Revealing the pathways of cadmium uptake and translocation in cacao trees (*Theobroma cacao* L.): a $^{108}$Cd pulse-chase experiment

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Context and objectives

- High cadmium (Cd) uptake in cacao limits cacao production in Latin America.
- Can bean Cd be lowered by breeding and or grafting? This is difficult to predict without information on the pathways (xylem or phloem) of Cd within the plant.
- A stable isotope ($^{108}$Cd) pulse-chase experiment was set up to identify the pathways of Cd loading into cacao nibs.

Methodology

- Two mature trees selected in Ecuador (December 2020).
- Leaf litter removed in a 2 m radius around the trunk of both trees, $^{108}$Cd stable isotope applied in 10 mm irrigation, litter placed back.
- Periodic soil and plant sampling over 548 days after spiking, analyses for Cd isotopes with ICP-MS.

Methodology

- Gradual rise in the $^{108}$Cd isotopic abundance with rates: immature leaves > mature leaves > nibs.
- Half of the equilibrium $^{108}$Cd IA reached in the nibs significantly later than in for mature and immature leaves.
- The rather slow rise in the $^{108}$Cd IA in the nibs compared to the leaves suggests that Cd in cacao nibs likely originates from phloem-redistribution from the stems, branches or mature leaves and not from direct root-to-nib transport via the xylem.

Results

- Topsoil has neutral pH (6.5) and low total Cd.
- Plant Cd concentrations lower than nationwide values and nib Cd concentrations are below limits for trade.
- Cd concentrations rank nib<young leaves<old leaves.

<table>
<thead>
<tr>
<th>Tree</th>
<th>Flowers</th>
<th>Immature leaves</th>
<th>Mature leaves</th>
<th>Nibs</th>
<th>Cherelles</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.40 A</td>
<td>0.29 B</td>
<td>0.39 A</td>
<td>0.12 C</td>
<td>0.33 AB</td>
</tr>
<tr>
<td>B</td>
<td>0.51 A</td>
<td>0.38 B</td>
<td>0.50 A</td>
<td>0.20 C</td>
<td>0.37 B</td>
</tr>
</tbody>
</table>

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<tbody>
<tr>
<td>A</td>
<td>124</td>
<td>152</td>
<td>191</td>
<td>156</td>
<td>225*</td>
</tr>
</tbody>
</table>

* Values significantly different (based on 95% CL) from that of the immature leaves.

Conclusion and interpretation

- Nib Cd is unlikely derived from direct xylem transport from the roots but rather from leaves (loaded somewhat faster) or the woody tissues (unsampled).
- Recent work (Blommaert et al. 2023) suggests that Cd in cacao originates from phloem- and xylem-mediated redistribution from the stems and branches of the tree.
- Data indirectly suggests that nib Cd is more under control of the scion than of the rootstock. This now awaits long term grafting experiments.

Reference