairil Anwar Siregar, Nobuo Ishibashi, Tsuyosi Kato, N.M. Herianto, and Kazuya Ando
(Forest and Nature Conservation Research and Development Center)
(Japan International Cooperation Agency)
Why charcoal? : Hypothetical framework

1. Activate mycorrhizae
   → Enhance nutrient uptake from soil
   Protect roots of seedlings
2. Increase pH of acid soil
   → Increase available phosphorus
3. Provide minerals (Ca^{2+}, K^{+}, Mg^{2+}, etc.)
4. Improve physical properties of soil
   → Improve water permeability and water retention potential
GREENHOUSE EXPERIMENTS:

1. Examining soil amendment through charcoal application with the potential to enhance better plant growth.

2. Evaluate the plant growth response to promote the most judicious use of charcoal in the plantation of *Acacia mangium*. 
EXPERIMENTAL DESIGN

- Completely randomized design with four replications
- One experimental unit: five seedlings in pot
- Medium: 4000 gr air dry soil
- No fertilizer added in pot seedlings
- Soil moisture: field capacity

<table>
<thead>
<tr>
<th>Tree species</th>
<th>Charcoal Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acacia mangium</em></td>
<td>0%, 10%, 15% and 20% (v/v)</td>
</tr>
</tbody>
</table>
# Chemical properties of charcoal

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (H₂O)</td>
<td>8</td>
</tr>
<tr>
<td>pH (KCl)</td>
<td>8</td>
</tr>
<tr>
<td>C – Organic, %</td>
<td>55</td>
</tr>
<tr>
<td>N – Kjeldahl, %</td>
<td>0.1</td>
</tr>
<tr>
<td>P Potential (HCl 25%, P₂O₅), ppm</td>
<td>290.6</td>
</tr>
<tr>
<td>K Potential (HCl 25%, K₂O), mg/100 g</td>
<td>18</td>
</tr>
<tr>
<td>P – available (Bray, P₂O₅), ppm</td>
<td>69</td>
</tr>
<tr>
<td>K – available (Morgan, K₂O), ppm</td>
<td>133</td>
</tr>
<tr>
<td>Ca (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>28</td>
</tr>
<tr>
<td>Mg(1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>8</td>
</tr>
<tr>
<td>K (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>17</td>
</tr>
<tr>
<td>Na (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>2</td>
</tr>
<tr>
<td>Total (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>55</td>
</tr>
<tr>
<td>CEC (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>19</td>
</tr>
<tr>
<td>BS, %</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>KCl 1 N, Al³⁺, me/100 g</td>
<td>0</td>
</tr>
<tr>
<td>KCl 1 N, H⁺, me/100 g</td>
<td>0</td>
</tr>
</tbody>
</table>
Soil: Chemical Properties

Orthic Acrisol (Very fine, mixed, semiactive, isohyperthermic, Typic Paleudult)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (H₂O)</td>
<td>4.4</td>
</tr>
<tr>
<td>pH (KCl)</td>
<td>3.7</td>
</tr>
<tr>
<td>C – Organic, %</td>
<td>0.61</td>
</tr>
<tr>
<td>N – Kjeldahl, %</td>
<td>0.12</td>
</tr>
<tr>
<td>C/N</td>
<td>5</td>
</tr>
<tr>
<td>P Potential (HCl 25%, P₂O₅), mg/100 g</td>
<td>13</td>
</tr>
<tr>
<td>K Potential (HCl 25%, K₂O), mg/100 g</td>
<td>51</td>
</tr>
<tr>
<td>P – available (Bray, P₂O₅), ppm</td>
<td>3.0</td>
</tr>
<tr>
<td>K – available (Morgan, K₂O), ppm</td>
<td>29.5</td>
</tr>
<tr>
<td>Ca (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>0.25</td>
</tr>
<tr>
<td>Mg (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>0.85</td>
</tr>
<tr>
<td>K (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>0.06</td>
</tr>
<tr>
<td>Na (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>0.13</td>
</tr>
<tr>
<td>Total (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>1.29</td>
</tr>
<tr>
<td>CEC (1 N NH₄Oac, pH 7.0 extraction), me/100 g</td>
<td>34.83</td>
</tr>
<tr>
<td>BS, %</td>
<td>4</td>
</tr>
<tr>
<td>KCl 1 N, Al³⁺, me/100 g</td>
<td>19.17</td>
</tr>
<tr>
<td>KCl 1 N, H⁺, me/100 g</td>
<td>0.95</td>
</tr>
</tbody>
</table>
Chemical properties of soil (1)

**pH**
- Initial data: 4.0A, 3.9B, 3.9B, 3.7C
- After experiment: 3.5, 3.6, 3.7, 3.8

**pH KCl**
- Initial data: 1.3A, 1.0B, 0.9B, 0.6C
- After experiment: 0.2, 0.4, 0.6, 0.8

**C organic (%)**
- Initial data: 0.14A, 0.13AB, 0.12B, 0.08C
- After experiment: 0.05, 0.1, 0.15

**N Kjeldahl (%)**
- Initial data: 8.8A, 8.0B, 8.0B, 7.0C
- After experiment: 8.8A, 8.0B, 8.0B, 7.0C

**C/N**
- Initial data: 21.5A, 18.0B, 18.3B, 11.8C
- After experiment: 21.5A, 18.0B, 18.3B, 11.8C

**P potential (mg/100 g)**
- Initial data: 18.3B, 18.0B, 21.5A
- After experiment: 18.3B, 18.0B, 21.5A

Significant differences are indicated by different letters (A, B, C).
Chemical properties of soil (2)

- **K potential (mg/100 g)**
  - Initial data: 6.6D
  - After experiment: 54.3A, 31.8C

- **P available (ppm)**
  - Initial data: 1.2A, 2.4A, 1.4A, 2.9A

- **K available (ppm)**
  - Initial data: 314.8B, 328.0B

- **Ca (me/100 g)**
  - Initial data: 2.73B, 2.78B, 0.64C

- **Mg (me/100 g)**
  - Initial data: 1.07D, 1.50B, 1.39C

- **K (me/100 g)**
  - Initial data: 0.08C

**Significance levels:**
- Significant
- Not significant
- Significant
Chemical properties of soil (3)

- **Na (me/100g)**:
  - Initial data: 0.11A
  - After experiment: 0.22A, 0.26A, 0.24A

- **Total (me/100g)**:
  - Initial data: 1.90C
  - After experiment: 5.11B, 1.90C, 7.61A

- **CEC (me/100g)**:
  - Initial data: 30.8AB
  - After experiment: 30.1B, 30.3B, 31.5A

- **BS (%)**:
  - Initial data: 6C
  - After experiment: 16.8B, 17B, 24.5A

- **Al3+ (me/100g)**:
  - Initial data: 19.4A
  - After experiment: 13.9B, 14.3B, 11.7C

- **H+ (me/100g)**:
  - Initial data: 1.75A
  - After experiment: 0.94B, 1.10B, 1.42AB

Not significant Significant Significant Significant

---

**Chemical properties of soil (3)**

- **Na (me/100g)**:
  - Initial data: 0.11A
  - After experiment: 0.22A, 0.26A, 0.24A

- **Total (me/100g)**:
  - Initial data: 1.90C
  - After experiment: 5.11B, 1.90C, 7.61A

- **CEC (me/100g)**:
  - Initial data: 30.8AB
  - After experiment: 30.1B, 30.3B, 31.5A

- **BS (%)**:
  - Initial data: 6C
  - After experiment: 16.8B, 17B, 24.5A

- **Al3+ (me/100g)**:
  - Initial data: 19.4A
  - After experiment: 13.9B, 14.3B, 11.7C

- **H+ (me/100g)**:
  - Initial data: 1.75A
  - After experiment: 0.94B, 1.10B, 1.42AB

Not significant Significant Significant

---
Effect of charcoal concentration on the plant growth (1)

**Height (cm)**
- 0%: 12.8B
- 10%: 23.4A
- 15%: 23A
- 20%: 23.5A

**Charcoal application**

**Diameter (cm)**
- 0%: 1.6B
- 10%: 2.4A
- 15%: 2.4A
- 20%: 2.4A

**Charcoal application**

**Leaf dry weight (gram)**
- 0%: 0.1B
- 10%: 1.5A
- 15%: 1.6A
- 20%: 1.6A

**Charcoal application**

**Stem dry weight (gram)**
- 0%: 0.4B
- 10%: 0.8A
- 15%: 0.8A
- 20%: 0.7AB

**Charcoal application**

**Root dry weight (gram)**
- 0%: 0.4A
- 10%: 0.6A
- 15%: 0.5A
- 20%: 0.5A

**Charcoal application**

**Significant**

**Not significant**
Effect of charcoal concentration on the plant growth (2)

**Significant**

### Top root ratio

- **Charcoal application**
  - 0%
  - 10%
  - 15%
  - 20%
  - 2.7B
  - 4.4A
  - 4.3A
  - 4.5A

### (Root+stem) / Leaf biomass

- **Charcoal application**
  - 0%
  - 10%
  - 15%
  - 20%
  - 1.4A
  - 1B
  - 0.9B
  - 0.8B
CONCLUSIONS

1. Charcoal additions to soil significantly increased height and diameter of *A. mangium* seedlings at age of 6 months in comparison to a control.

2. Charcoal treatment significantly increased soil pH, soil organic C, N, P, K, Ca, Mg, K, percentage of base saturation. Significantly decreased CEC, Al3+ and H+.

3. Rate at 10% gave the optimum plant growth.
Thank you