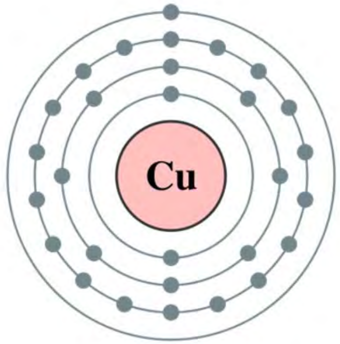
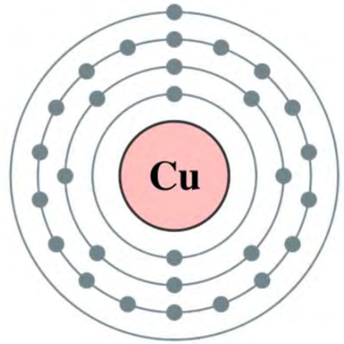
Immobilization of copper in vineyard soils – the role of the organic additives biochar and compost





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Source: Gallica Digital Library

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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}

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; 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 addives** (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_{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

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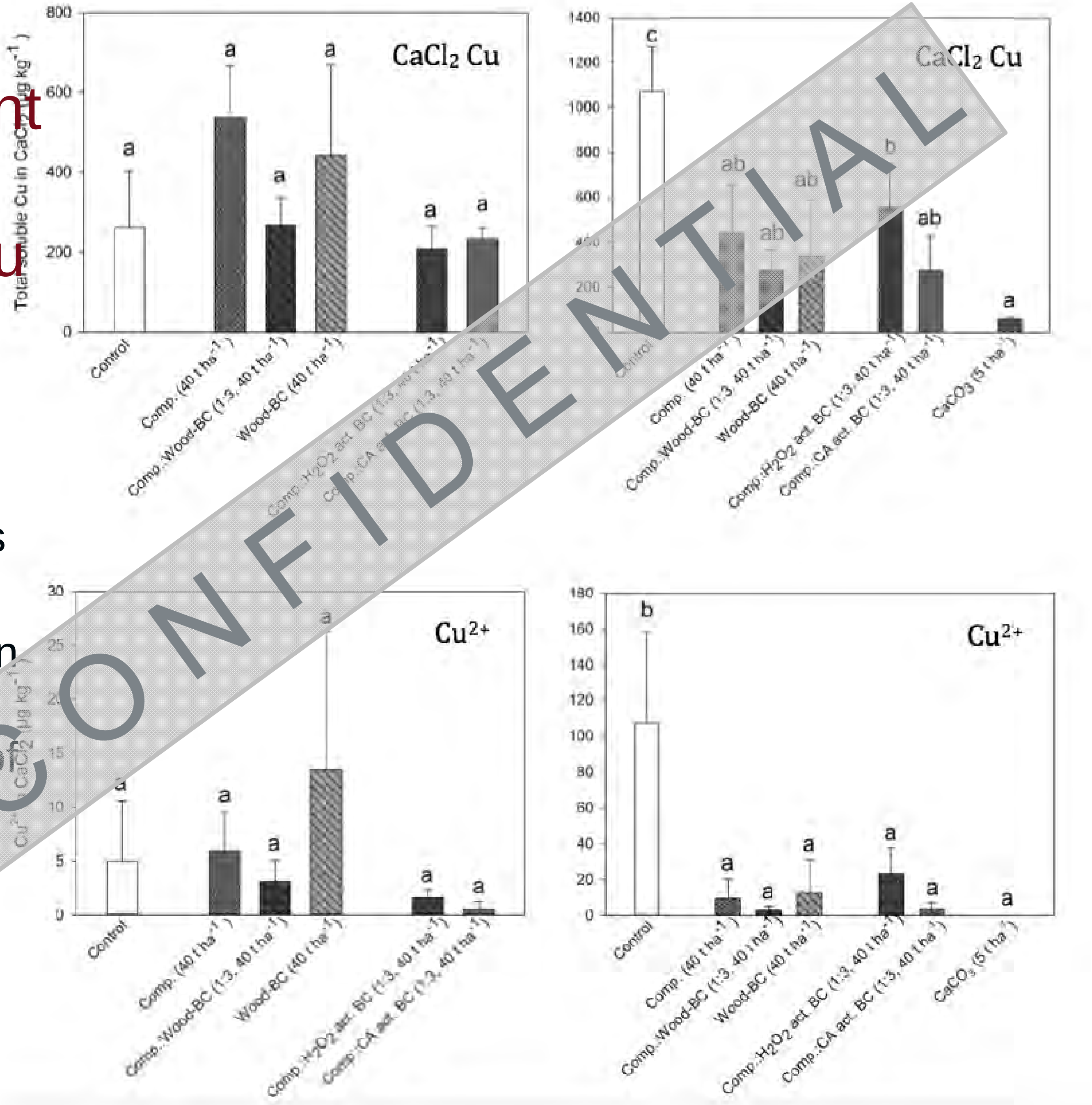
Lab results I: Effects of different additives on exchangeable Cu and ionic Cu

Site Rossatz (sandy soil, pH 7.3) **Site St. Stefan**(soil rich in C_{org}, pH 6.5)

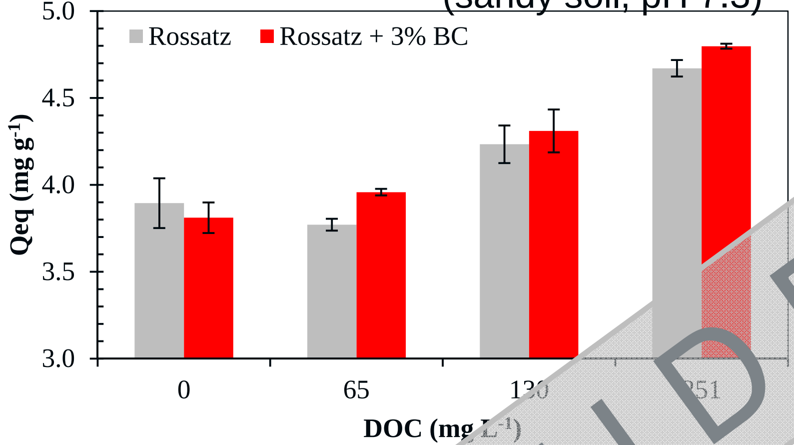


- Effect of pH-shift: clearer Cu-reductions in more acidic soil
- In acidic soil reduction of ionic Cu is still more apparent than of exchangeable Cu

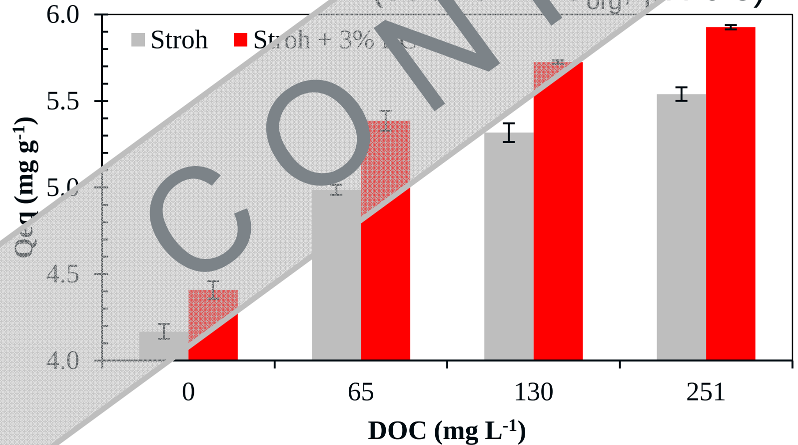
Source: Deinhofer, 2015

Lab results II:
Analysis of Cu-DOC sorption interactions

(sandy soil, pH 7.3)



(soil rich in C_{org}, pH 6.5)



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

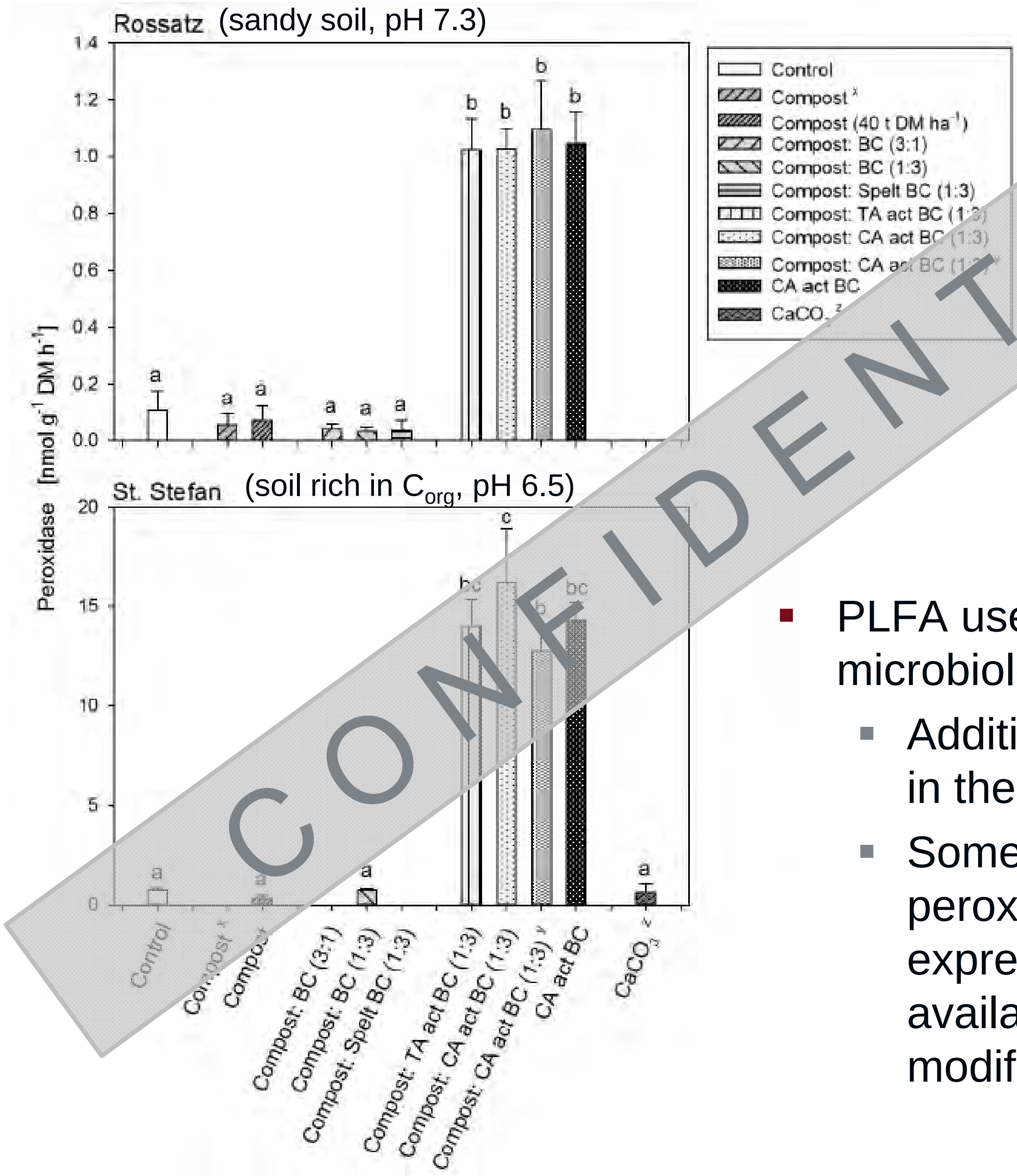
DOC was added as extract of humic acids from forest litter, in combination with 300 mg Cu l^{-1}

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



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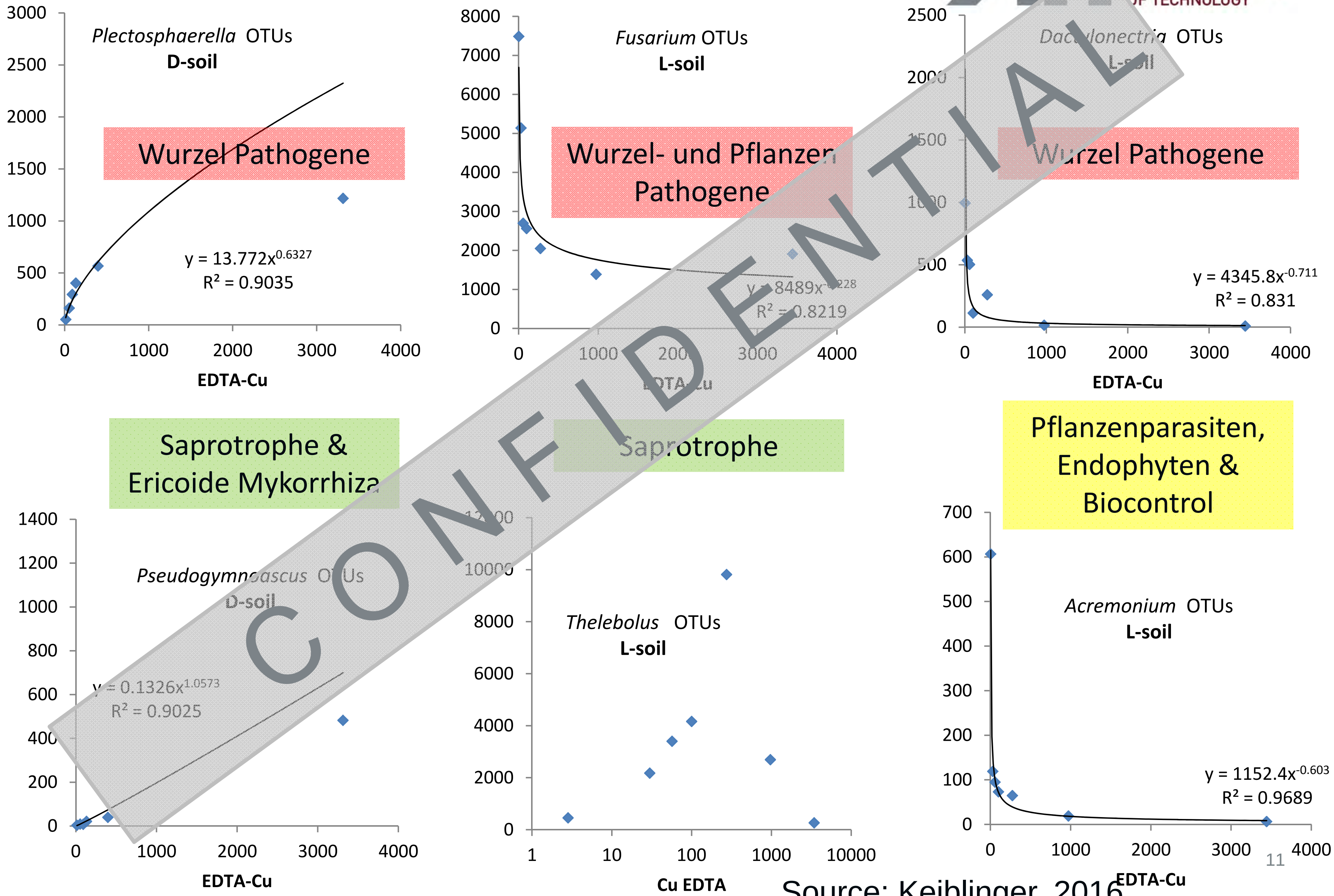
Pot experiment: Effects of different additives on soil enzymatic activity

- PLFA used as indicator for microbiological activity
  - Additives were more beneficial in the sandy soil, poor in C_{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

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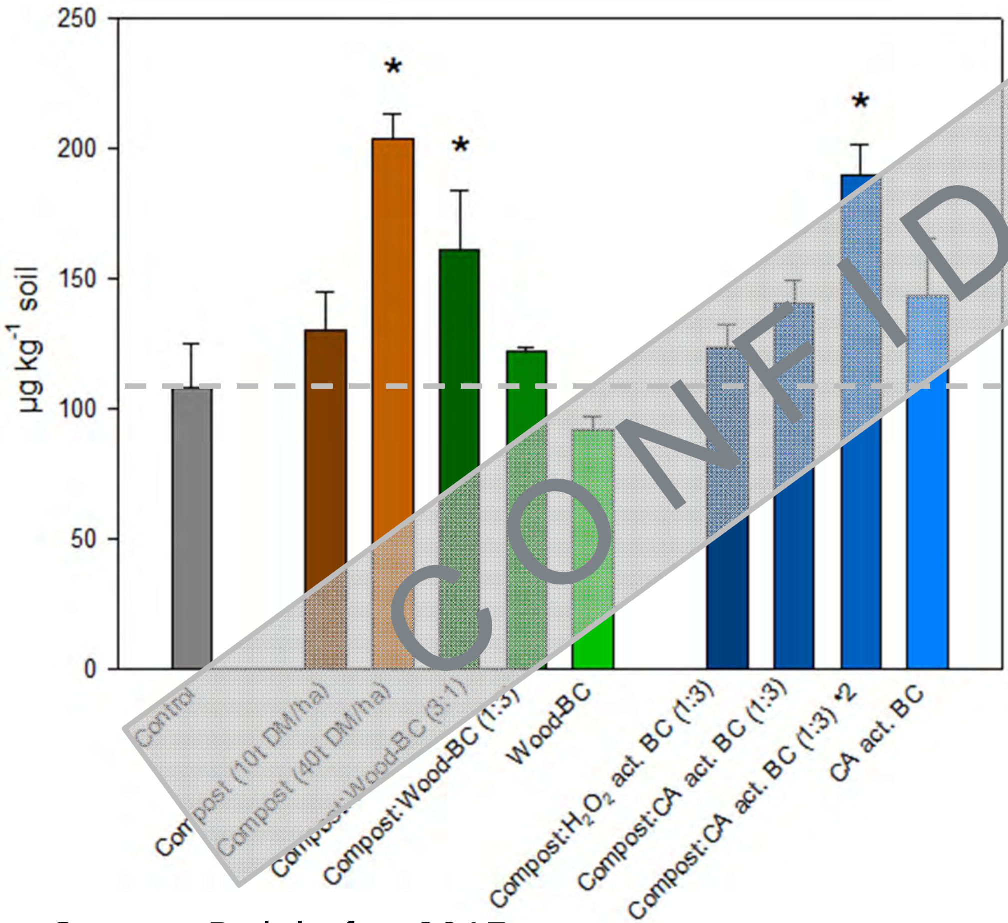
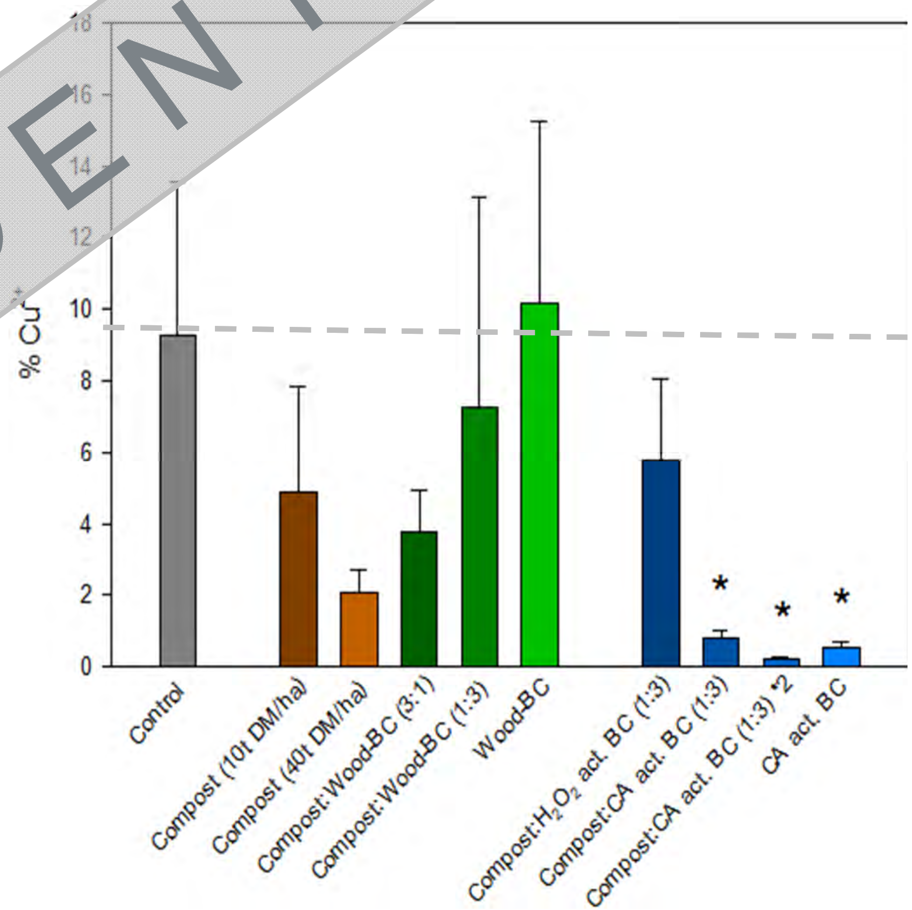
Cu in 0.01 M $CaCl_2$ — Soil pH = 7.3



Proportion of Cu^{2+} (Visual Minteq)



Source: Deinhofer, 2015

Seepage water analysis from the pot experiment

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

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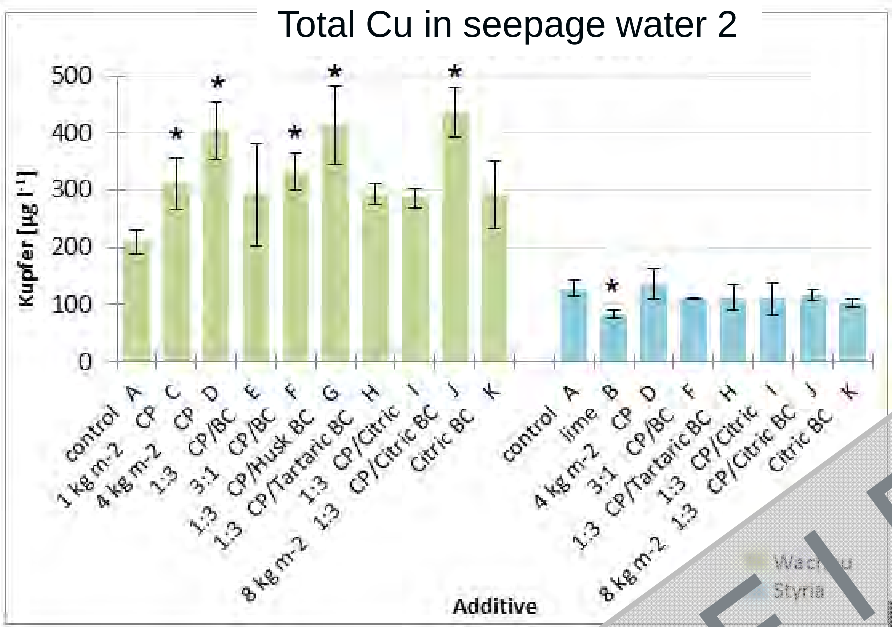
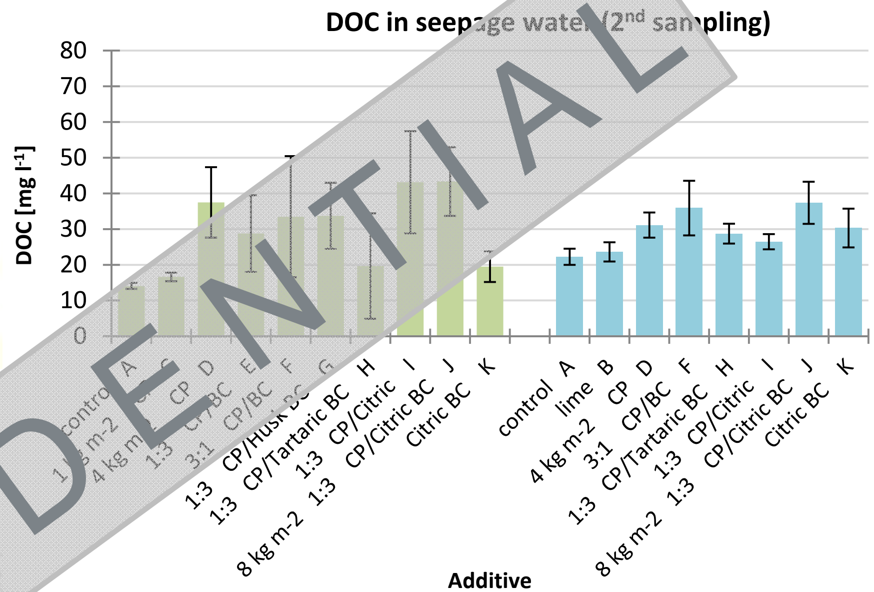
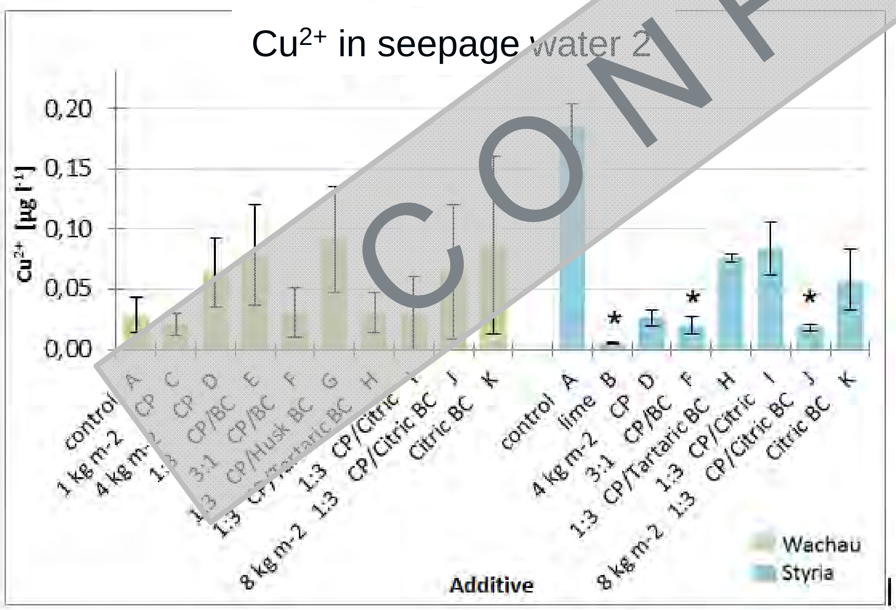
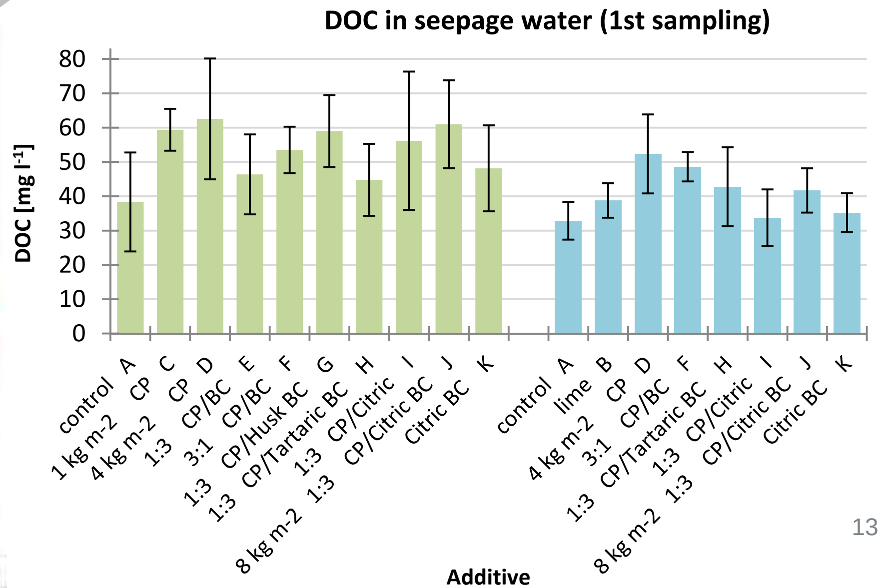






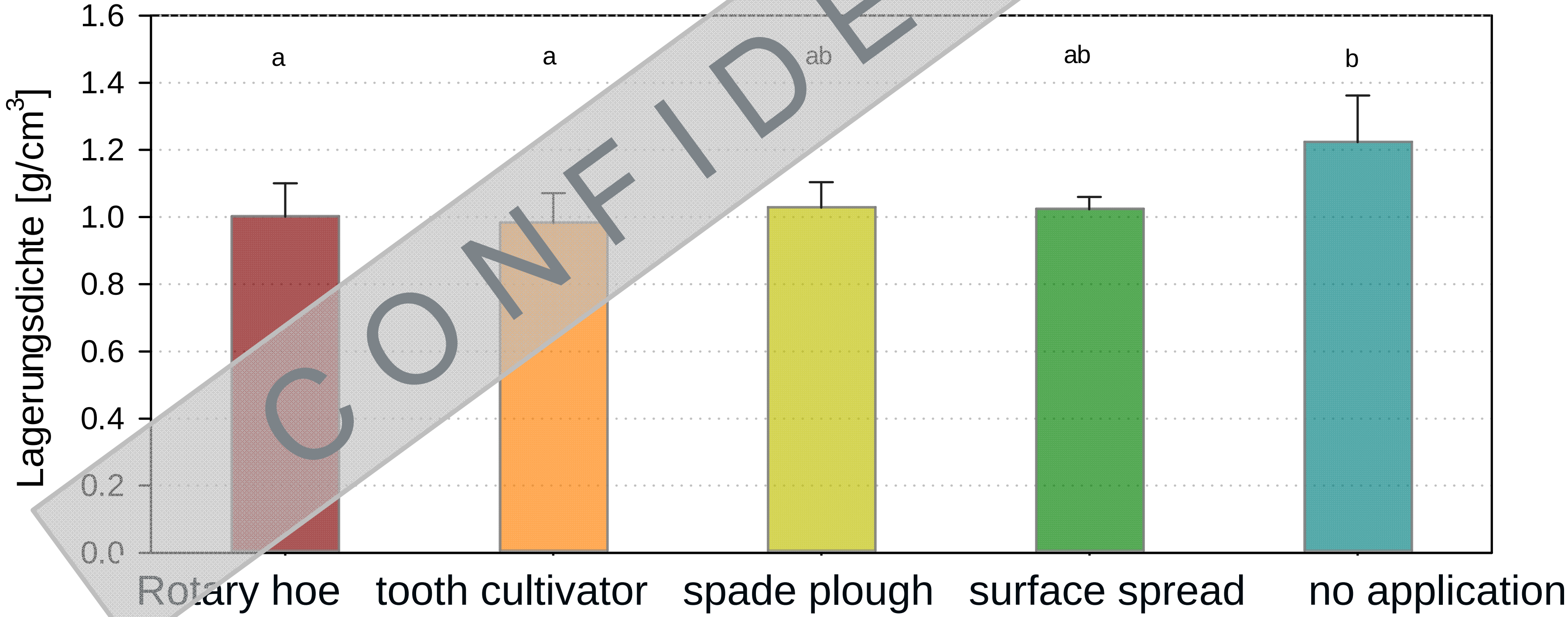


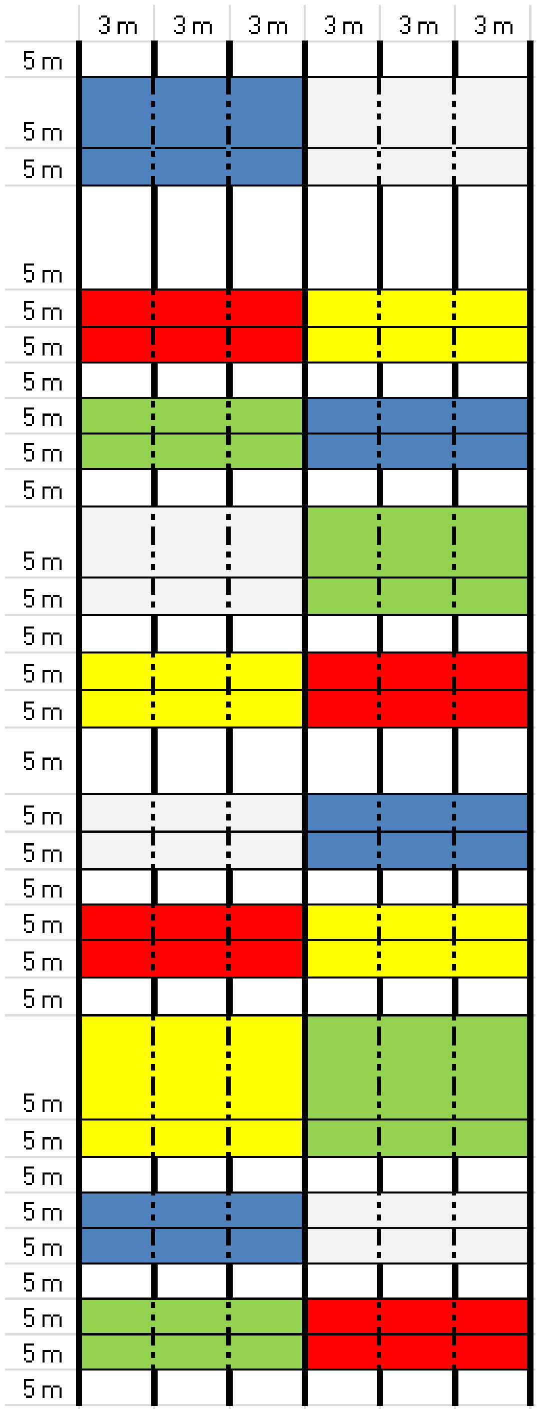
Source: Chamier-Gliscinski, 2016

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}))

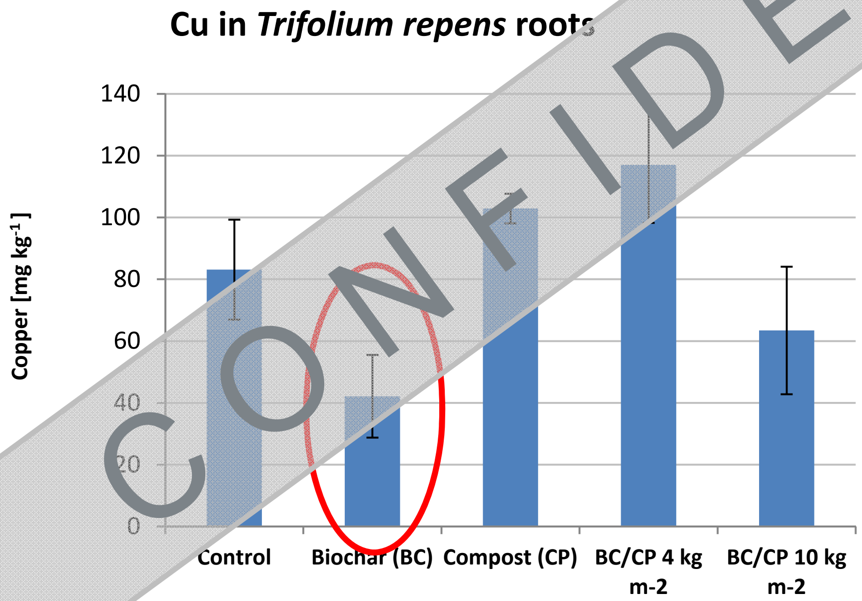




Field experiment 2: additive comparison

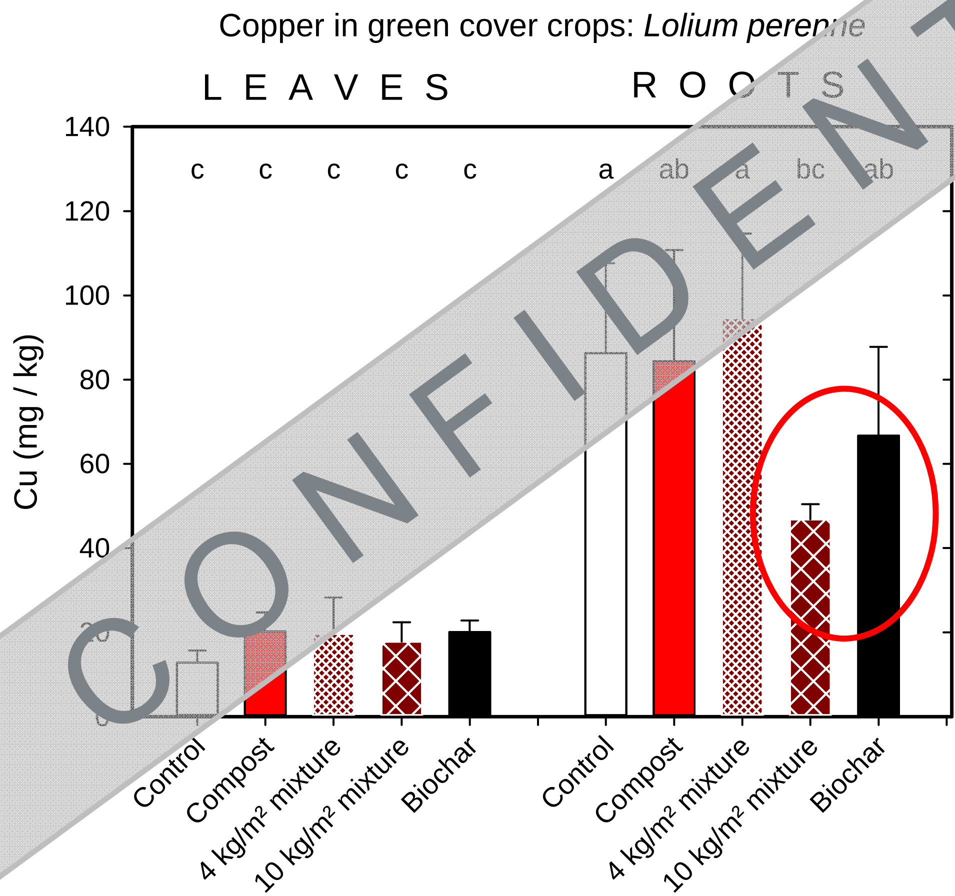
Control	-
Biochar	4 kg TM / m^2
Biochar:Compost = 1:1	4 kg TM / m^2
Biochar:Compost = 1:1	10 kg TM / m^2
Compost	4 kg TM / m^2

Green cover crops in the field 2015:
Biochar reduced Cu uptake into the roots
but not in combination with compost



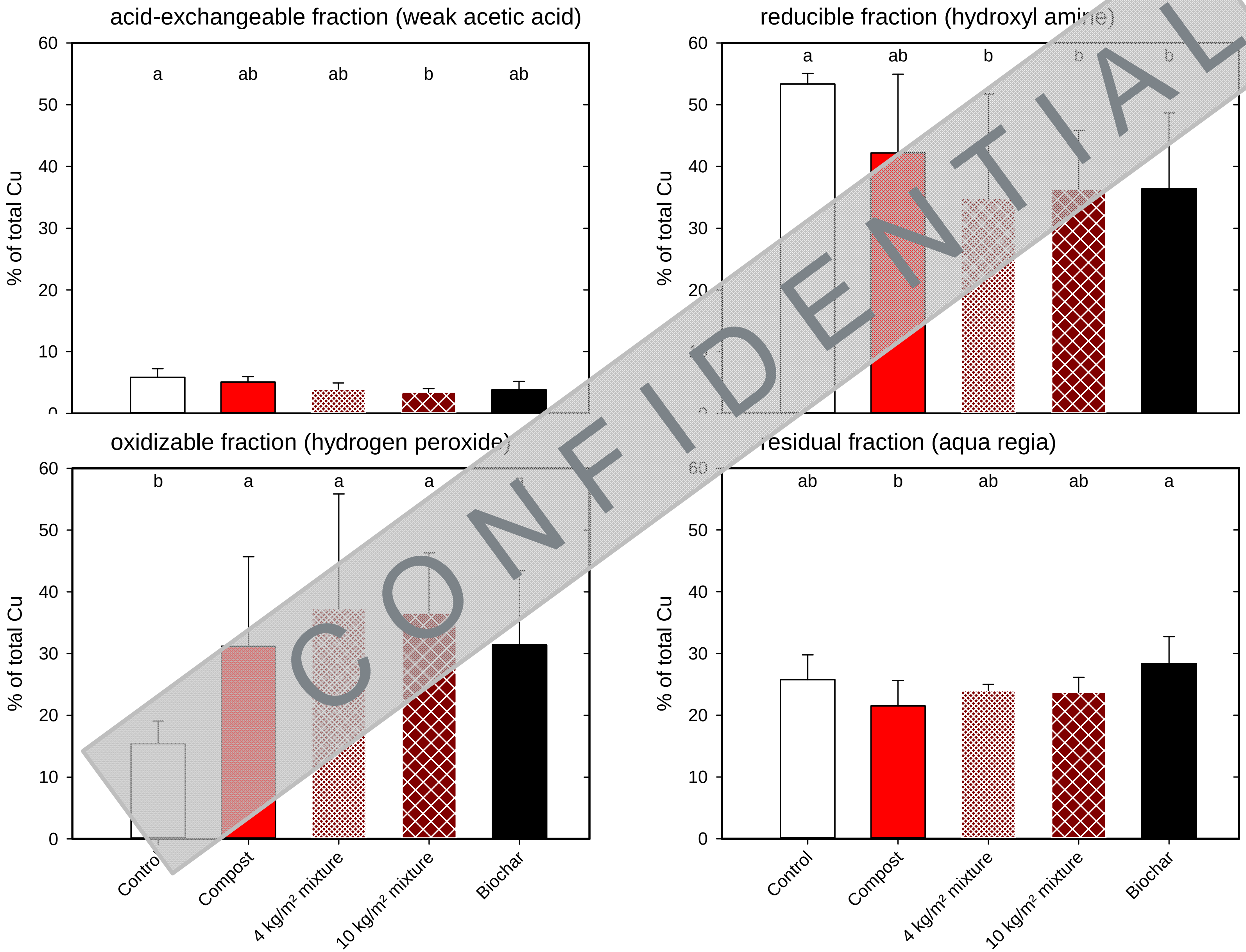
Source: Chamier-Glisczinski, 2016

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_{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 ecotoxicologically relevant Cu^{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!