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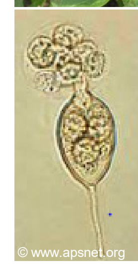
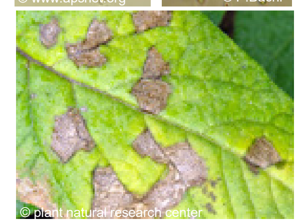
Agroscope

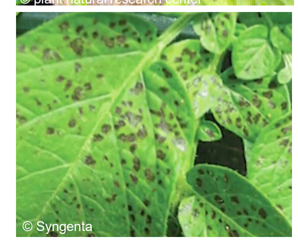
Use of alternative products for the control of late and early blight on potatoes

T. Musa, H.R. Forrer, S.Vogelgsang, K. Sullam
Agroscope, Ecological Plant Protection in Arable Crops

EuroBlight Workshop, 12.-15. May 2019, York







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Overview

- Introduction
- Sources of possible alternative products and modes of action
- Examples of products
- Conclusion and Outlook

Introduction

- For more than 20 years, investigators have been looking for alternative products to control late and early blight on potatoes

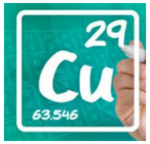
- At first, focus mainly on replacement of copper products in organic farming due to its negative environmental impact

- Importance of early blight increased during the last decade

  (resistance to fungicides (QoIs/SHDI's), climate change)

- Societal pressure to reduce pesticides in general came to the fore - not only for organic production

Introduction

- Copper 

Pros:

- Trace element and an essential micronutrient
- Broad efficacy (fungicide, bactericide, foliar fertilizer)
- Hardly any documented resistance against fungi, oomycetes

Cons:

- Accumulation in the soil → detrimental effects on the environment and non-target organisms
- Resistance against some bacteria (e.g. *Pseudomonas syringae* pv. *tomato*)

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Introduction

- Since 2006, EU has set limits for the use of copper (6 kg/ha*year)

- In several EU countries, use of copper already forbidden or more restricted amount allowed to use

- Intention to ban copper, but registration prolonged until 2025 (max. 28 kg CU/ha in 7 years, Ø 4 kg CU/ha*year)
  - Within the registration: particular attention should be paid to the application rate and kept as low as possible

→ Challenge for potato production, especially organic potato production

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Funded EU-projects

- Blight MOP: Development of a systems approach for the management of late blight in EU organic potato production, 2001-2005
- Co-Free: Innovative strategies for copper-free low input and organic farming systems (2012-2016), registration processes completed earliest 2022
- RELACS: Replacement of Contentious Inputs in Organic Farming Systems', aims to develop new products and strategies to minimise use of copper in organic plant production, focus on grapes, 2018-2022
- OrganicPlus: means minimising, and eventually phasing out contentious inputs from certified organic agriculture, 2018-2022

- In addition several national projects

Many products tested:

Appl Microbiol Biotechnol (2012) 96:37–48 41

Table 1 Biological control of *P. infestans* by different microorganisms

Microorganism	Activity spectrum	Antifungal compounds/mode of action	Reference
Penicillium aurantiogriseum	In vitro and in situ (potato)	Antagonistic effects	Jindal et al. (1988)
Xenorhabdus boienii A2	In vitro	Indoles	Li et al. (1995)
Serratia sp. *Trichoderma* sp.	In vitro	Antagonistic effects	Garita et al. (1998)
Fusarium sp.			
Penicillium sp.			
Nigrospora sphaerica	In vitro and in situ (tomato)	Phomalactone	Kim et al. (2001)
Pseudozyma flocculosa	In vitro	*cis*-9-Heptadecenoic Acid	Avis and Belanger (2001)
Bacillus pumilus SE34 *Pseudomonas fluorescens* 89B61	In situ (tomato)	Growth-promoting rhizobacteria	Yan et al. (2002)
Bacillus subtilis (B1, B2, B3, J1) *B. pumilus* (B2, M1, W1 and Y1)	In vitro and in situ (potato)	Antibiosis, and (or) indirectly (induction of plant defence system)	Daayf et al. (2003)
B. amyloliquefaciens C1			
Pseudomonas fluorescens (DF35, DF37 and DF40)			
P. viridilivida DF3			
P. putida (P1 and P2)			
Rahnella aquatilis W2			
Serratia plymuthica DF1			
P. fluorescens SS101	In vitro	Massetolide A	de Souza et al. (2003)
Bacillus cereus	In situ (tomato)	Induction of systemic resistance	Silva et al. (2004)
Streptomyces sp. AMG-P1	In vitro and in situ (tomato)	Paromomycin	Lee et al. (2005)
Pseudomonas putida (TRL2-3) *Micrococcus luteus* (TRK2-2)	In situ (potato)	Induced resistance	Kim and Jeun (2006)
Flexibacteraceae bacterium (MRL412)			
Burkholderia spp. *Streptomyces* spp.	In situ (potato)	Inhibitory effect	Lozoya-Saldana et al. (2006)
Pseudomonas spp.			
Bacillus cereus	In vitro and in situ (tomato)	Antagonistic effects	Lourenco et al. (2006)
Cellulomona			
Candida sp.			
Cryptococcu			
Fusarium ox			
Pseudomona S22:T:04,P			
Enterobacter			
Fusarium gr			
Fusarium c			
Pseudomona			
Arbuscular n (Glomus sp			
Xenorhabdu *pekingensi*			
Pseudomona			
Lactobacillu IMAU100			

[a] Showed an

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Table 2 Commercially available microbial-based anti-*Phytophthora* fungicides

Commercial products	Activity spectrum	Antifungal compounds/mode of action	Reference
Plant Shield HC (*Trichoderma harzianum* T22) G41 (*Gliocladium virens* G41)	In vitro and in situ (tomato)	Ineffective	Becktell et al. (2005)
Rhapsody AS (*Bacillus subtilis*)			
Serenade (*Bacillus subtilis* QST-713)	In vitro and in situ (potato)	Cyclic lipopeptides	Stephan et al. (2005)
Serenade (*Bacillus subtilis* QST 713) EM (effective microorganism), mixture of bacteria (LAB), yeasts, fungi	In situ (potato)	Insufficient	Olanya and Larkin (2006)
Serenade (*Bacillus subtilis* QST 713) Sonata 1 (*Bacillus pumilus* QST 2808)	In vitro and in situ (tomato), field (potato)	Ineffective in field	Dorn et al. (2007)
Trichodex 1 (*Trichoderma harzianum var.* T-39)			
EM 5 (mixture of bacteria (LAB), yeasts, fungi)			
Polyversum (*Pythium oligandrum*)			
Xenorhabdus bovienii 4722			
Agro-Mos™ (*Lactobacillus plantarum*)			
Polyversum (*Pythium oligandrum*)	In vitro and field (potato)	Inconclusive	Kurzawinska and Mazur (2009)

C. Axel et al., 2012, Appl. Microbiol Biotechnol, 96:37-48

Lists are not exhaustive!

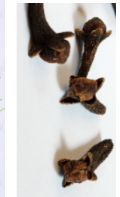
selected examples of plant extracts

88 plants amoung 44 botanical families	Wang et al. (2001)
Innula viscosa	Wang et al. (2004)
Rheum rhabarbarum *Solidago canadiensis* *Artemisia vulgaris* *Impatiens parviflora* *Urtica dioica*	Stephan et al. (2005)
Rheum palmatum *Potentilla erecta* *Galla chinensis*	Krebs et al. (2006)
Rheum rhabarbarunn *Potentilla erecta* *Salvia officinalis* *Salix* spp. *Solidago canadiensis* *Malva silverstris* *Spohora flavescens* *Artemisia annua* *Ocium balsilicum*	Dorn et al. (2007)
Yucca extract	Bengtsson et al. (2009)
garlic extract commercial garlic product (AMN BioVit) commercial knotweed product (Regalia) commercial citrus extract (ViCare) *Equisetum arvense* *Citrus* spp. *Glycyrrhiza glabra* commercial conifer bark extract	Nechwatal and Zellner (2015)
Macleaya cordata	Schuster and Schmitt (2015)
Thymus vulagris	Perina et al. (2015)
Frangula alnus	Forrer et al. (2017)

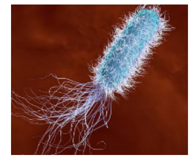
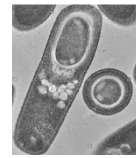
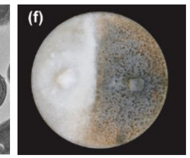
Sources of alternative products

- Plants:
  plants extracts and essential oils

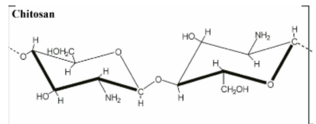


- Biological control agents:
  saprophytic, epiphytic and endophytic organisms

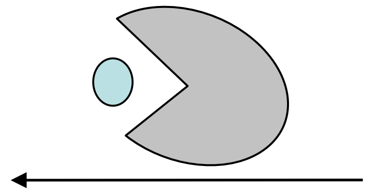
- non-fungicidal chemical inducers



- Other products

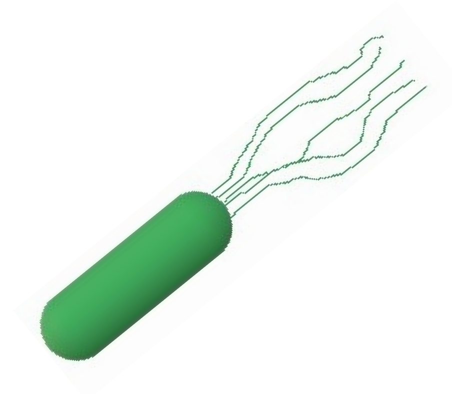
Modes of action

- directly:

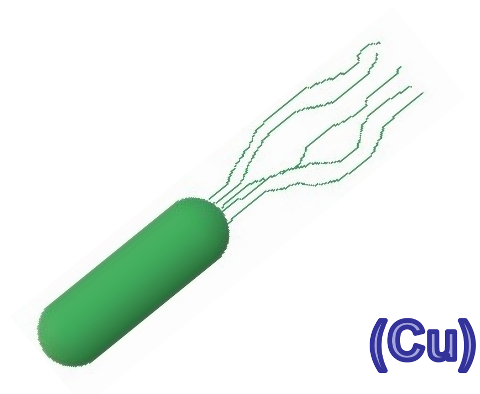


predation, parasitism

e.g. *Trichoderma* spp.



direct toxicity



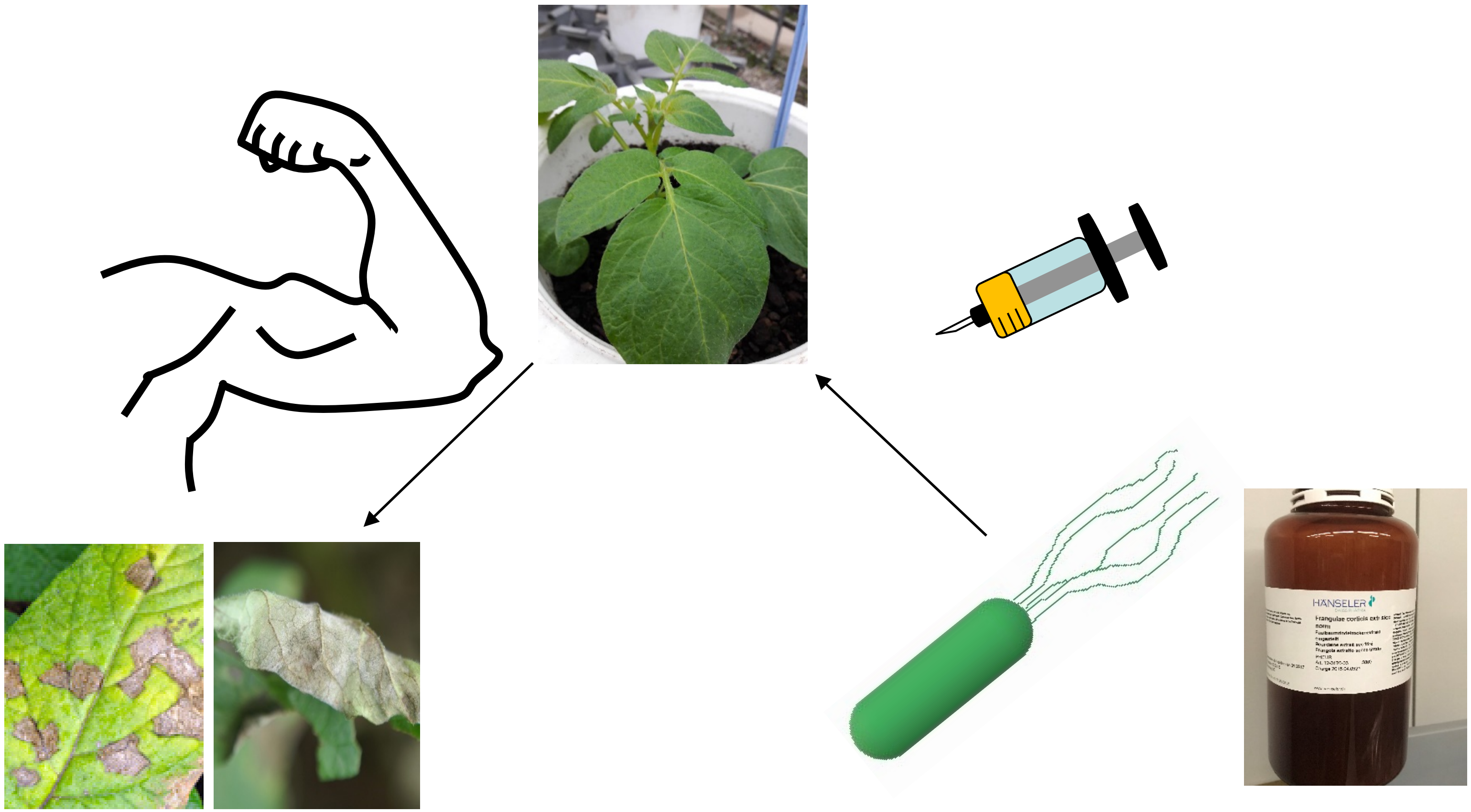
A. solani /P. infestans

Biological (and chemical) plant protection products

Modes of action

- Indirectly by:

Induced resistance



A. solani /P. infestans

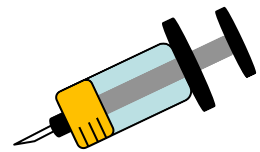
Biological plant protection product

Modes of action

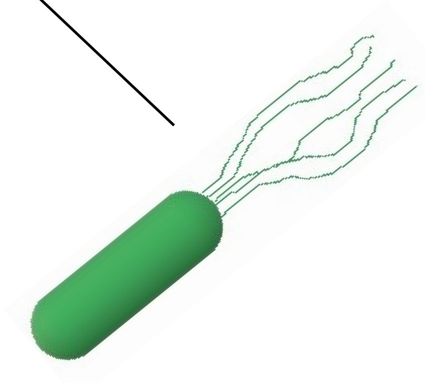
- Indirectly by:

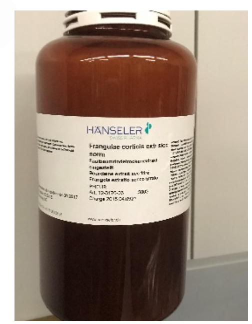
Induced resistance

- Gene-induction of plant pathogenesis related proteins
- callose deposition
- Increased activity of defence related enzymes
- Cell wall lignification



A. *solani /P. infestans*



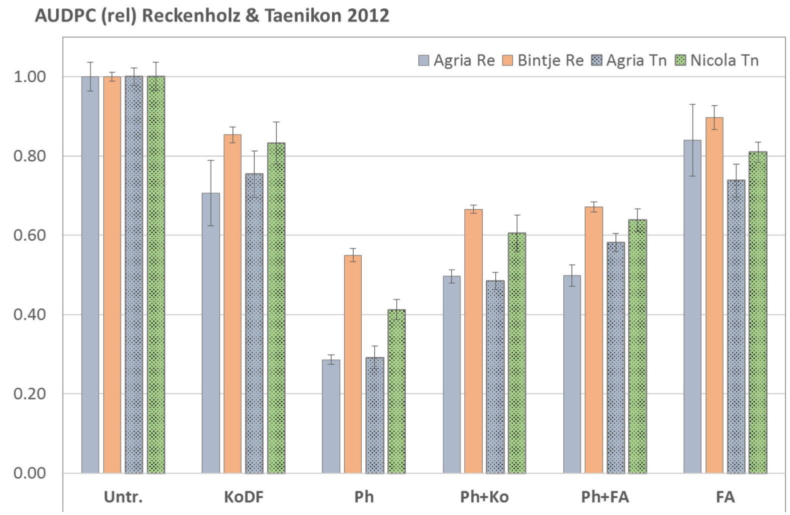


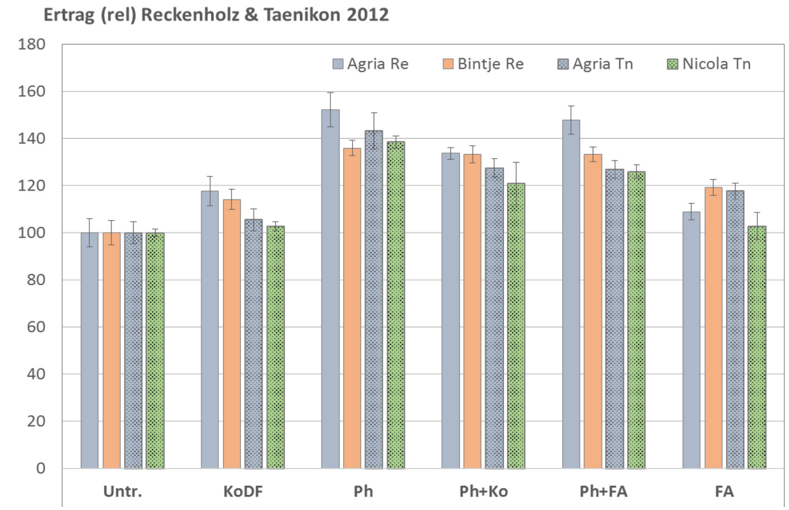
Biological plant protection product

Promising field trials with a plant extract and non-fungicidal inducer

→ Bark of bucktorn *(Frangula alnus)* and Phosfik®

Field trial at Zürich Reckenholz and Tänikon 2012





Untr.: untreated control
KoDF: Kocide DF (300g/ha)(8x)
Ph: Phosfik (8x)

Ph+Ko: Phosfik (4x)+Kocide DF (4x)
Ph+FA: Phosfik (4x) + *F. alnus* (4%) (4x)
FA: 4% *F. alnus* suspension (8x)

F. alnus: mode of action on potatoes not yet confirmed

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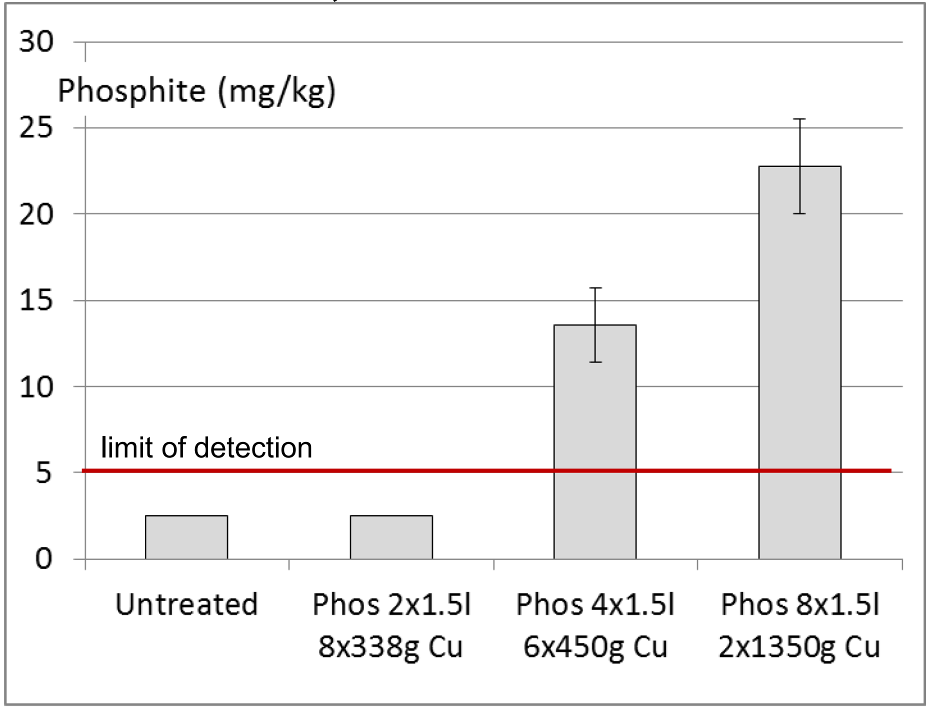
Phosphite residues in potato tubers in relation to the applied Phosfik® amount

Field trials 2013, Reckenholz & Tänikon

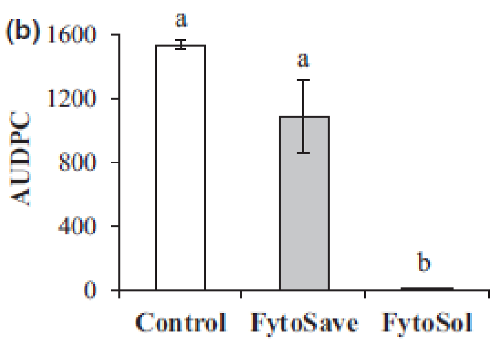


With two applications of Phosfik®, phosphite (PO_3^{3-}) residues were below the limit of detection (5 mg/kg), (EFSA: minimal risk level 20mg/kg)

Forrer et al., 2017, Journal of fungi

FytoSol

- New class of elicitor
- Combination of chitosan oligomers (COS) and pectin-derived oligogalacturonides (OGA): COS-OGA elicitor
- mimic plant interaction with fungi and inform plant cells on both cell wall degradation and pathogen presence
- induces the expression of defense-related genes
- FytoSol appears to be a promising elicitor that may block SA-related potato gene hijacking by *P. infestans* and triggers a still unknown defense pathway.



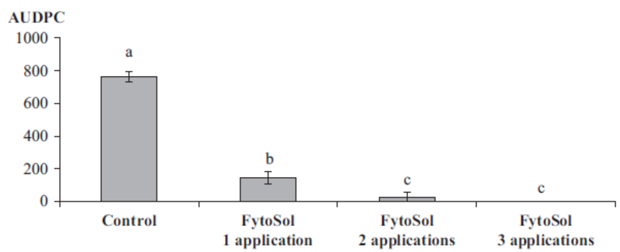


Figure 4 Cumulative effect of FytoSol applications. Area under the disease progression curve (AUDPC) calculated from leaf disease severity followed over 2 weeks after the inoculation of potato plants with *Phytophthora infestans*. Control plants were untreated and FytoSol-treated plants were preventively sprayed either once, twice or three times. Data presented are the means ± standard deviation on eight plants per experimental condition and values with different letters are significantly different (ANOVA and Tukey test, $P < 0.05$).

van Aubel et al., 2018, Plant Pathology

Experiments using the yeast strain H213

Bio-Protect

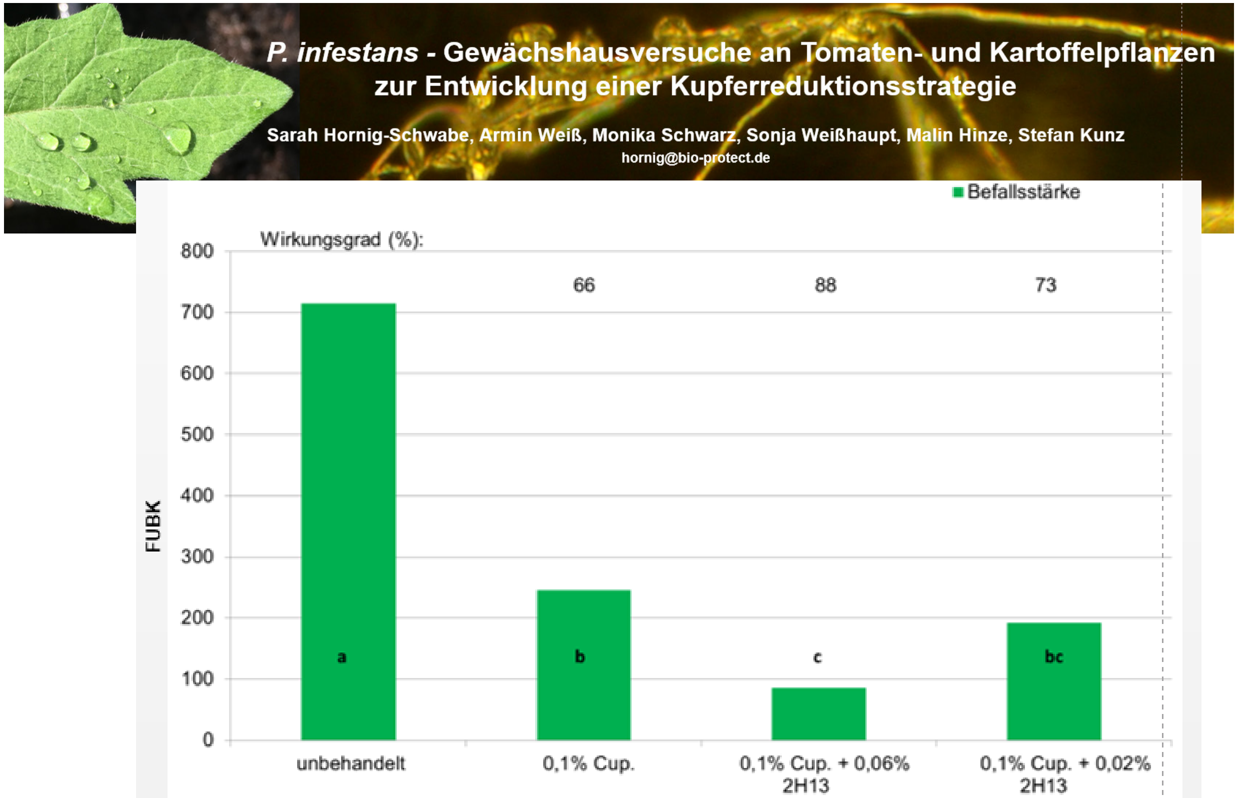


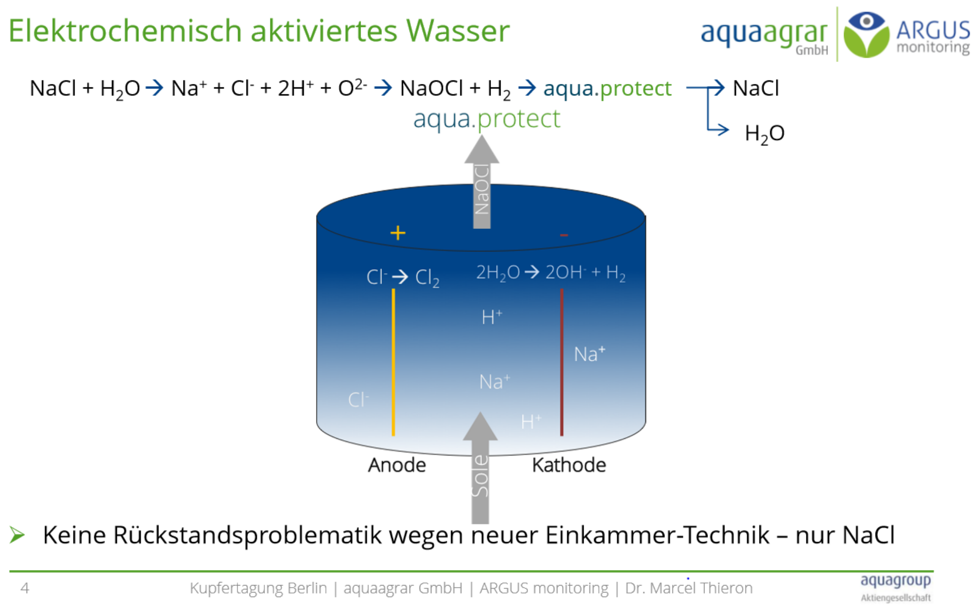
Abb. 2: Fläche unter der Befallskurve (FUBK) von *P. infestans* an Tomatenblättern. *P. infestans* M16: 5E+03 Sporangien/ml. Pflanzen: Hellfrucht Hilmar. 2H13: Charge V9. Cup.: Cuprozin progress. Unterschiedliche Buchstaben innerhalb einer Säulenfarbe zeigen signifikante Unterschiede im Dunn's Multiple Comparison Test ($p<0{,}05$).

A. Weiss (LTZ Augustenberg, Germany) Bio-Protect Gesellschaft für Phytopathologie mbH

Aqua.support

amagrar GmbH

- Application of chlorine-containing water
- after drying NaCl on leaves



Dr. Marcel Thieron, amagrar GmbH

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Direct inhibitory effect on sporangia and zoospores

→ challenge: accurate point of treatment

→ Development of a decision support system

Combination of aqua.support and the *amagrar* DSS
→ up to 50% copper reduction

registration as plant strengther requested in 2018

Experiments with different *Trichoderma* strains against early blight

- Greenhouse and field experiments

Field experiments:
untreated control
chemical reference (multisite fungicide)
different biological treatments:
T. asperellum, T. atroviride,
T.harzianum,
T. hamatum,
TrichoStar®, TrichoMix®,
Serenade® (*B. subtilis*) (spore solutions)

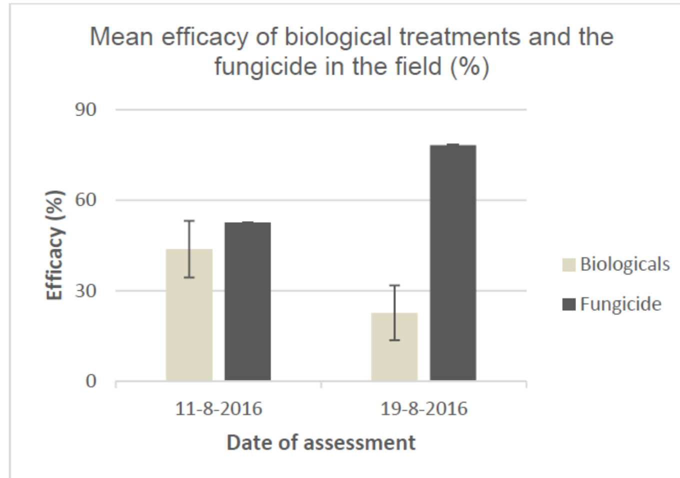
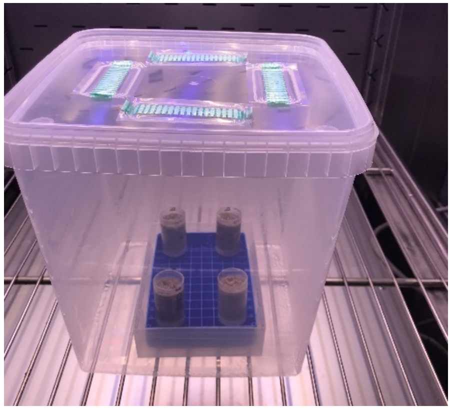


Figure 2. *Mean efficacy of biological treatments and the fungicide in the field (%). For the biologicals, the averages of all efficacies for the two dates were calculated (n=9).*

Information: H. Hausladen, TUM, PhD Nicole Metz

Conclusions

Experimental scale



Lab trials

Pot and/or greenhouse experiments

Field trials

Transition to practice

Conclusions

- Full substitute for copper is unlikely so far

- system approach through combination of preventive, indirect and direct measures:
  - Choice of variety adapted to local conditions
  - Crop rotation
  - Mechanical methods
  - Enhance functional biodiversity
  - Plant protection products/ alternative products
  - Use of DSS and precision agriculture techniques

→ Reduction of the amount of used copper and reduced dependency on copper achieved

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Conclusions and Outlook

- Efforts needed:

- improving formulations of alternatives products

- reduction of survival structures (oospores/plant debris) to reduce primary infection

Foto: S. Jensen, Cornell University, Bugwood.org

Acknowlegement

- Bio-Protect Armin Weiss
- Dr. Annegret Schmitt, JKI
- *amagrar* **GmbH** Dr. Marcel Thieron
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- Dr. Hans Hausladen, technische Uni München
- RG Ecolgcial Plant Protection
- Field group

Thank you for your attention!

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