Immobilization of copper in vineyard soils – the role of the organic additives biochar and compost

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The Bordeaux mixture:
Cu as active ingredient inhibits the germination of fungal spores – preventive action

Pre-WW II: Cu input rates to vineyard soils reached levels up to 50 kg ha⁻¹ yr⁻¹

Source: Gallica Digital Library
Cu-concentrations in the soils of Austrian wine-growing regions

- **Analytical Basis**
  - comprehensive soil analysis survey about Cu-concentrations in agricultural regions
  - EDTA-extractable Cu (= exchangeable Cu)
  - **75 % percentile** for all analytical results: 61-75 EDTA-Cu (mg.kg\(^{-1}\)) in the most important wine growing regions (=11 000 of 45 000 ha vineyards)

Source: [www.oewm.at](http://www.oewm.at); Berger et al., 2012
The Wachau valley of the river Danube

- 26% of Wachau vineyard soils show >150 mg Cu kg\(^{-1}\) (= 390 ha; Berger et al., 2012)

Austrian standard for agricultural / horticultural soils: 100 mg Cu kg\(^{-1}\)
Potential benefits of organic additives (compost, biochar)

- **Reduction of Cu-availability (= general project objective):**
  - Lower ecotoxicity for soil cover crops or for re-planting of a new vineyard
  - Higher activity for soil life, including rhizobia

- **Increase of soil organic matter $$(C_{\text{org}})$$:**
  - Erosion reduction, better infiltration
  - Higher water storage capacity
  - Carbon sequestration
  - Hypothesis: lower release of spores of soil fungi
Methodology of the research project KUSTAW (copper stabilization in vineyard soils)

- Lab experiments
  - Sorption behaviour
  - Microbiological effects
- Greenhouse pot experiment
  - Additive combinations
  - Cu-translocation, 1 vine + soil cover crops
- Field experiment 1
  - Application technology
- Field experiment 2
  - Cu-translocation to soil cover crops, soil microbiology, phytopathology, grape and wine analysis
Lab results I: Effects of different additives on exchangeable Cu and ionic Cu

- Effect of pH-shift: clearer Cu-reductions in more acidic soil
- In acidic soil reduction of ionic Cu is still more apparent than of exchangeable Cu

Source: Deinhofer, 2015
Lab results II: Analysis of Cu-DOC sorption interactions

Grey columns: soil only
Red columns: soil + 3% biochar

DOC was added as extract of humic acids from forest litter, in combination with 300 mg Cu l⁻¹

More DOC → more complexes → more sorption to soil-clay mineral complexes

Source: Bell, 2016
Greenhouse pot experiment

- 2 soils, differing in
  - pH (6.5 and 7.3)
  - elevated copper (110 and 251 mg EDTA-Cu kg\(^{-1}\))
  - humus (5.0 vs. 1.5 % SOM)
- 8-10 treatments each
- \(n = 4\)
- Seepage water collection with suction plate
Pot experiment: Effects of different additives on soil enzymatic activity

- PLFA used as indicator for microbiological activity
  - Additives were more beneficial in the sandy soil, poor in C\textsubscript{org}
  - Some enzymes (e.g. peroxidase) are more expressed if there is an easily available C source at the modified biochar surface

Source: Johnen, 2015
Correlation soil fungi and soil Cu-concentration

Source: Keiblinger, 2016
Cu speciation in Cu-impacted soil with organic additives

Cu in 0.01 M CaCl₂

Soil pH = 7.3

Proportion of Cu²⁺ (Visual Minteq)

Source: Deinhofer, 2015
Seepage water analysis from the pot experiment

Green: sandy neutral soil; blue: acidic soil, rich in $C_{org}$

Source: Chamier-Gliszinski, 2016
Field experiment 1 (application technique): before soil incorporation

Field experiment 1 (application technique): after soil incorporation
### Effects of different soil incorporation techniques on soil bulk density (biochar : compost = 1 : 1 (40 t ha⁻¹))

<table>
<thead>
<tr>
<th>Technique</th>
<th>Lagerungsdichte (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotary hoe</td>
<td>1.0 ± 0.1</td>
</tr>
<tr>
<td>Tooth cultivator</td>
<td>1.2 ± 0.1</td>
</tr>
<tr>
<td>Spade plough</td>
<td>1.2 ± 0.1</td>
</tr>
<tr>
<td>Surface spread</td>
<td>1.2 ± 0.1</td>
</tr>
<tr>
<td>No application</td>
<td>1.4 ± 0.1</td>
</tr>
</tbody>
</table>

**Note:**
- Different letters (a, b, ab) indicate significant differences at α = 0.05.
Field experiment 2: additive comparison

<table>
<thead>
<tr>
<th>Control</th>
<th>Biochar</th>
<th>Biochar:Compost = 1:1</th>
<th>Biochar:Compost = 1:1</th>
<th>Compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>4 kg TM / m²</td>
<td>4 kg TM / m²</td>
<td>10 kg TM / m²</td>
<td>4 kg TM / m²</td>
</tr>
</tbody>
</table>
Green cover crops in the field 2015: Biochar reduced Cu uptake into the roots but not in combination with compost.

Source: Chamier-Glischzinski, 2016
Green cover crops in the field 2016: Biochar again reduced Cu uptake into the roots but not to above-ground parts

Source: Mlinkov, 2016
Sequential extraction of Cu from rhizosphere soil after 13 months in the field

Biochar reduced the proportion of Cu in the more available fractions

Source: Mlinkov, 2016
Conclusions (and outlook)

- Soil characteristics determine the efficacy of different additive applications: especially pH, C\text{org}-content
- Complexation of Cu with soil organic matter determines the availability of Cu
- Surface modification of biochar was less important for Cu sorption than the organic complexation option
- Additives have more benefits for reducing the ecotoxically relevant Cu\textsuperscript{2+} fraction, but not the mobile fraction of total Cu
- Effects appear clearer in acidic soils than in neutral soils
- Biochar without compost or high doses of biochar/compost mixtures in the field reduce Cu uptake into the roots of cover crops
Thank you for your attention!