Soil-borne Pest Management in Grape and Strawberry

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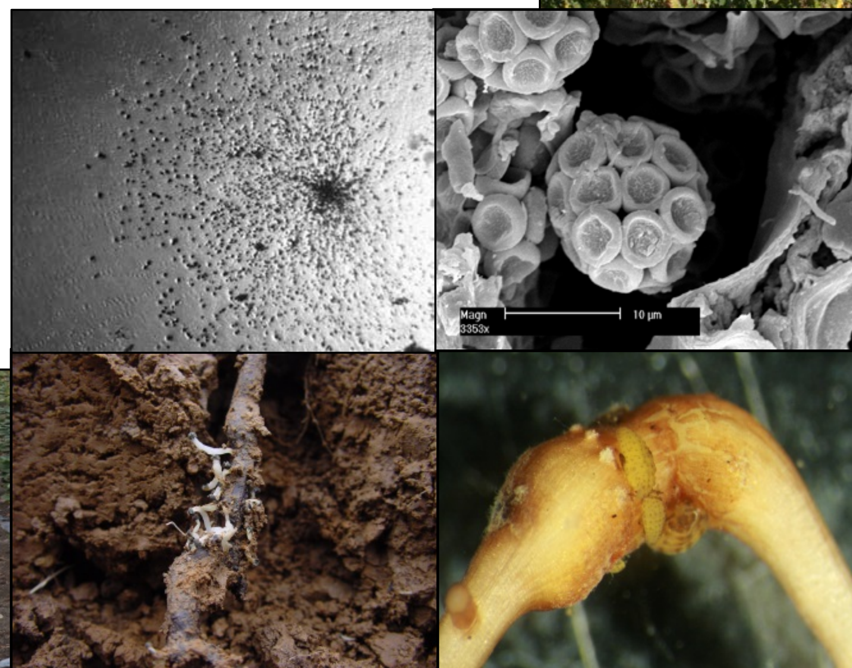

Recent Research and Building a competitive Extension and Research Program at NCSU

Road-Map

- Introduction
- Research and Extension Experience
    - Viticulture in Germany
    - Strawberry Production in California
- Envisioned Program at NC State University
- Project Example
- Conclusions

Introduction

Education

❖ **2005**

Dipl.-Biol. (M.S.) in Biology, Inst. of Zoology, University of Mainz, Germany

In-vitro research on grape root rot (Roesleria subterranea)

❖ **2011**

Dr. rer. nat. (PhD) in Biology, Inst. of Zoology, University of Mainz, Germany

Research on grape root systems and grape phylloxera (Daktulosphaira vitifoliae)

❖ **2011**

Diploma (A.A.) in Economy and Employment Law, University of Hagen, Germany

Introduction

Appointments

- ❖ **2010-2012:**

Research Assistant, University of Geisenheim, Germany

Distribution and control of grape root rot in Germany

- ❖ **2013-2014:**

Post-Doctoral Researcher, University of Florida, USA

Behavior and control of Asian Citrus Psyllid

- ❖ **2015-current:**

Post-Doctoral Researcher, University of California Davis, USA

Integrated fumigation alternatives in CA Strawberry

Introduction

Audience Question

Do you think it is important to manage soil health? (Yes/No)

Introduction - History

Soil-borne Diseases

Insects, Nematodes, Bacteria, Viruses, FUNGI!

- Baker & Cook 1974.

‘Biological Control of plant pathogens’

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tive indicators of vitality. It therefore seems

Selmon A. Waksman 1916.
‘Do fungi life and produce mycelium in the soil?’

Summary.—The fact that Weber's law governs antagonism is explained by a dynamical theory formulated by the writer.

This theory assumes that injury and death result from processes which are inhibited by salt compounds formed by the union of salts with the protoplasm. If these compounds are formed in a surface the amounts will (above a certain limit) be independent of variations in concentration and will depend only on the proportions of the antagonistic salts. From this it results that Weber's law must govern the phenomena of antagonism.

No matter what theory of antagonism we adopt, it is evident that if the antagonistic substances act in a saturated surface antagonism must be governed by Weber's law.

W. J. V. Osterhout

Laboratory of Plant Physiology,
Harvard University

DO FUNGI LIVE AND PRODUCE MYCELIUM IN THE SOIL?

The recent investigations on soil microorganisms have revealed the fact that fungi are found in soils in very large numbers sometimes reaching as high as 1,000,000 per gram of soil. These numbers are found by diluting the soil and then plating out only a small portion of a gram. The colonies developing on the plates represent the spores or pieces of mycelium found in the soil. But this does not tell us about the actual active life of the fungi in the soil. However large the numbers that are found, it remains to investigate whether those organisms existed in the soil only in

the form of spores, which were brought in by

the Bureau of Chemistry in Washington, a direct isolation of fungi producing mycelium in the soil was attempted. Soil samples taken at different depths, under absolutely sterile conditions, were brought into the laboratory; lumps of soil, about 1 cm. in diameter, were transferred with sterile forceps into sterile plates containing cooled sterile Czapek's solution agar. The lump was placed carefully in the center of the dish, which was immediately covered and allowed to incubate for 24 hours at 20–22° C. After this period mycelium was found to radiate out of the lump of soil into the medium. This mycelium was now transferred with a sterile platinum loop to sterile slants of Czapek's agar, care being taken to select the tips of the hyphæ so as not to bring the loop in too close contact with the soil. The agar slants containing the transferred portions of mycelium were allowed to incubate till the organisms had developed well and were ready for study. The organisms thus isolated were not always pure. They had to be often separated from one another; this was accomplished

Disease suppressive soils

[1] The methods of isolation and establishment of pedigree cultures, as well as the details of the work, formulæ for media used and identification of organisms will be published later.

- Pace et al. 1991: J. Bact. 173(14):4371-4378.
  16S community structure of picoplankton
- Poinar et al. 2006: Science 311(5759):392-394.
  454 Pyrosequencing (Mammoth DNA)
- Fierer et al. 2012: PNAS 109(52): 21390-21395.
  Illumina HiSeq for metagenomic analysis of desert soils

High Throughput Technology:
Metagenomics

< 10 years: Illumina HiSeq
Comparatively few studies target ITS regions

Research and Extension Experience

Experience – Viticulture

Disease Symptoms – non-specific

Heppenheim (Pfalz), Germany, 2010

Geisenheim (Rheingau), Germany, 2010

Experience – Viticulture

Soil-borne Grape Diseases

Fungi:

- *Fusarium oxysporum* f.sp. herbemontis ('Fusarium wilt')
- *Cylindrocarpon destructans* ('Black foot disease')
- *Pythium* species
- *Phytophtera* species
- *Phaeoacremonium* species ('Petri Disease')
- *Phaeomonilla chlamydospora* (assoc. with 'ESCA')
- *Rosellinia nectarix*
- *Armillaria* species
- ***Roesleria subterranea***

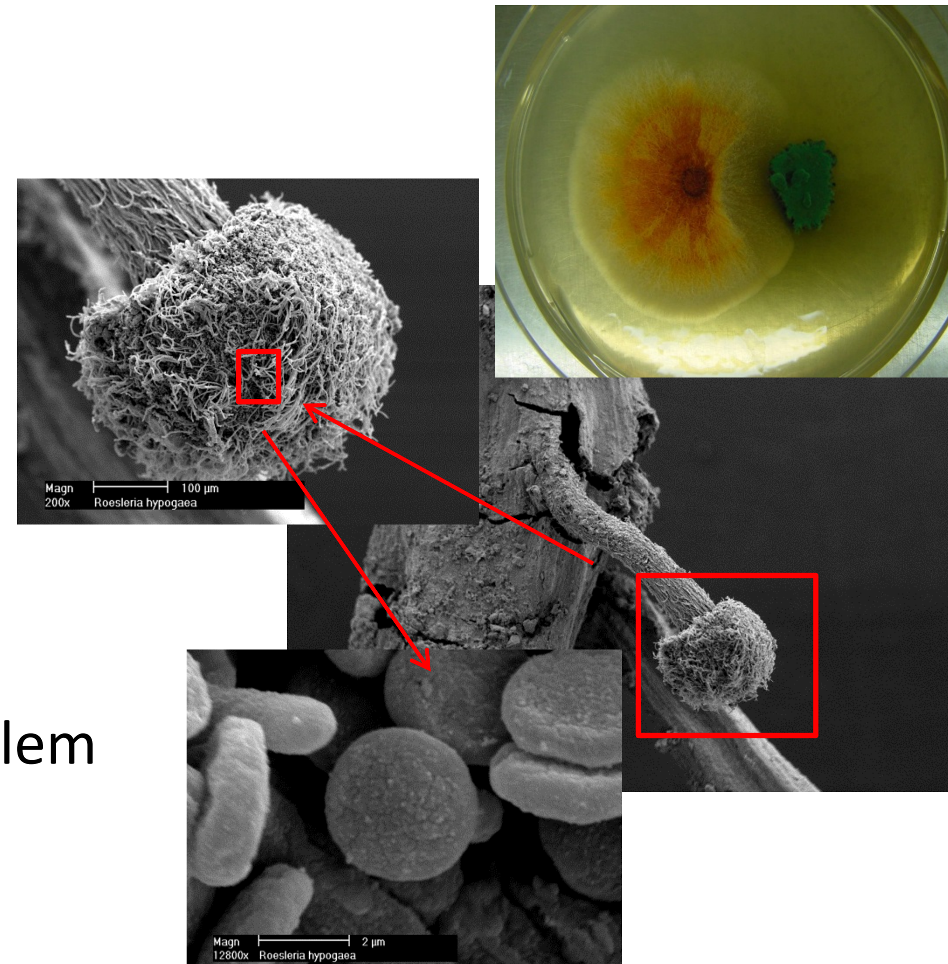
} **'Grape Root Rot'**

Insects:

- *Fidia* species ('Grape Root Worm')
- *Vitacea polistiformes* ('Grape Root Borer')
- ***Daktulosphaira vitifoliae* ('Grape Phylloxera')**

Experience – Viticulture Extension

Grape Root Rot (*Roesleria subterranea*)



- Infects healthy roots: plugs Xylem
- Die back and dead of plant
- Saprophyte and parasite

Experience – Viticulture Extension

Grape Root Rot – Aims

- Distribution of pathogen in Germany
- Develop Identification Guidelines
- Transfer information to grower

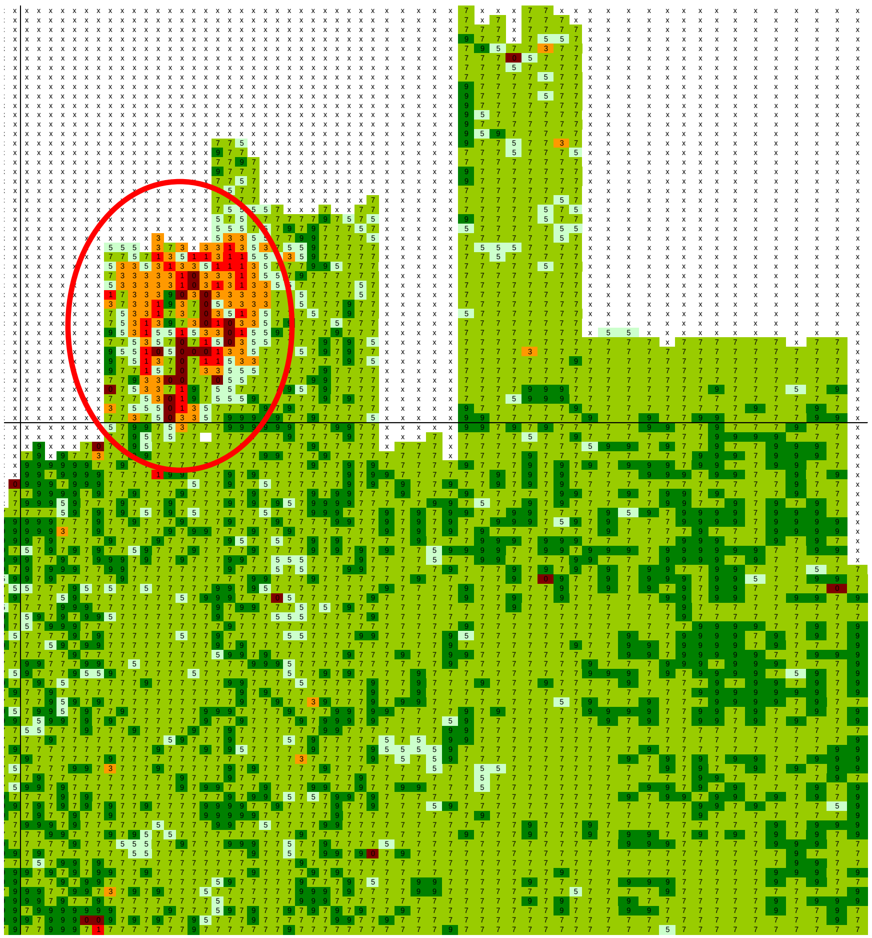
HESSEN

Hochschule Geisenheim University

universität innsbruck

Experience – Viticulture Extension

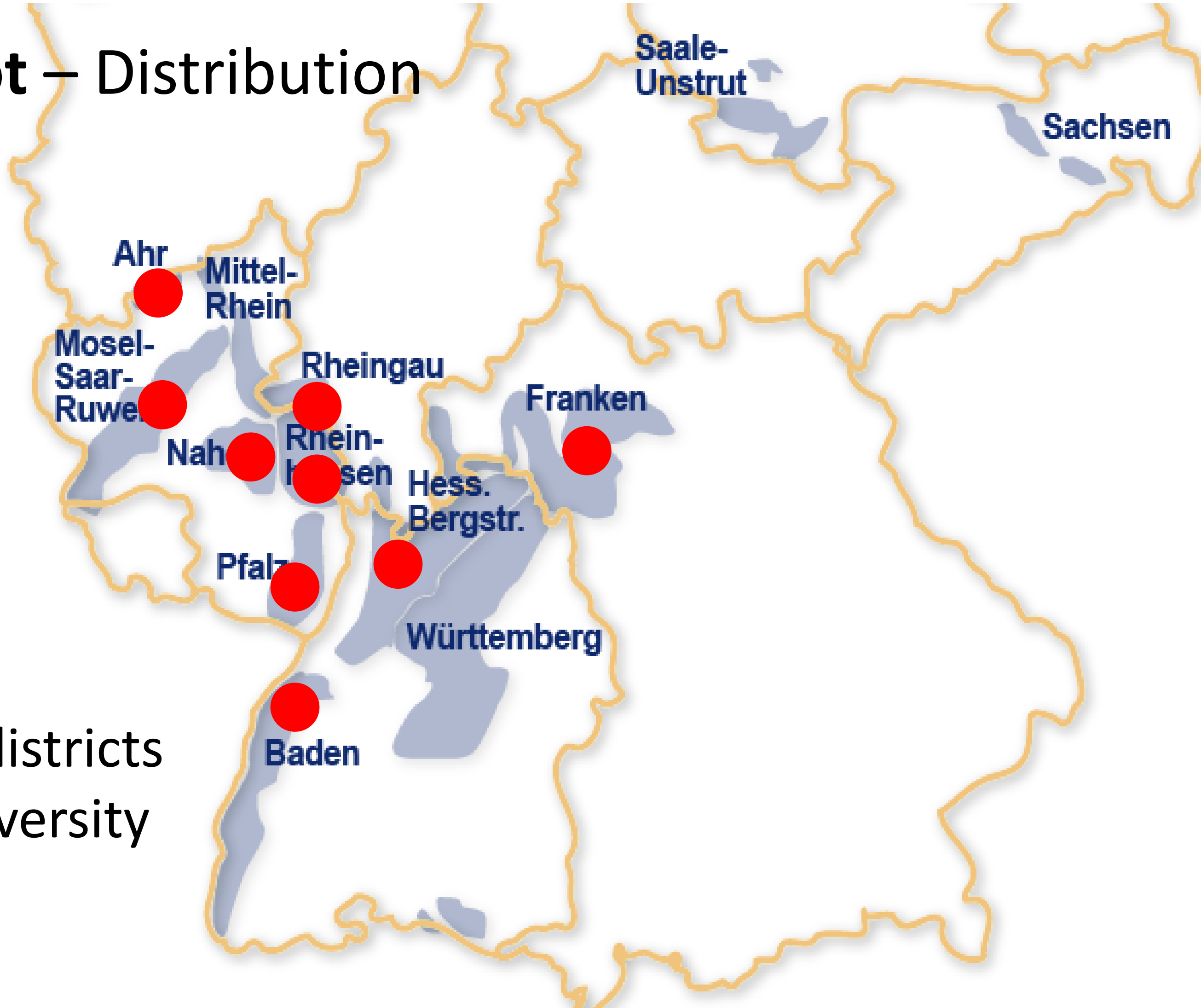
Grape Root Rot – Damages



Wiltingen (Mosel), Germany, 2008

Experience – Viticulture Extension

Grape Root Rot – Distribution



- 2010 and 2011
- > 50 fields / 9 districts
- Samples in University Herbarium

Hoffmann et al. (2012), German Wine Grower Magazine

Experience – Viticulture Extension

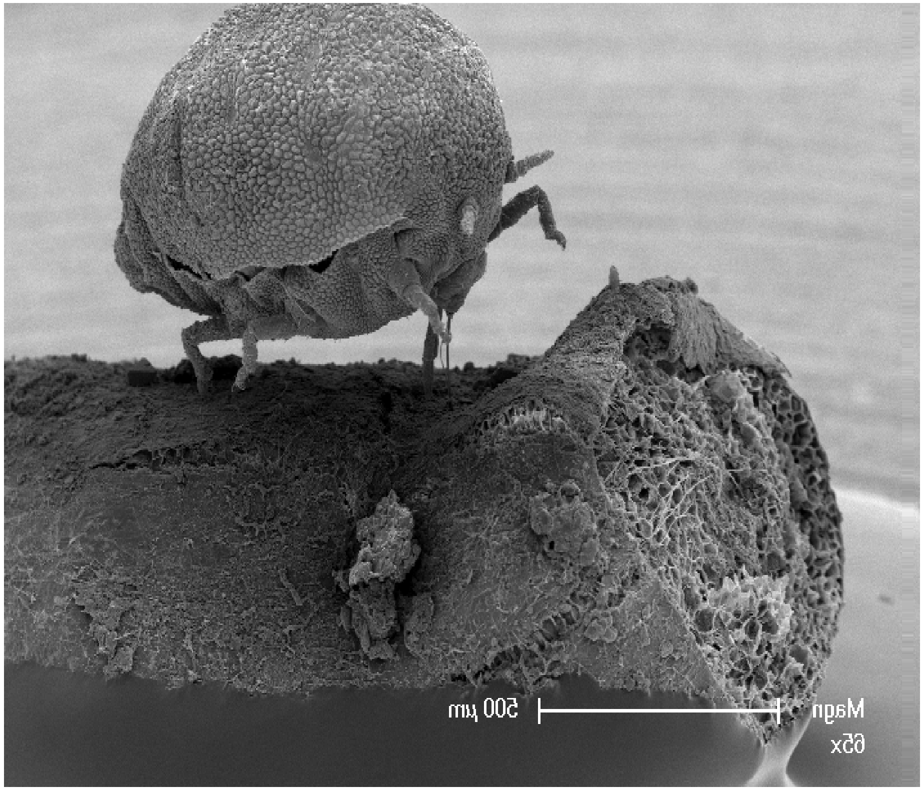
Grape Root Rot – Outreach 2010-2011

- Identification and Containment Guidelines (online, print, publication)
- Grower Phone Hotline at Univ. Geisenheim
- *Collaboration with Univ. Innsbruck: Genetic Detection Method*

Hoffmann (2012), *Online publication*, Hessian Regional Board Homepage
Hoffmann et al. (2012), *German Wine Magazine* 9/2012: 16-19.

Experience – Viticulture Research

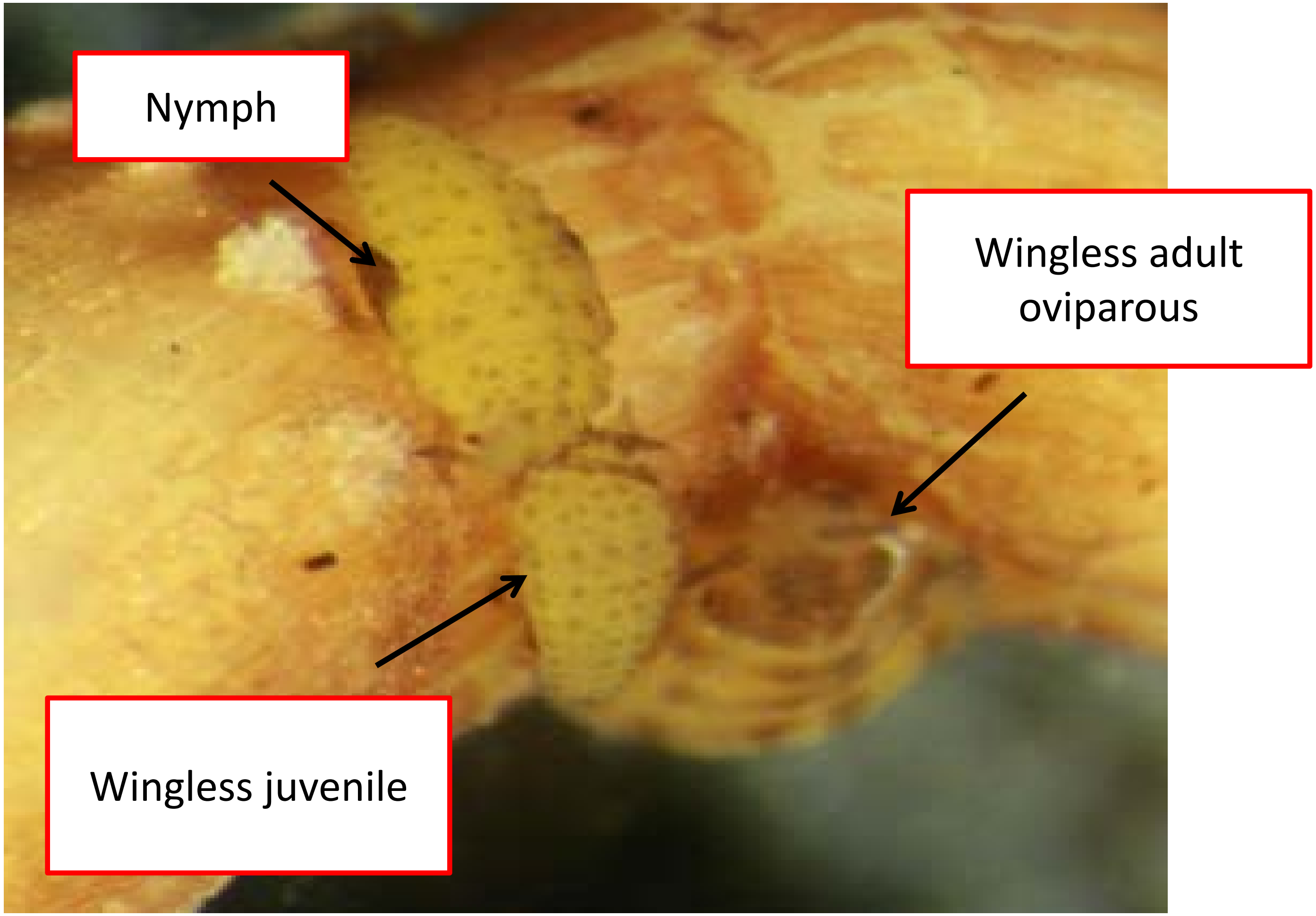
Grape Phylloxera (*Daktulosphaira vitifoliae*)



- Aphid
- Host-specific to *Vitis spec.*
- Native North America
- Root and Foliar Pest

Experience – Viticulture Research

Grape Phylloxera (*Daktulosphaira vitifoliae*)



Experience – Viticulture Research

Grape Phylloxera – Aims

Investigation of Population Dynamics

Investigate root system and population specific patterns to describe life-cyle dynamics of root feeding grape phylloxera in mature vineyards

Investigation of Suppressive Soils

Investigate soils for their suppressive effects on die-back symptoms related to root feeding grape phylloxera

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

DFG

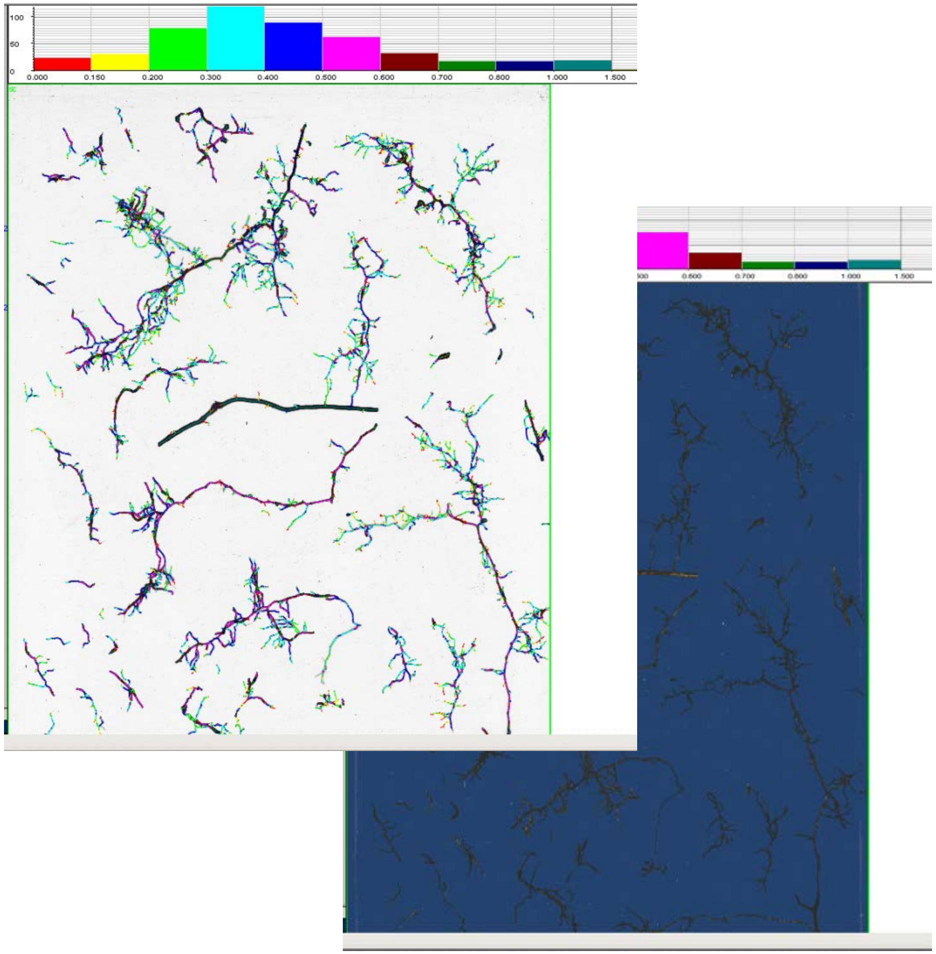
Hochschule Geisenheim University

universität innsbruck

Experience – Viticulture Research

Grape Phylloxera – Methods

- Field study with involving different rootstocks (>three seasons)
- Frequent assessment of >60 root system and population paramenters
- Statistical analysis to identify frequent patterns based on PCA and GLM



Hoffmann et al.,2011, *Acta Hort.* 904:101-110.
Hoffmann et al. 2015, *Vitis* 54:137-142.
Hoffmann et al. 2016, *Aus. J. Grape and Wine Res.* 22: 271-278.

Experience – Viticulture Research

Grape Phylloxera – Population Dynamics

Three stages of population dynamics:

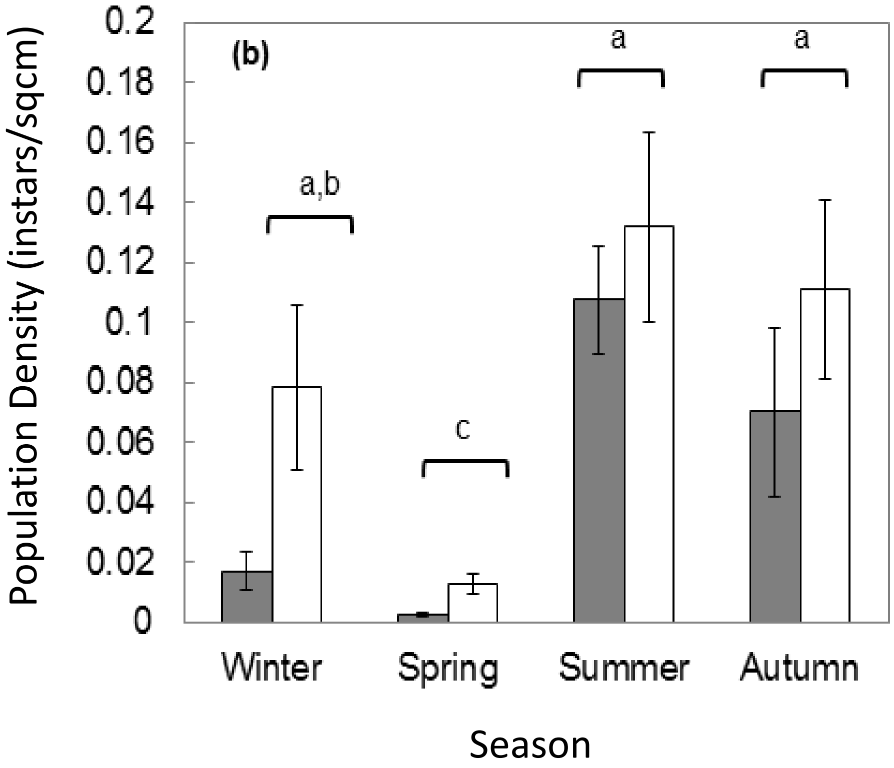
- Summer to Fall: Reproduction
- Fall to Winter: Overwintering
- Winter to Spring: Depletion

	Population structure	Population density	Crowding	Root gall pigmentation
Reproduction	Diverse	High	Low	Predominantly light
Overwintering	Not diverse	High – medium	High	Predominantly dark
Declining	Not diverse	Low	Low	Predominantly dark

Hoffmann et al. 2016, *Aus. J. Grape and Wine Res*. 22: 271-278.

Experience – Viticulture Research

Grape Phylloxera – Population Dynamics



Hoffmann et al.,2011, Acta Hort. 904:101-110.
Hoffmann et al. 2015, Vitis 54, 137-142.
Hoffmann et al. 2016, Aus. J. Grape and Wine Res. 22: 271-278.

Experience – Viticulture Research

Grape Phylloxera – Aims

Investigation of Population Dynamics

Investigate root system and population specific patterns to describe life-cyle dynamics of root feeding grape phylloxera in mature vineyards (*PhD*)

Investigation of Suppressive Soils

Investigate soils for their suppressive effects on die-back symptoms related to root feeding grape phylloxera (*long-term collaborative effort*)

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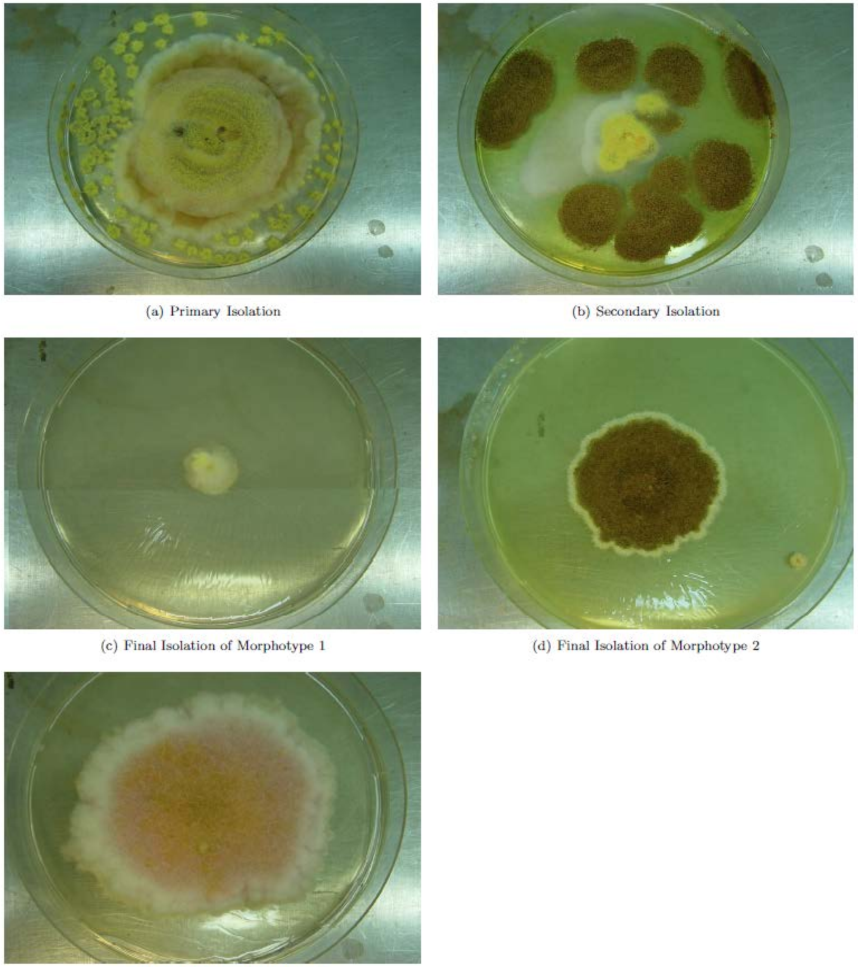
Experience – Viticulture Research

Grape Phylloxera – Methods

- Field study involving four mature vineyards
- Assessment of soil and endophyte community via isolations
- Classification of fungi based on literature research



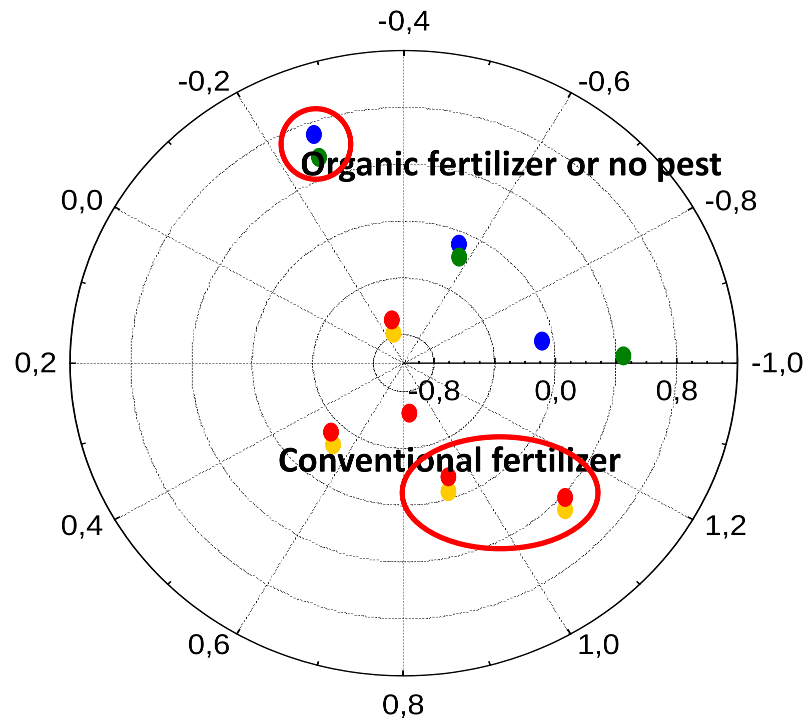
(a) Primary Isolation
(b) Secondary Isolation
(c) Final Isolation of Morphotype 1
(d) Final Isolation of Morphotype 2
(e) Final Isolation of Morphotype 3

Experience – Viticulture Research

Grape Phylloxera – Fungal Community: Species Composition

Field Sites:

Color	Management	Phylloxera	Growth
●	Conventional	Not present	No depression
●	Organic	Present	No depression
●	Conventional	Present	No depression
●	Conventional	Present	Depression



Based on isolations and classification

Huber, Hoffmann et al. 2009, *Acta Hort* 816: 41-51.

Experience – Viticulture Research

Grape Phylloxera – Conclusions

Damages in grafted vineyards are not always related to grape phylloxera *per se*, but to also soil microbial community!

Overwintering capacity of grape phylloxera on roots depends on root stock variety !

Huber, Hoffmann et al. 2009, *Acta Hort* 816: 41-51.
Hoffmann et al.,2011, *Acta Hort.* 904:101-110.
Hoffmann et al. 2015, *Vitis* 54:137-142.
Hoffmann et al. 2016, *Aus. J. Grape and Wine Res.* 22: 271-278.

Experience – California Strawberry

California – Production

Watsonville/Salinas

Santa Maria

Oxnard

Experience – California Strawberry

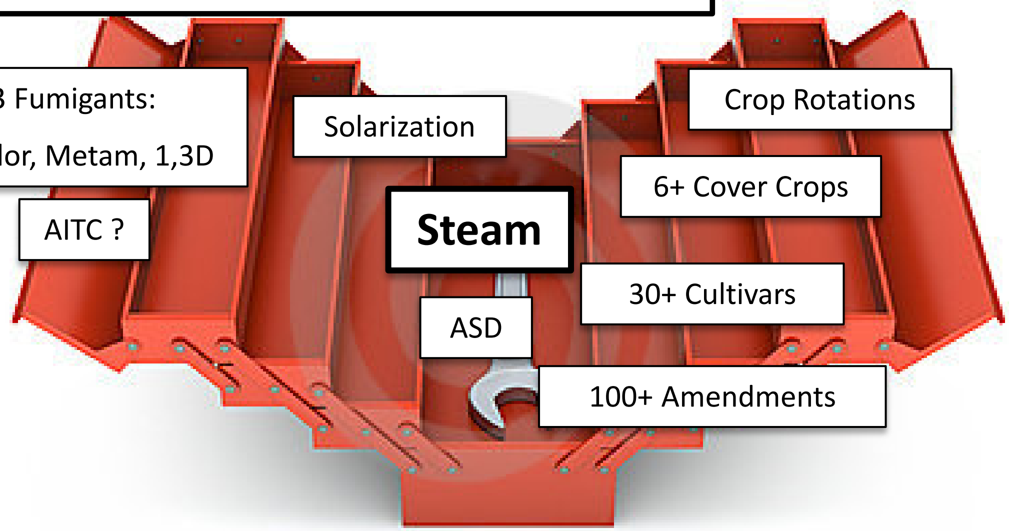
California – Methyl Bromide Alternatives?

- Buffer-zones
- Fumigant Regulations
- Fumigant Reduction
- Organic Production

Experience – California Strawberry

California – Tools in the Toolbox

Disinfestation



Microbial and SOM management

Experience – California Strawberry

Soil Disinfestation with Steam – Aims

- Proof of Concept
- Can Steam Application be Improved?
- Soil Microbial Communities?

Experience – California Strawberry

Steam – Methods

- 2011 – 2015: **Prototype 1:** Proof of Concept
- 2015 – current: **Prototype 2:** Improvement
- 2015 – current: Integration: Improvement
- 2016: MiSeq 16S analysis of microbial community in Rhizosphere of a test plot in Watsonville, CA (*ongoing*)

Experience – California Strawberry

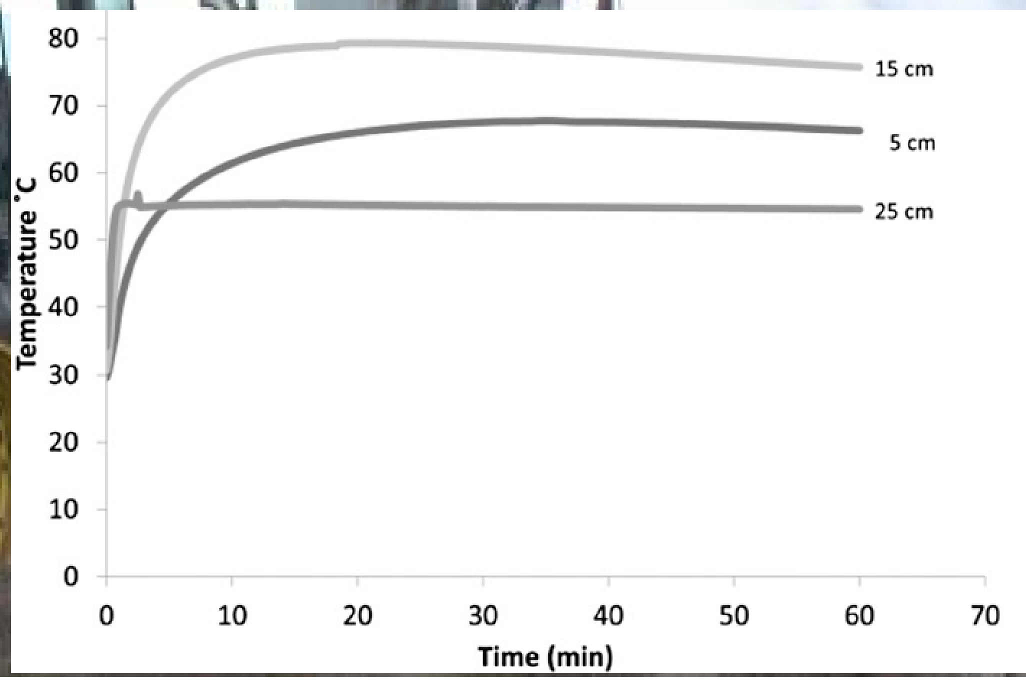
Prototype I (2011-2015)

Speech: **31 – 51 hours/acre**

Propane consumption: **1500 – 2500 gal/acre**

Water consumption: **10.000 – 17.000 gal/acre**

Costs: **$3.500 - 4.500 / acre**

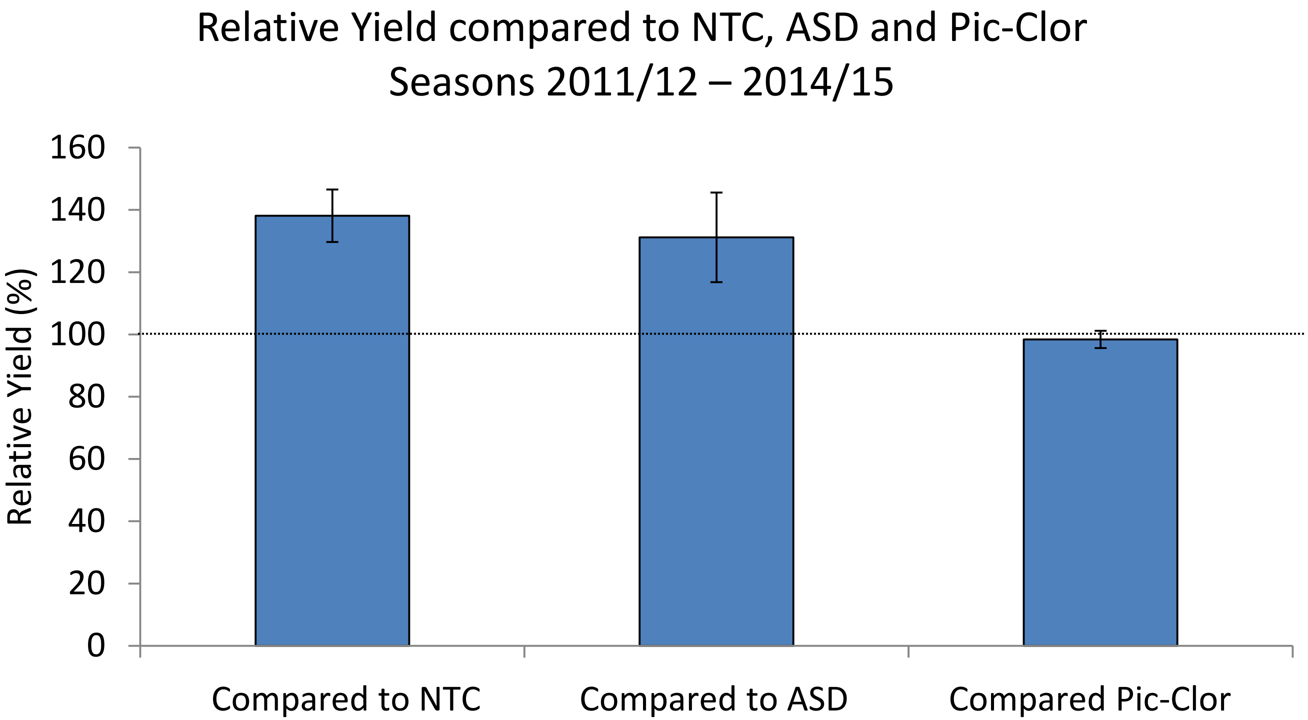


Experience – California Strawberry

Steam – Visuals

Experience – California Strawberry

Steam Prototype 1 – Yields



Hoffmann et al. *(in prep)*

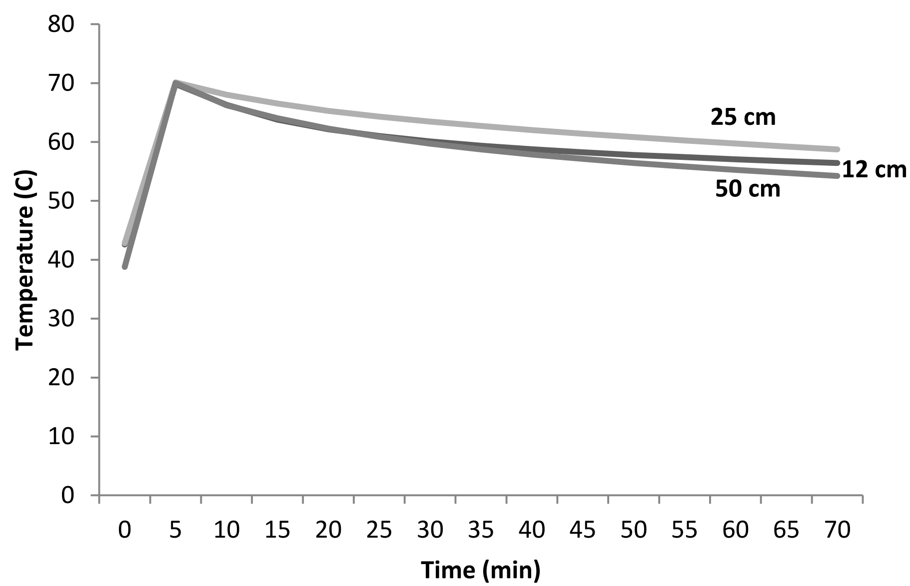
Prototype II (2015-current)

Speed: **15 hours/acre**

Propane consumption: **1000 gal/acre**

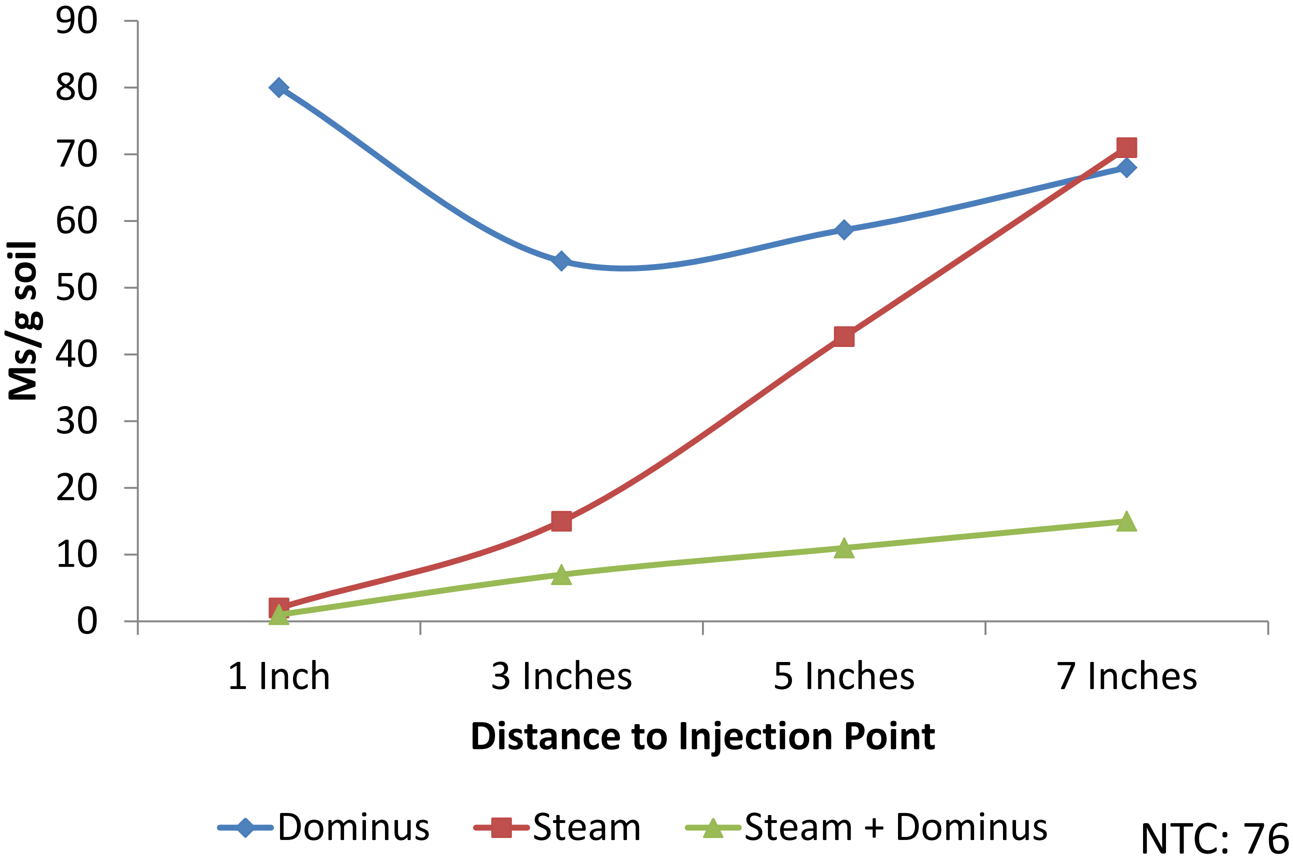
Water consumption: **10.000 gal/acre**

Costs: **$2.500 / acre**



Experience – California Strawberry

Steam + Allyl Isothiocyanate – *Verticillium dahliae* control



NTC: 76 ± 8 MS/g soil

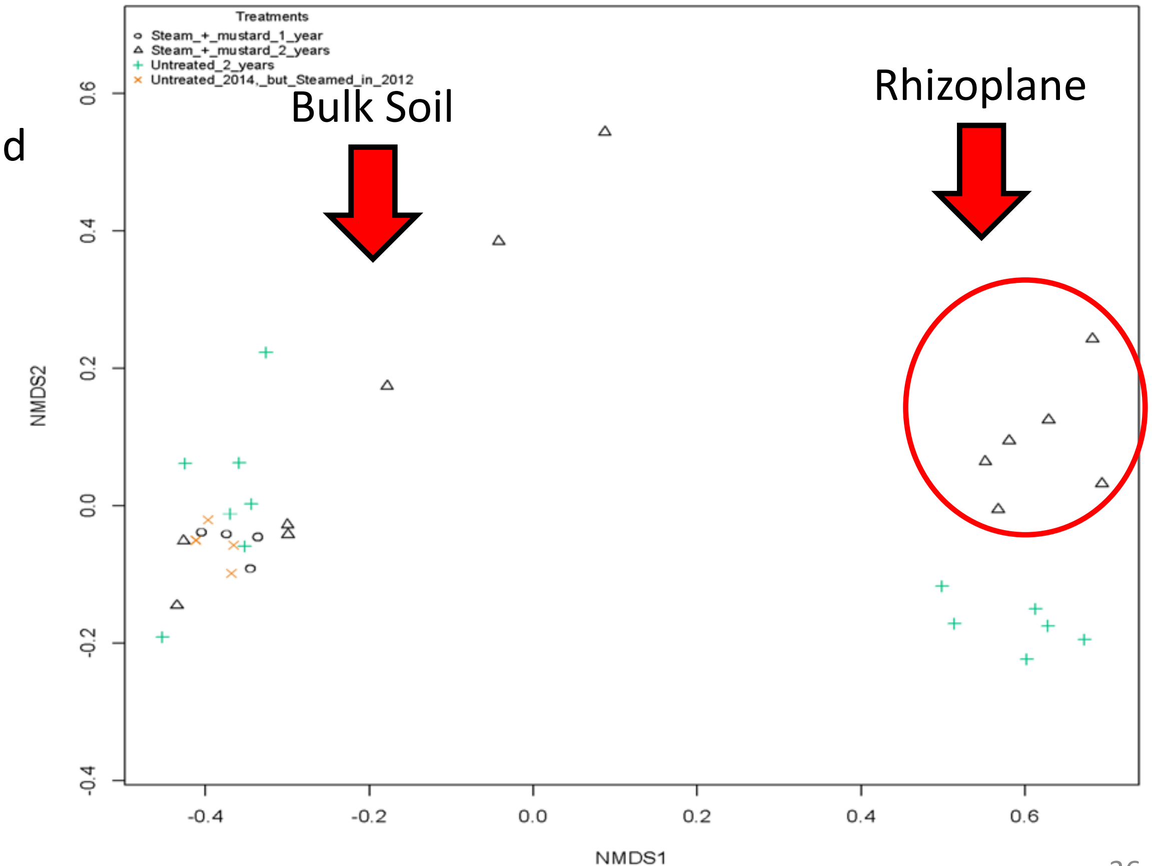
Hoffmann et al. *(in prep)*

Experience – California Strawberry

Steam Prototype 1 – Microbial Community (16S MiSeq)

Rhizoplane associated included *Novosphingobium, Sphingomonas, Phenylbacterium*

Bulk soil associated included *Kaistobacter, Arthrobacter, Thermomonas*



Hoffmann et al. *(in prep)*

Experience – California Strawberry

Steam – Conclusions

- Proof of concept over four seasons of steam applications with Prototype 1
- Improvement of Steam efficacy by engineering Prototype 2 over the course of 2016
- Improvement of Steam by combining with Allyl Isothiocyanate (AITC)
- Steam seems to affect bacterial soil community

Envisioned Program at NC State University

Small Fruit Extension and Research

- **Personal Guidelines**
- **Goals**
- **Potential Collaborations**
- **Potential Funding Sources**
- **Example:** Manage soil-borne biotic stress factors in berry fruits

Small Fruit Extension and Research

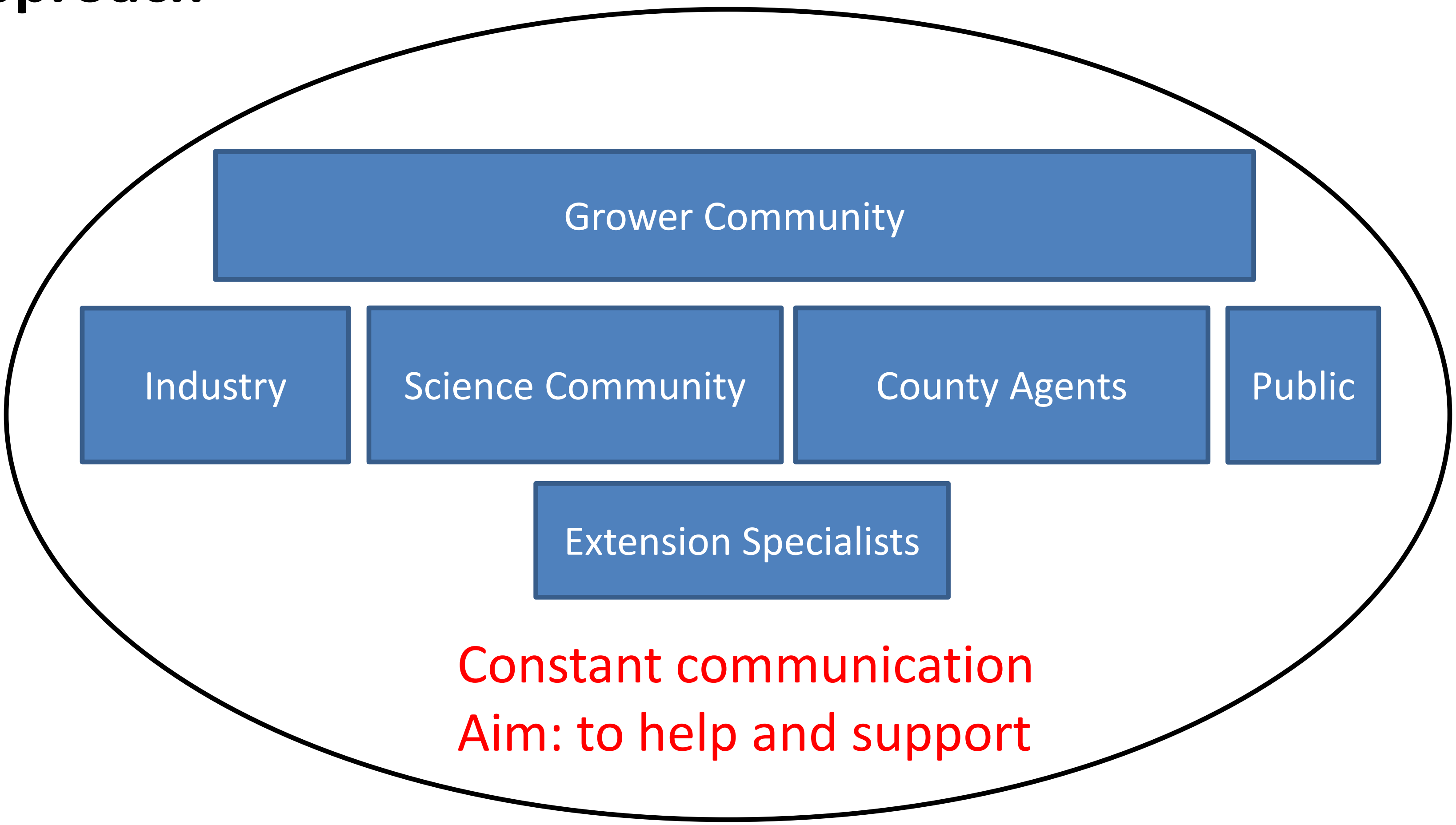
Core Principles

- Build **trust** in community
- Bring **value** to pubic
- Team: Together Everyone Achieves More
- Communicate, collaborate, network

"Life's most persistent and urgent question is: What are you doing for others?"
Martin Luther King Jr.

Small Fruit Extension and Research

Approach



Small Fruit Extension and Research

Main Goals

- Short – Term

Network! Establish grower and science collaborations

Explore need and funding sources

Integration into team and existing structures at NCSU (e.g. NSF CIPM, PSMCC, CIFR, etc.)

Establish a sound extension and research program

Small Fruit Extension and Research

Main Goals

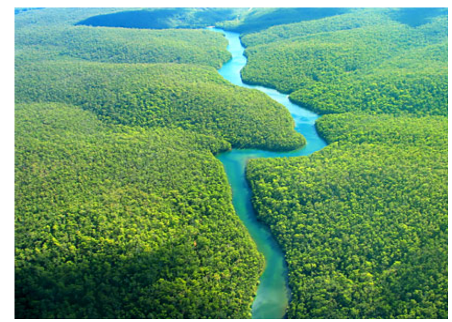
- Long – Term

Develop a national and international recognized extension and research program for small fruits in NC, known for bringing constant value to community.

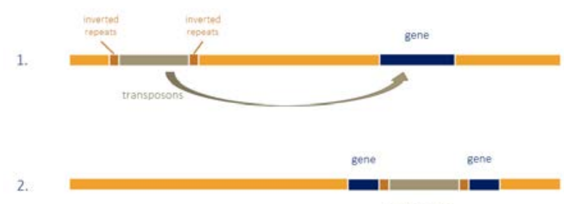
Small Fruit Extension and Research

Big Questions

- ❖ Can we bring value to Small Fruit Farming with new technologies?



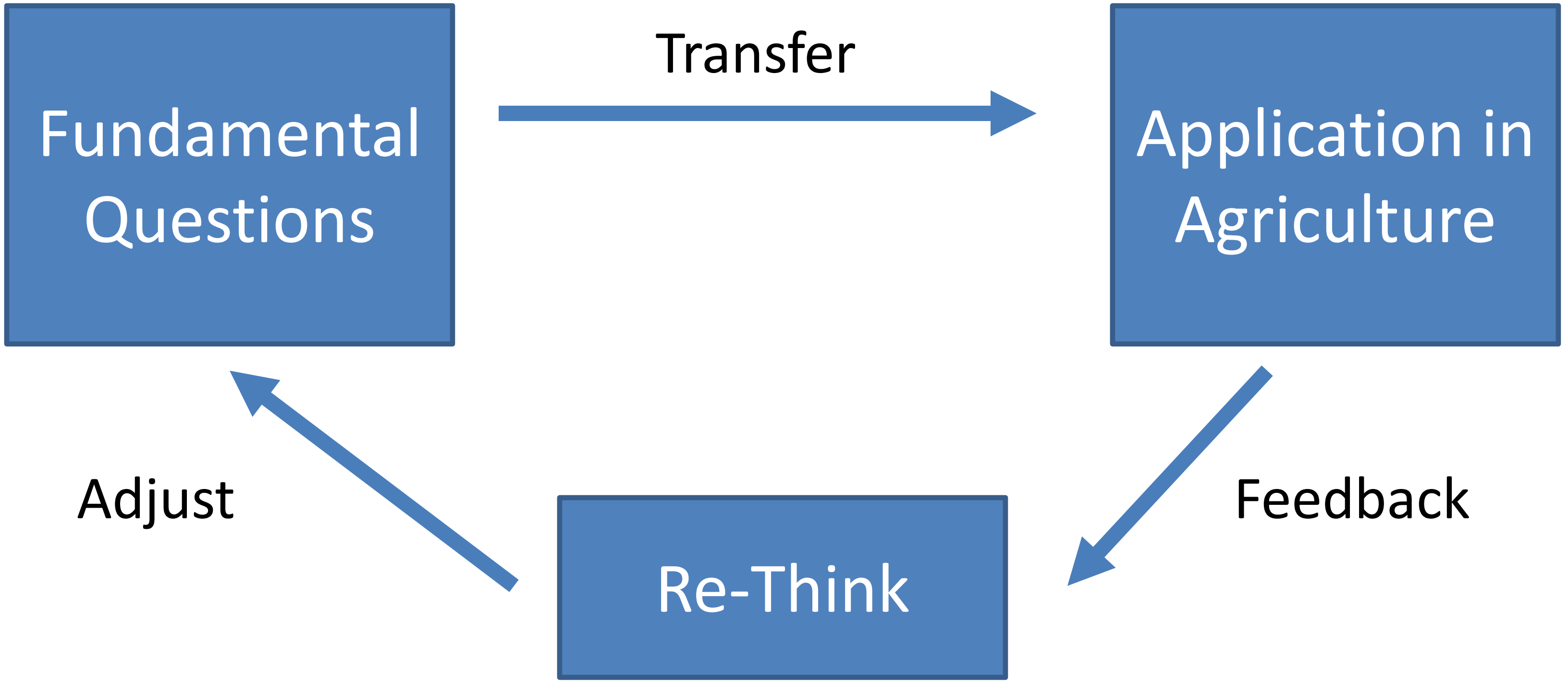
- ❖ Would understanding the productivity and self regulating mechanisms of ecosystems bring advantages in agriculture?



- ❖ Would understanding of limits, plasticity and ecosystem functions of pest organisms would help in management?

Small Fruit Extension and Research

Big Questions – What has that to do with Extension?



Small Fruit Extension and Research

Outreach and Education Program

❖ Interactive:

State-Wide Seminars, Work-Shops, Field-Days, Annual Meetings
Outcome Measures

❖ State of the Art:

Video Production, Social Media Channel, Homepage, Extension Publications

❖ Bi-lingual: *Collaboration: Language Specialist*

Small Fruit Extension and Research

Extension Program

❖ Investigating Locally Adapted Management Systems

Cash-flow analysis for local farm systems

Economic models to support scientific direction and funding rational

Local Weed and Disease Management

❖ Supporting Disease, Pest and Weed Management

Up-to Date Disease Diagnostic, Management and Prediction Tools

Install Raspberry Pi2 Weather Station in Vineyards

Small Fruit Extension and Research

Research Program

❖ Integrating New Technology into Small Fruit Farming

Integrating Substance Technology in Grape Frost Management

Animation, Camera and Robotic Technique for Strawberry Harvester

Battery and Sustainable Energy Technique for Strawberry Cooling Systems

❖ Investigating Sustainable Soil Management Strategies

Integrated Soil Health Management Systems

Precision Soil Disinfestation

Integrating Engineering, Breeding, Pest Management, Farming

Small Fruit Extension and Research

Program – Feedback Loop

- Investigate impact of management systems, varieties etc. on fruit quality, wine quality and net-revenues
- Outreach Program
- Interactions, Networking, Meeting

Small Fruit Extension and Research

Collaboration

NC STATE UNIVERSITY

Small Fruit Extension and Research

Funding

- NC Strawberry Commission
- CA Strawberry Commission (Harvester?)
- NC Specialty Crop (Frost Management, Harvester)
- NC Grape and Wine Organization
- Southern Small Fruit Consortium
- Industry (Robotics, Soil Management, Disease Management)
- Science Crowd Funding
- PhD and Post-Doc Fellowships
- USDA MB Transition, USDA Organic Farming, USDA-SCRI etc.
- IR-4 Programs
- Later probably: NSF (Robotics, Ecosystem)

Small Fruit Extension and Research

Example – Manage soil-borne biotic stress factors in berry fruits

Rational:

- Since MB fade-out: current fumigants less effective.
- Expected increased restrictions on fumigant-use in U.S.
- Fumigants can not be used in organic agriculture and buffer-zones.

Small Fruit Extension and Research

Example – Manage soil-borne biotic stress factors in berry fruits

Overall Proposal Aim:

Develop locally adapted soil-borne pest and weed management systems which lead to sustainable increased revenues in conventional and organic small fruit farming

Small Fruit Extension and Research

Example – Manage soil-borne biotic stress factors in berry fruits

Target Crops:

- Strawberry: annual
- Raspberry/Blackberry: perennial
- Grapes: perennial: replant and new plantings

Small Fruit Extension and Research

Example – Manage soil-borne biotic stress factors in berry fruits

Proposal Objectives:

Phase 1 (Year 1-3)

(1) Develop rapid soil borne disease diagnostic tools
(2) Develop precision fumigation approaches
(3) Investigate integrated fumigant- and non-fumigant systems in conventional and organic farm systems

Small Fruit Extension and Research

Example – Manage soil-borne biotic stress factors in berry fruits

Proposal Objectives:

Small Fruit Extension and Research

Example – Manage soil-borne biotic stress factors in berry fruits

Proposal Timeline:

Year 1 -3

Phase 1
(1) Diagnostics
(2) Precision Management
(3) Integrated Systems

Year 3-5

Phase 2
(1) Transfer
(2) Local adaption

Breeding

Outreach, Economy, Communication

Small Fruit Extension and Research

Example – Manage soil-borne biotic stress factors in berry fruits

Potential Collaborations:

Small Fruit Extension and Research

Example – Manage soil-borne biotic stress factors in berry fruits

Proposal Funding Source:

Conclusions

Summary

- Collaborative Approach
- Multidisciplinary
- Integrative

Conclusions

Audience Question

Do you think it is important to manage soil health? (Yes/No)

Funding & Collaborations

UC DAVIS
UNIVERSITY OF CALIFORNIA

Hochschule Geisenheim University

universität innsbruck

BOKU
University of Natural Resources and Life Sciences, Vienna

JG|U
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

UF UNIVERSITY of FLORIDA
IFAS

California Environmental Protection Agency
dpr Department of Pesticide Regulation

CRDF

VALLEY FABRICATION

California STRAWBERRY COMMISSION

TriCal INC.

USDA

HESSEN

DFG

Driscoll's
ONLY THE FINEST BERRIES

PROPANE education & research COUNCIL

gti

REITER AFFILIATED COMPANIES

University of California
Division of Agriculture and Natural Resources

Johnson

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Mike Mellano, Mellano-Flowers, Oceanside, CA;
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Researchers and collaborators:
Dr. Lars Huber, SCC GmbH, Bad Kreuznach, Germany
Matthias Porten, DLR Bernkastel-Kues, Germany
Prof. Dr. Ernst Ruehl, Geisenheim University, Germany
Prof. Dr. Gerhard Eisenbeis, Mainz University, Germany
Dr. P.D. Martin Kirchmair, Innsbruck University, Austria
Dr. Mag. Sigrid Neuhauser, Innsbruck University, Austria
Prof. Dr. Astrid Forneck, BOKU, Vienna, Austria
Dr. Heather Kingdom-Gibbard, United Kingdom
Prof. Dr. Kirsten Pelz-Stelinski, University of Florida, FL
Prof. Dr. Xavier Martini, University of Florida, FL
Dr. Monique Coy, Pioneer, IA
Dan Hodel, Johnson Gas, IA
Dr. Calum Russell, Novozymes, NC
Dr. Steven Fennimore, University of California Davis, CA
Dr. Husein Ajwa, University of California Davis, CA
Dr. Tom Miller, University of California Davis, CA
Dr. Jenny Broome, Driscoll's, CA
Alexandra Barbella, Driscoll's, CA
Dr. Ian Greene, Ramco, CA
Nathan Dorn, RAC, CA
Dr. Frank Martin, UDSA-ARS, CA
Dr. Eric Brennan, USDA-ARS, CA
Dr. Mike Stanghellini, TriCal Inc., CA

Thank you for your attention