Executive Summary

Copper fungicides: Necessary evil in organic farming

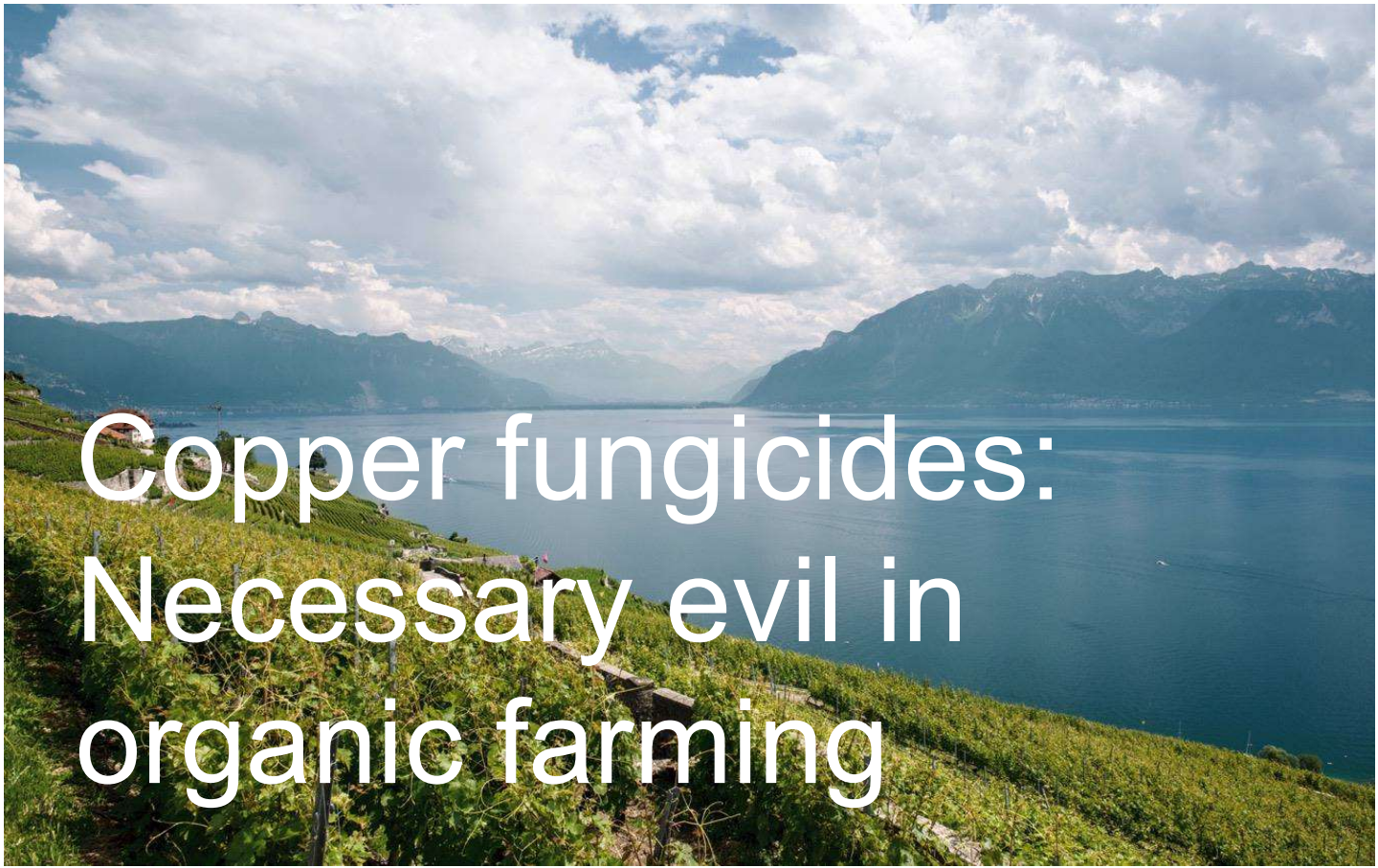
- Organic farming growth leads to pressure for fully organic plant protection products
- Copper currently considered essential to prevent major crop losses in organic farming
- However, Copper use comes with considerable side effects on soil, water, and microorganisms
- Especially, soil accumulation of copper is a big concern in vineyards across EU
- So far, no satisfying, copper-free alternatives with similar efficacy exist

A copper-free, organic and efficient alternative

- We have a Copper-free, biodegradable and naturally effective PPP alternative: Surface-Modified Alkaline Calcium Compounds (SMAC)
- SMAC acts as a reservoir of alkalinity and can be used as biodegradable and biological fungicides
- Alkalinity has clear antimicrobial activity; proven in dental application as slow acting medication
- SMAC show a 40x slower release of alkalinity in water versus pure CaO
- Efficacy of SMAC comparable to copper reference products

Promising market size and good product fit

- EU Copper market estimated at $240M driven by vine and Italy, Spain and France
- With high copper use and limited alternatives, Vine seems very promising


Copper fungicides:
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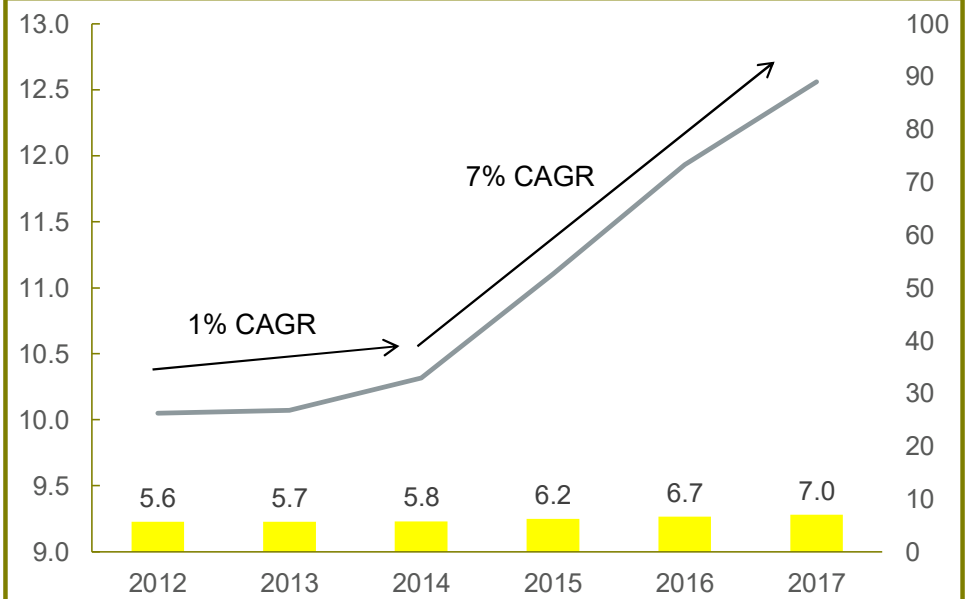
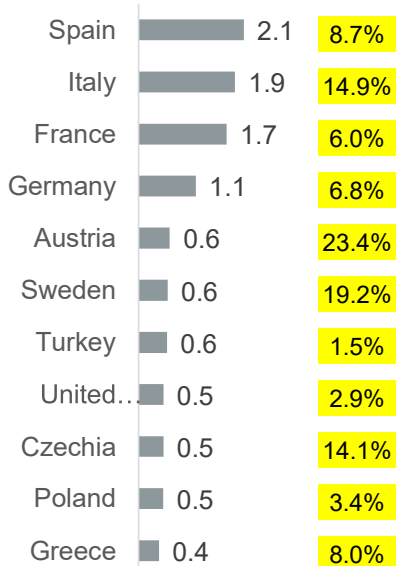
Organic farming growth leads to pressure for fully organic plant protection products

Organic farming area in EU-28 countries, 2012-2017, in M ha



Largest area per EU country 2017, in M ha



Source: Eurostat

Copper currently considered essential to prevent major crop losses

- Copper is used in Europe by most types of agriculture to control certain fungal or bacterial diseases, **and plays an important role in protecting crops grown under organic conditions.** The use of copper is currently approved in more than 50 situations in arboriculture, viticulture, market garden or arable crops, using formulations **that are permitted by the specifications for organic farming**. In particular, it is used in vineyards to control downy mildew (*Plasmopara viticola*), on arable crops to protect potato against late blight (*Phytophtora infestans*) and, to a lesser extent, in apple orchards to prevent the spread of scab (*Venturia inaequalis*). These three pathogens are responsible for major crop losses
- Copper products can be used in organic farming and are usually considered the reference in efficacy studies (Source: private conversation with FiBL)
- **Copper use is completely banned by Denmark, Finland, Netherlands, and Norway**; **most other European countries have a limit of 3-4 kg / ha / year**

Source: http://institut.inra.fr/en/Objectives/Informing-public-policy/Scientific-Expert-Reports/All-the-news/Can-organic-farming-manage-without-copper

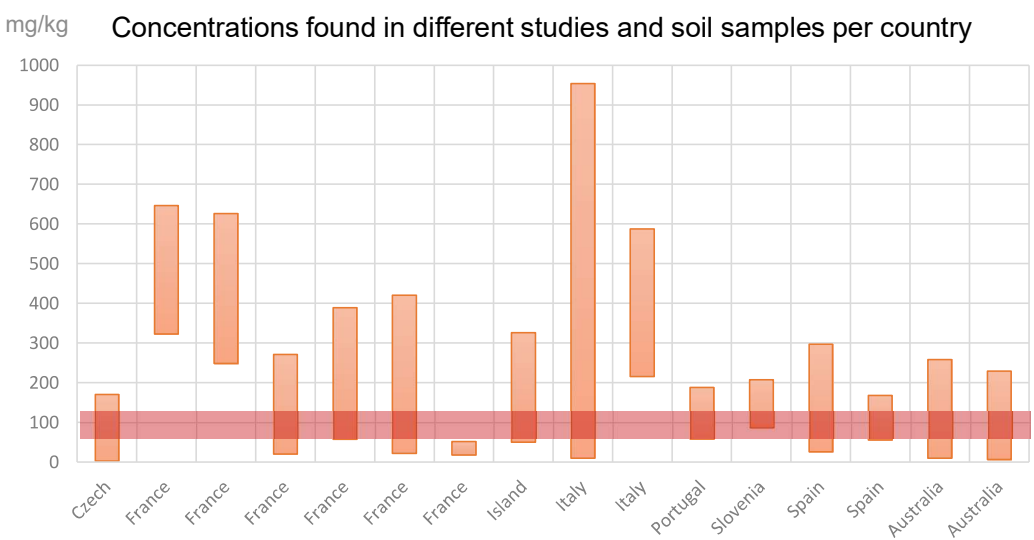
Copper use with considerable side effects

Effects on soil	▪ Since copper cannot be degraded, and its removal from the soil is negligible through leaching, run-off or plant uptake, this heavy metal can potentially remain as contaminant in the environment for long periods **and cause bioaccumulation and toxicity**
Effects on micro and macroorganisms	▪ **Accumulation is hazardous to micro and macroorganisms**: ▪ Copper contamination can greatly modify both the size of microbial biomass and soil process, reduced activity of some terrestrial microorganisms; ▪ High copper concentrations can also reduce populations of earthworms and carabids
Effects on plants	▪ **Excess copper adversely affects the metabolic activity of roots** and the absorption of nutrients, through antagonist and synergistic effects
Effects on aquatic organisms	▪ Copper is moderately soluble in water and binds to sediments and organic matter, it can interfere with aquatic organisms (sediment dwellers, algae, invertebrates and fish) ▪ **Toxic effects on algae** cascades throughout aquatic ecosystems
Effects on human and animal health	▪ Heavy metals can be transferred easily to animals and humans through food chains, causing toxicity problems ▪ Studies examining the effects on animals have shown **hepatic and gastrointestinal problems caused by copper accumulation**

Source: “Copper in plant protection: current situation and prospects”, A. La Torre, Phytopathologia Mediterranea (2018), 57, 2, 201-236

Soil accumulation of copper is a big concern in vineyard topsoils across EU

Total copper concentrations in vineyard topsoils, mg/kg



EU regulatory aspects

EU has extended once again the authorization for copper sulphate, a controversial pesticide in organic farming, which is on the EU's "substitution" list and its effects on consumers are still unknown.

Limit values of copper in soil are set from 50 to 140 mg/kg of dry matter (Council Directive 86/278/EEC)

Source: "Copper in plant protection: current situation and prospects", A. La Torre, Phytopathologia Mediterranea (2018), 57, 2, 201-236
https://www.euractiv.com/section/agriculture-food/news/eu-renews-toxic-pesticide-amid-safety-uncertainty/, accessed on 6. Mai 2019

So far, no satisfying, copper-free alternatives with similar efficacy exist

"There were 20 years of trials with copper free plant based alternatives but nothing worked. In the laboratory results where good, **but it is difficult to scale and very expensive for field application.**"

Claudia Jung, Vine Farming Department, Regional Board Darmstadt

"In organic vine farming, *downy mildew is a big problem* **not solved at this point** in time. If you had a product suitable for organic farming that actually works, there would be a free market for that."

„Also conventional farmers are increasingly worried about soil quality and the effect of chemicals on their soil."

Benedikt Bösel, organic farmer

"Sometimes the pressure is so high that farmers try to find every reason to use copper and still stay within the restricitions."

Carl Peter Hagge, conventional and organic farmer

Lars Osterhoff, farmer (in conversion from conventional to organic farming)

„I see a big potential and high interest for **non-harmful plant treatments in the market.**"

Source: Private interviews

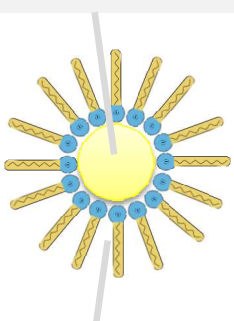
Copper-free, biodegradable and naturally effective PPP alternative: SMAC

- Published patent (EP 2920248 A1 with priority date November 15, 2012) outlining a novel class of materials which are **surface-modified alkaline calcium compounds (SMAC)**
- SMAC are **calcium-based particles** which are **coated with an hydrophobic layer of fatty acids** and were developed as **biological fungicides and pesticides** in plant and crop protection applications
- In contact with water, the hydrophobic layer is **slowly dissolved** and thus **calcium oxide** or **calcium hydroxide particles are released** (“time release”)
  - **Time-released fungicidal** and **biocidal effects** against fungus and bacteria
  - Release of calcium stearate as **hydrophobic, water-repellent adhesives** for plant surface
- **SMAC are completely biodegradable and show a promising potential for a novel class of biological fungicides with a similar efficacy as copper-based products**

Efficacy of SMAC comparable to copper reference products

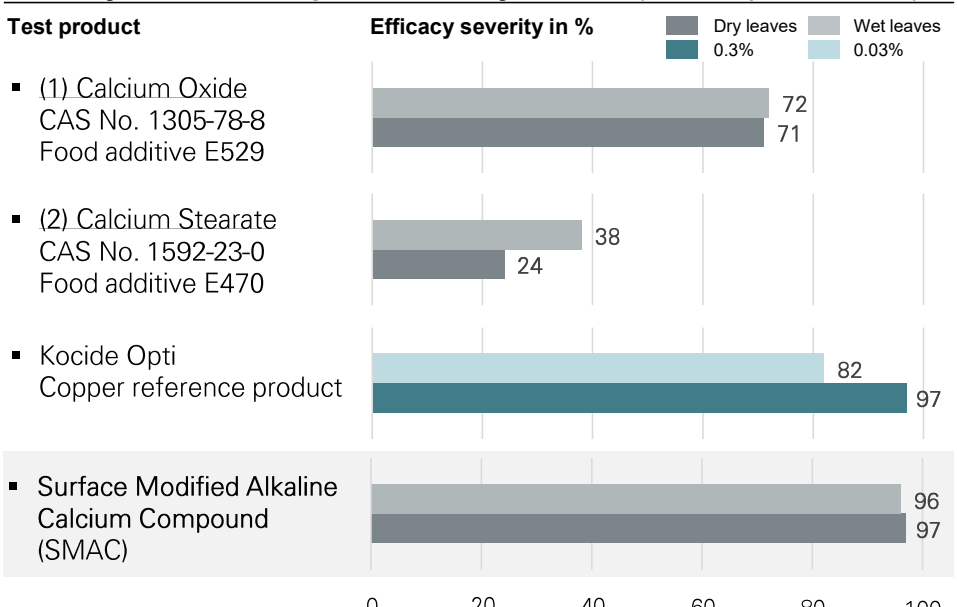
Illustration of a SMAC particle

Alkaline particle core consists of **pure calcium oxide** (or calcium hydroxide)



Surface modification is a coating of aliphatic hydrocarbon chains (fatty acid)

Efficacy trials on Grapevine downy mildew *(Plasmopara viticola)*[1)]



1) Indoor and outdoor efficacy trials have been conducted with FiBL over the last two years; efficacy data shown are from indoor studies on Plasmopara viticola on grapevine for comparison reasons.

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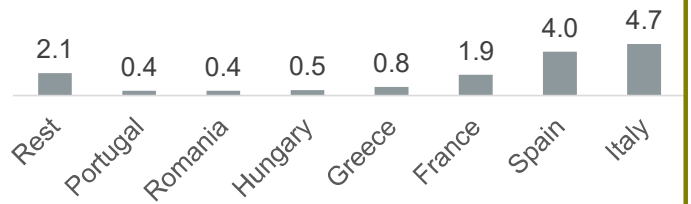
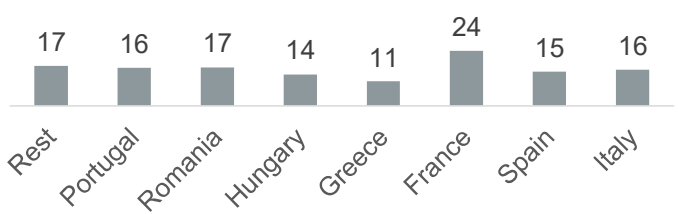
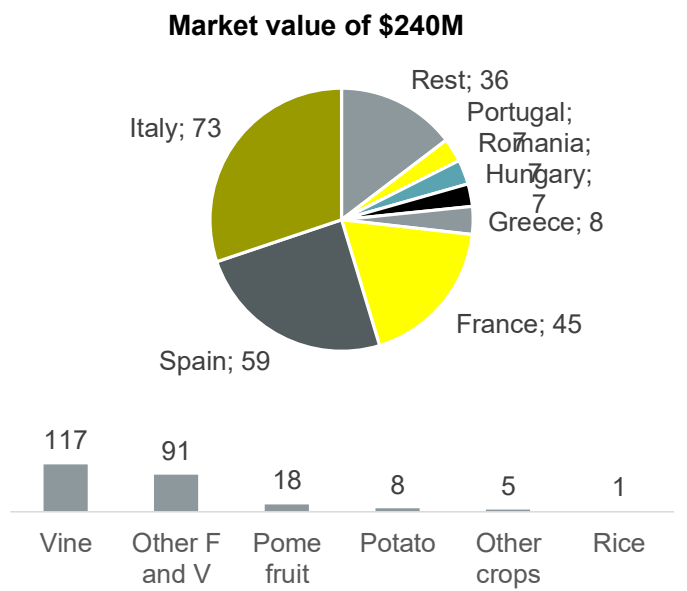
Active volume of copper PPP, 2015, in M kg



Average price per kg, 2015, in US$/kg



Active ingredient value, 2015, in US$ M



Source: Kleffmann, 2016; Prices ex-manufacturer (first level of distribution chain)

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