# From the root's point of view: understanding the interaction with beneficial microbes for improved plant performance


Projects: Weiqi Kuang, Debika Sarkar

Platforms: JPPC, Enabling Technologies, Northen Lab, Vogel Lab; Roessner Lab

05.05.2020 I Borjana Arsova

@Borjana_A

# Plant growing under field conditions is not an individual

- It grows with subtle and relatively constant partner relationships with microorganisms.
- The plant has considerable control of the rhizo-microbiome.
  - It recruits species that are useful!
- Additionally the bacterial community can self regulate too.

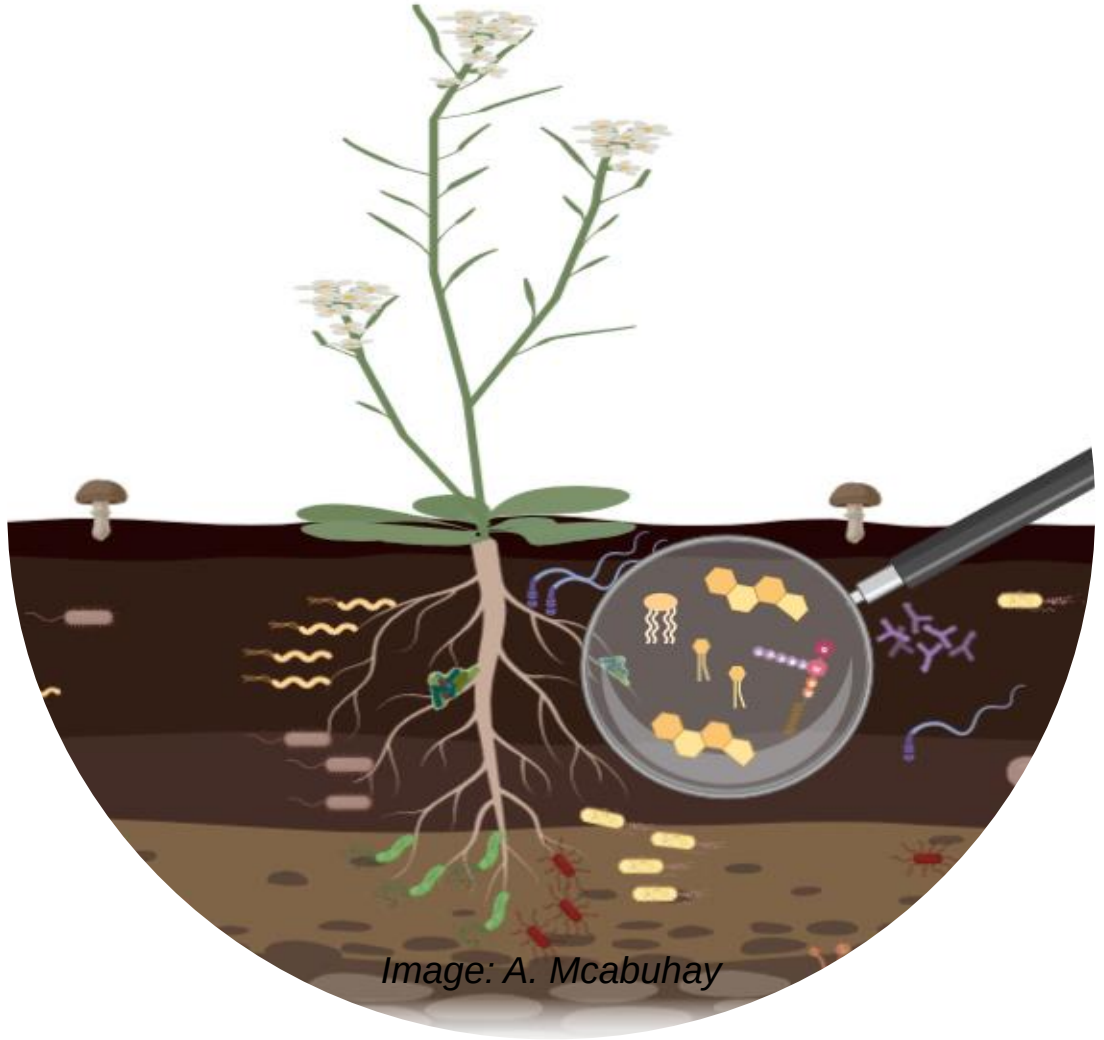


*Image: A. Mcabuhay*


Arsova, *et al*., New Phytol, 2019
Lundberg *et al., Nature* 2012
Backer *et al.,* Front. Plant. Sci. 2018

# What are Plant Growth Promoting Rhizobacteria (PGRP)?

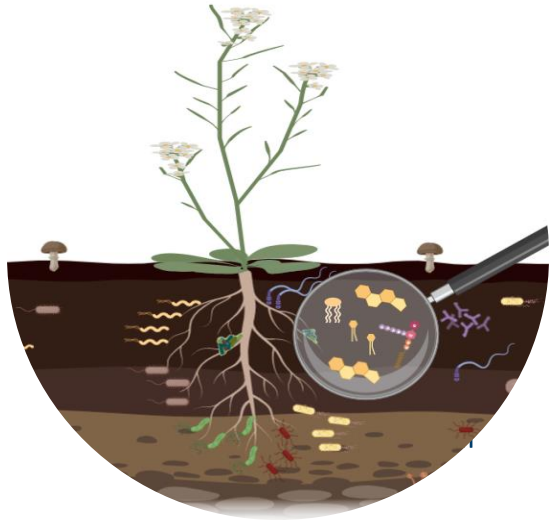
- Colonize root and/or rhizosphere
- Benefit plant growth
- No pathogenic reaction

# PGPRs can be advantageous in commercial agriculture and are relevant to the bio-economy

- Fewer inputs & reduced environmental impact

Challenges:

- Understanding the mode of action (especially around the root and in soil environment) is still a major bottle neck
- Transfer of knowledge from lab to field (reproducibility under filed conditions)



Backer *et al.*, Front. Plant. Sci. 2018

# Use of PGPR under biotic stress


D. Pflugfelder


R. Koller

University of Cologne


A. Zuccaro

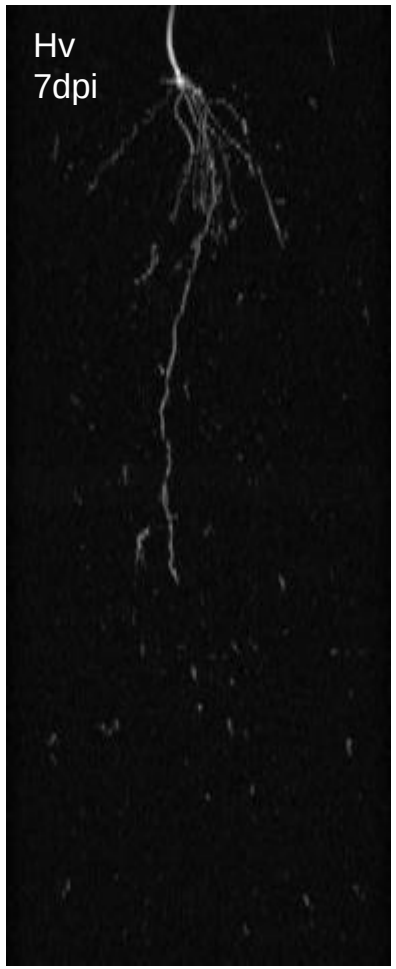

D. Sarkar

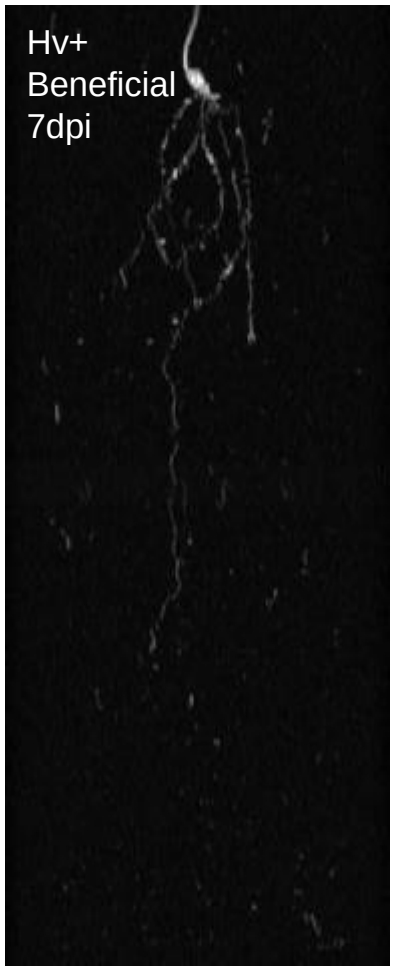
- What happens when a (Barley) root is colonized by pathogenic fungi (P)?
  - With and without the presence of beneficial species (B)

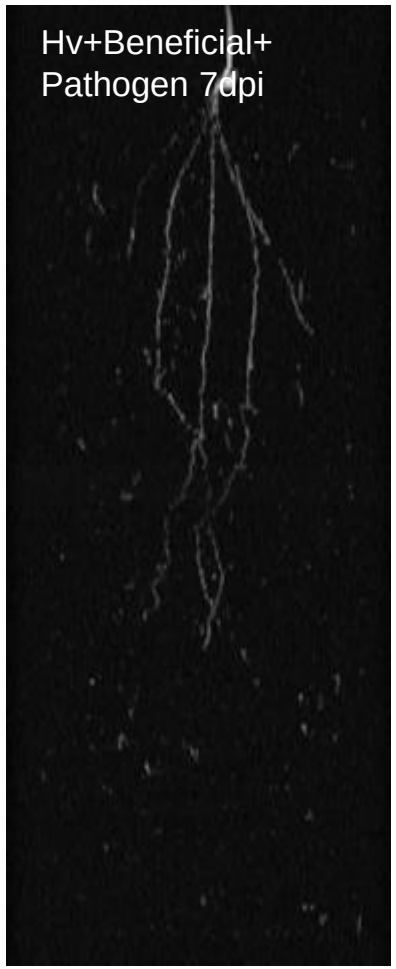
- Approach: Non-invasive phenotyping through time using magnetic resonance imaging (MRI) in soil.

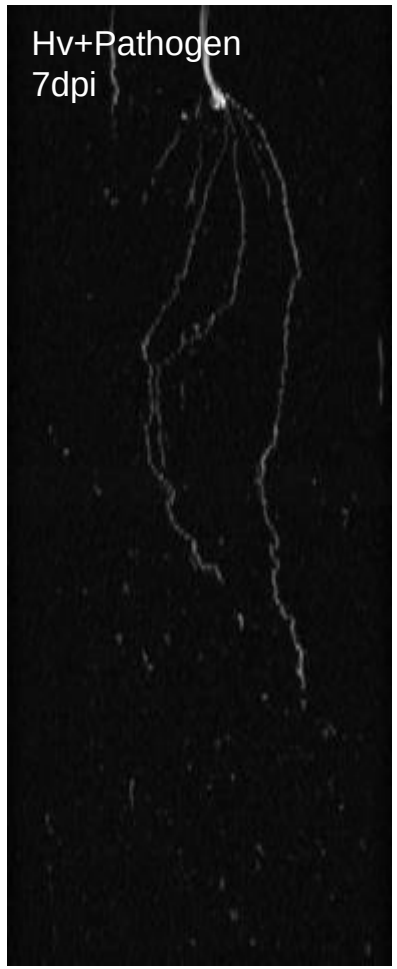
Sarkar *et al.*, *New Phytologist* 2019

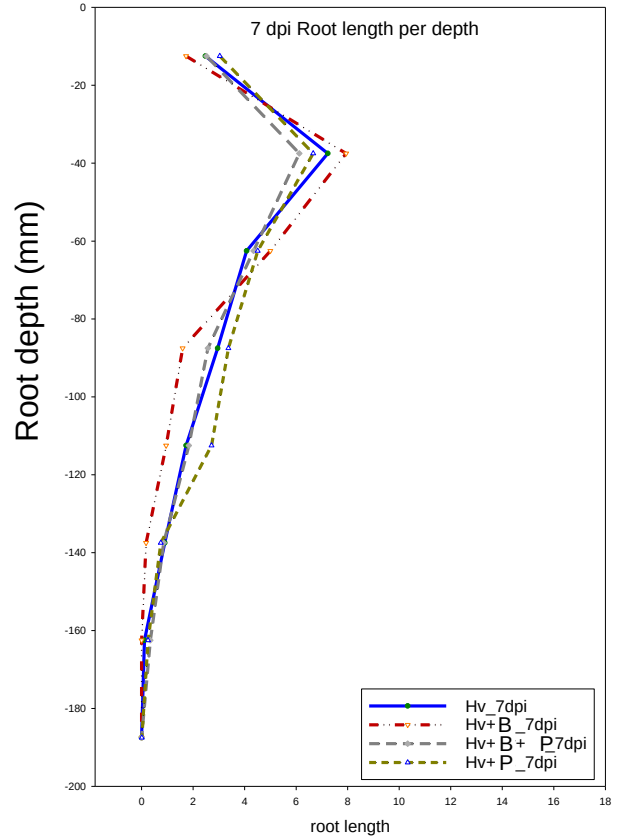
# Comparison of root profiles through time and depth




Each fungus affects the root profile in an independent manner, and this action is time dependent.

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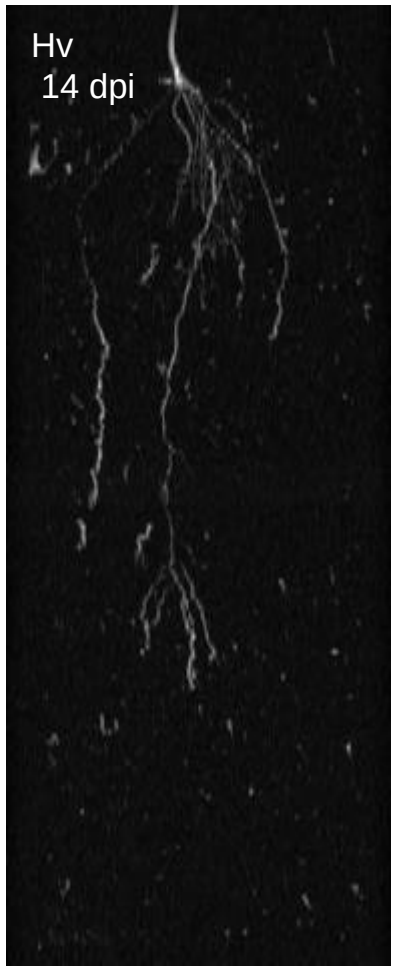
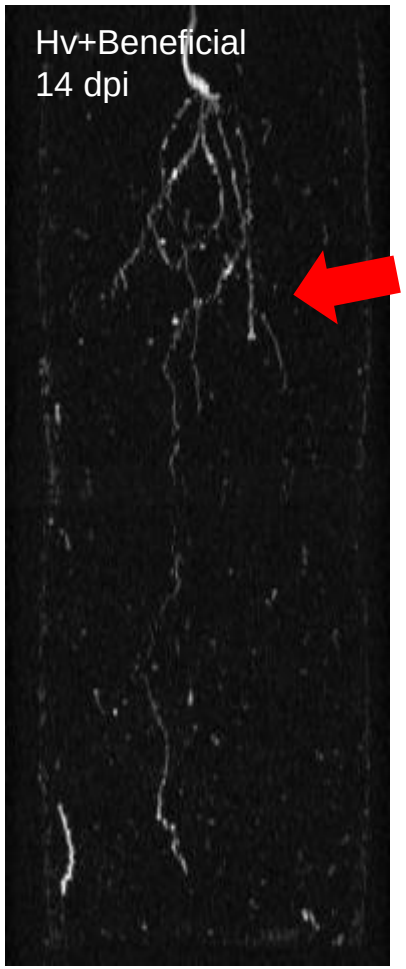
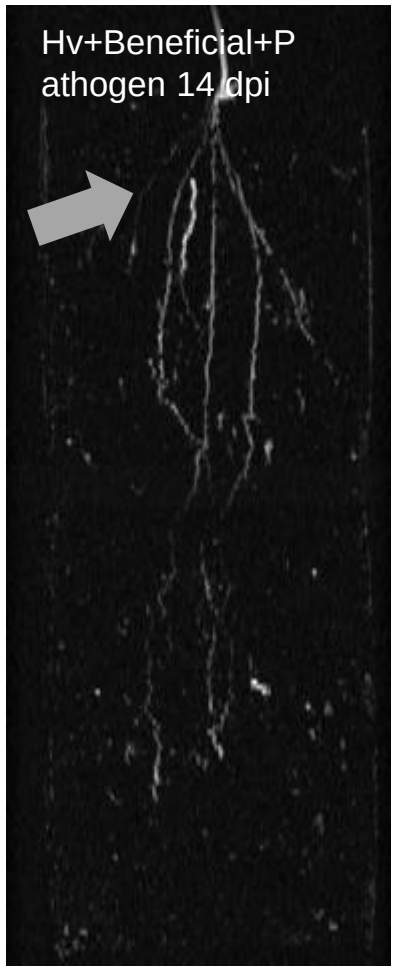
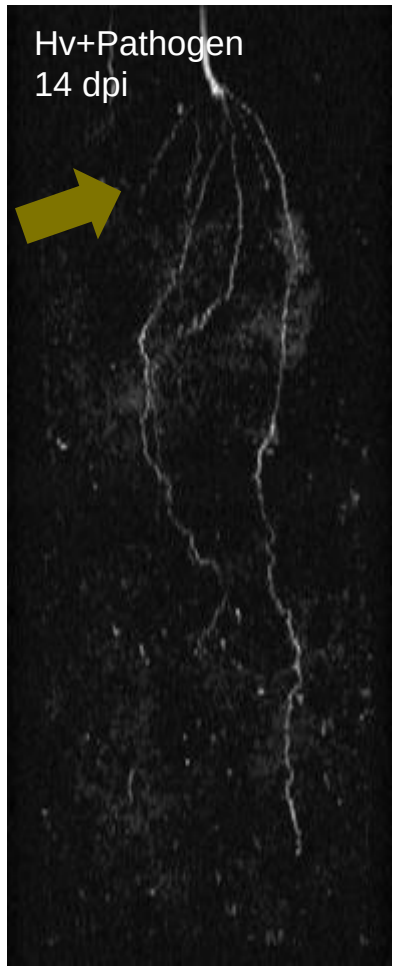
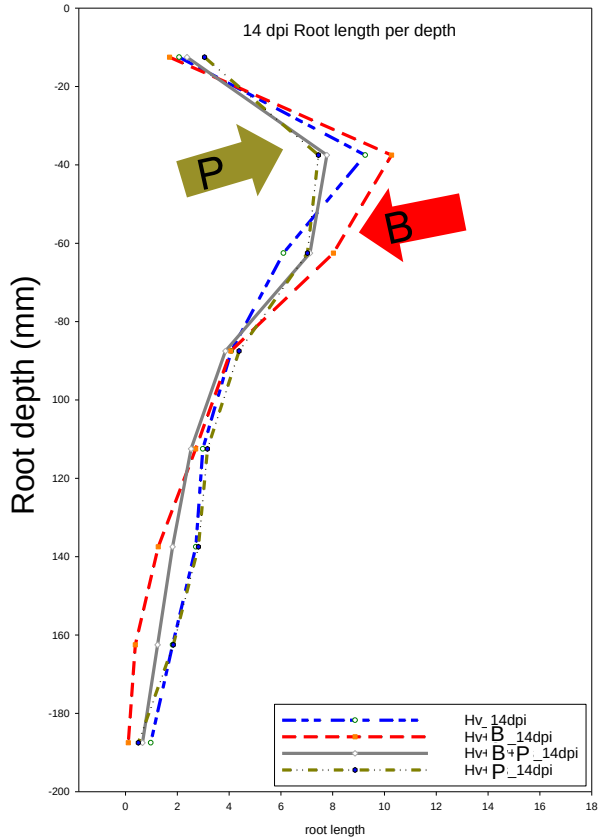
# Comparison of root profiles through time and depth



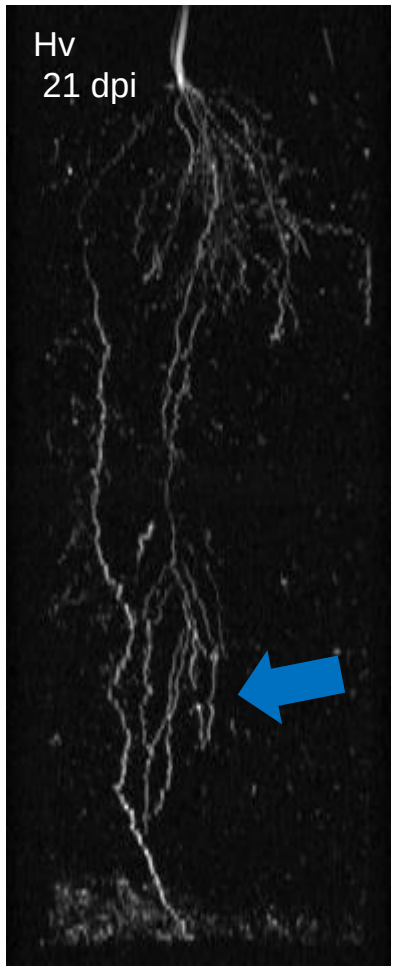



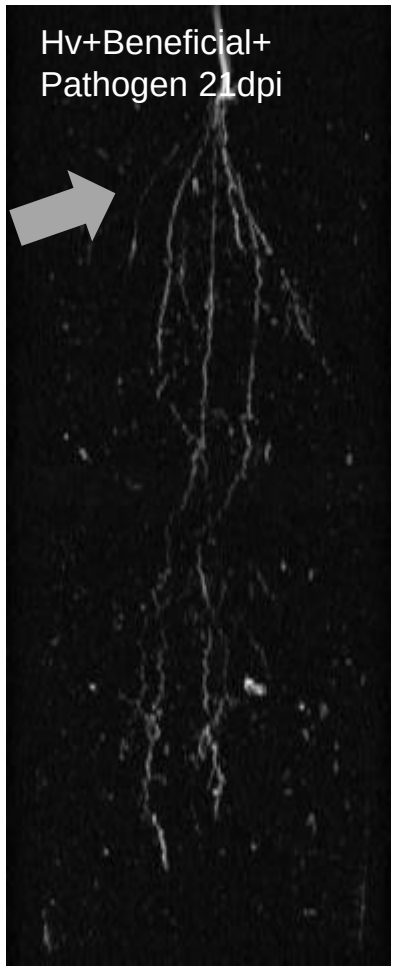



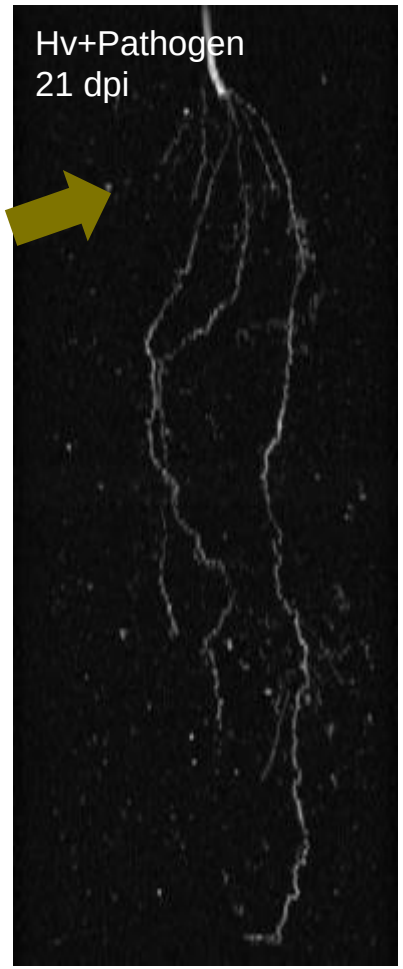



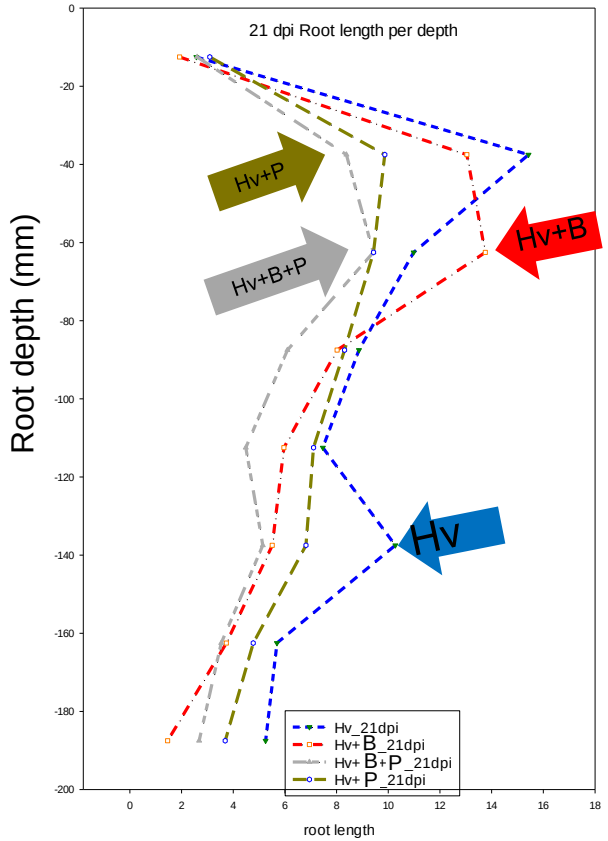
# Comparison of root profiles through time and depth








By day 21- change of root length distribution at various depths. Transcript analysis ongoing.

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# Use of MRI in the study of plant-microbe interactions


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A. Zuccaro


D. Sarkar

- Advantages:
  - Field-like conditions
  - Proper root system architecture development

- Disadvantages:
  - Limited growing time (Pot / MRI size)
  - Fine root structures are at the detection limit.
  - Experimental protocols for soil packing, seed germination and inoculation are crucial.
  - Data analysis and measurement time are a bottle neck (low throughput).

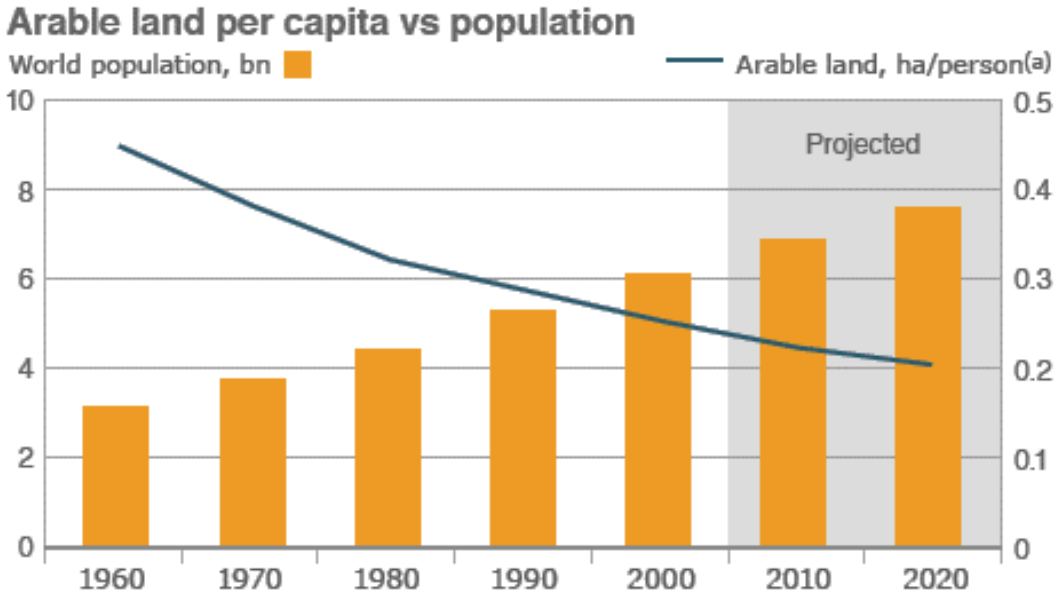
*So we simplify even more!*

# Nitrogen

04.04.2019
www1.wdr.de/radio/


**Der falsche Feind der Bauern**

Von Tanja Busse




Source: GS & PA Research, FAO, 2013

Cereal N use efficiency has seen only minor improvement in the period from 2002 to 2015

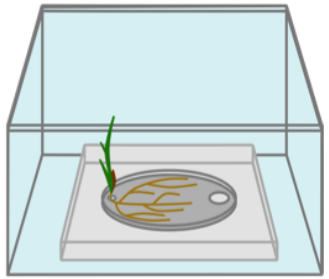
- from 33% to 35% globally
- Varies through regions
- Linked to the use of precision agriculture and modern N efficient varieties

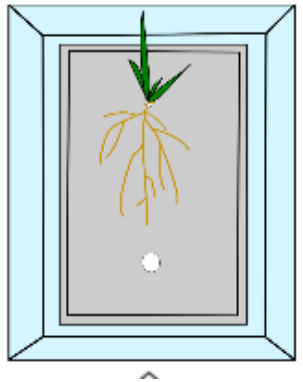
(Omara *et al.*, 2019)

# Can we measure the N contributon from a PGPR?

Dr. Weiqi Kuang

- Establishment of N starvation in EcoFab
  - Total number of available N molecules should be taken into account
  - Size of chamber matters
- Adaptation of original EcoFab chamber
- Final conditions
  - Liquid medium; 5mM and 0.5mM $NH_4NO_3$
  - PGPR (N - fixer)
  - Non Invasive phenotyping on same individuals through time
    - Root and Shoot
  - Invasive Harvest





Sasse *et al., New Phytologist* 2019

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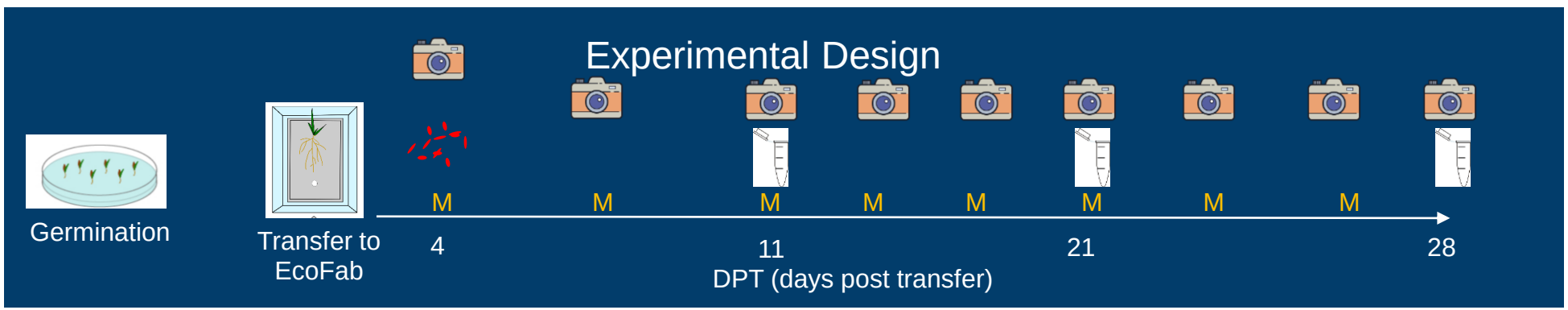
J. Sasse

T. Northern

J. Vogel

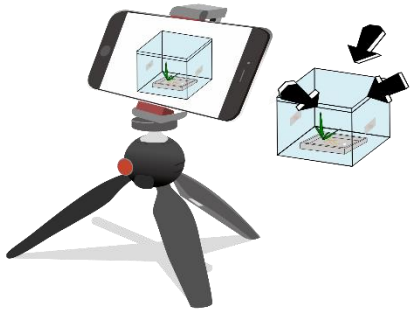


# Non-Invasive phenotyping under limited N

Dr. Weiqi Kuang

## Shoot phenotyping using smartphone

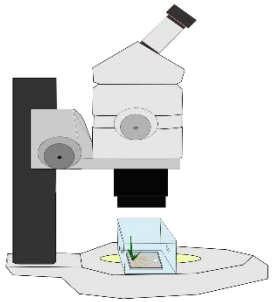
Setup



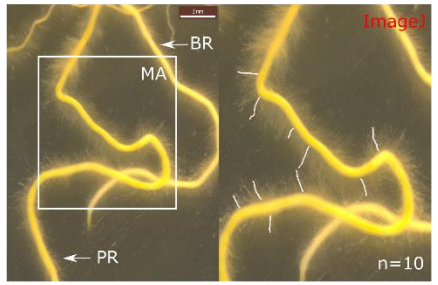
Color segmentation mask

## Root Hair phenotyping using stereo-mic.

Setup



Root hair imaging




## Root phenotyping using scanner

Setup

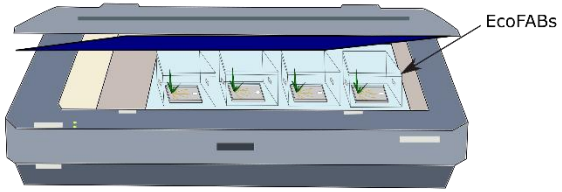
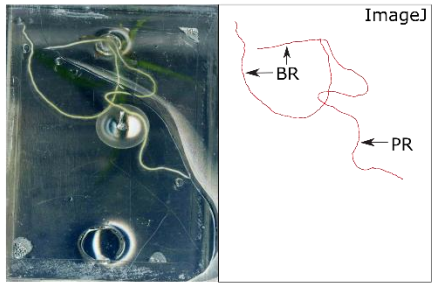
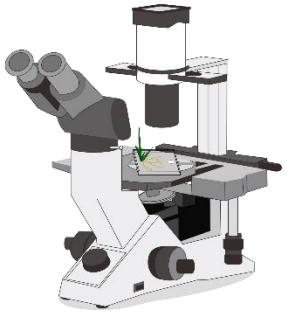



Image and root characterization

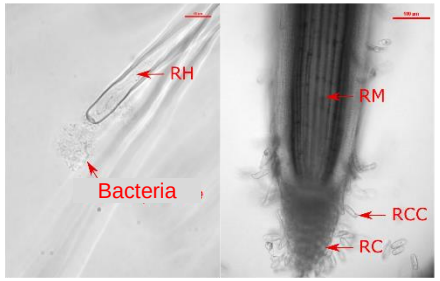



## Live imaging of bacterial colonization

Setup



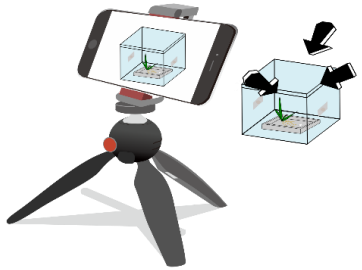
Images 4h post PGPR addition to medium

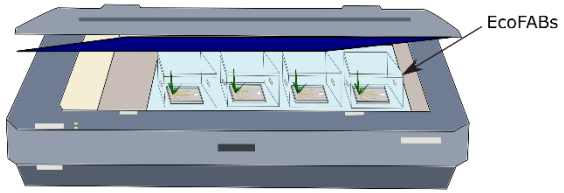


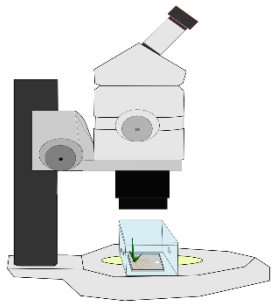

Kuang *et al*, in preparation; Müller-Linow, M., *et al.* (2019). Plant Methods; Sasse, J., *et al*., (2019) New Phytol.

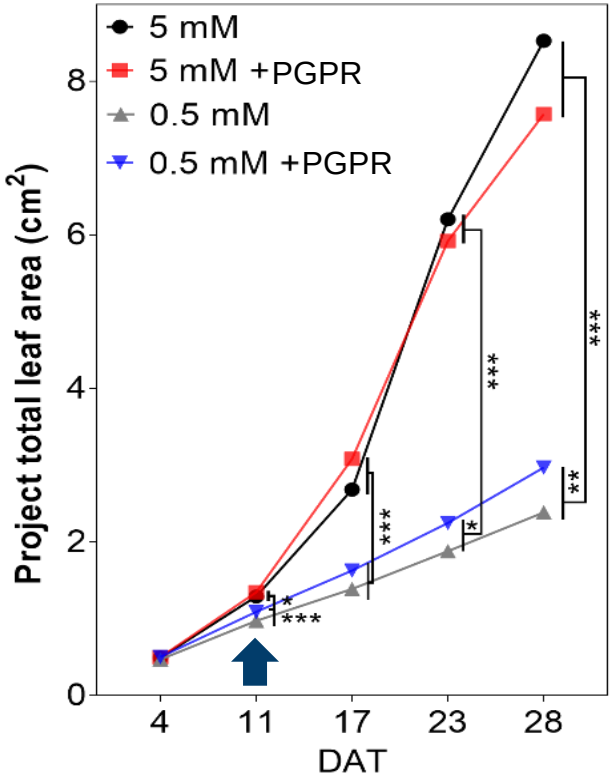
# PGPR increases leaf area and root length, time and N availability play a role in the interaction.

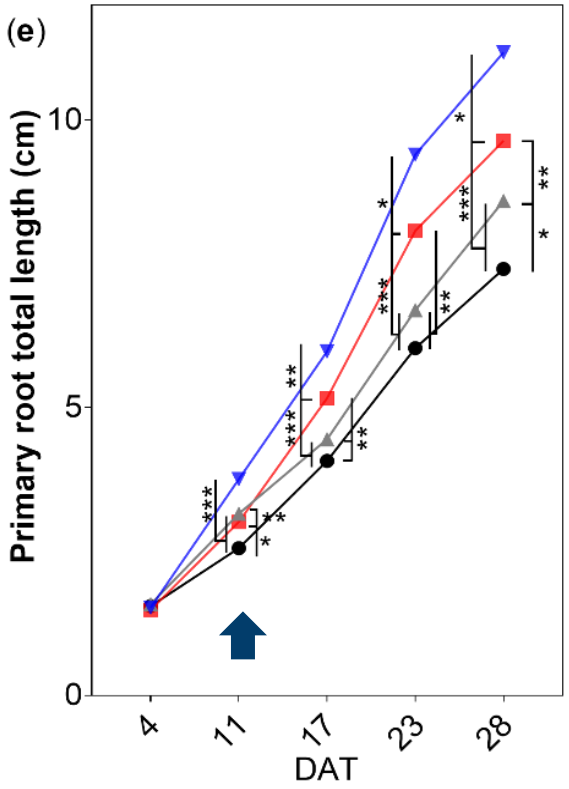
Dr. Weiqi Kuang

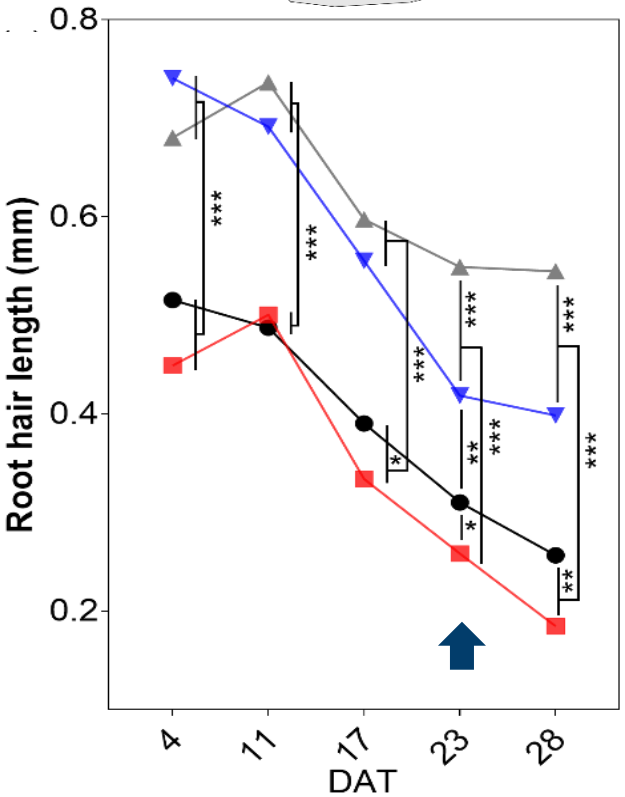






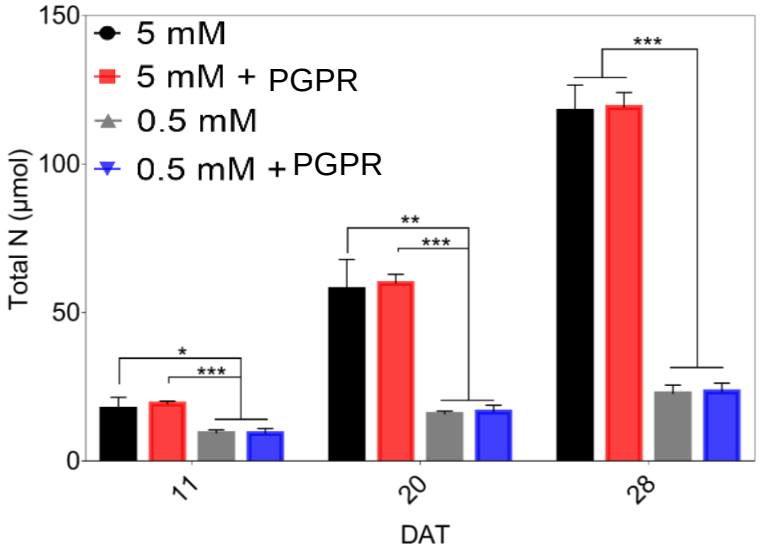




Kuang *et al*, in preparation

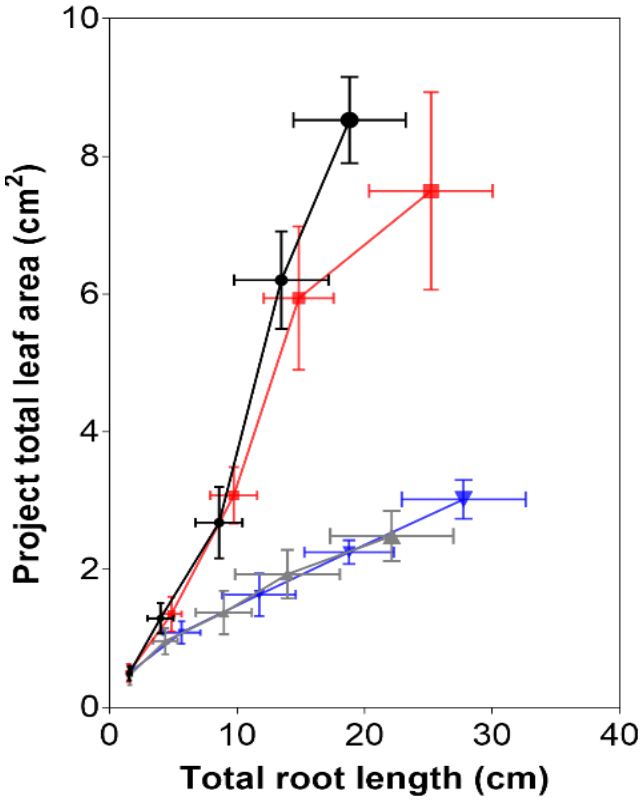
# This PGPR does not increase total N content in plants but impacts biomass (esp. root)

Dr. Weiqi Kuang

## Total N content in plants




## Biomass allocation




qPCR data for transcripts of N metabolism is under analysis

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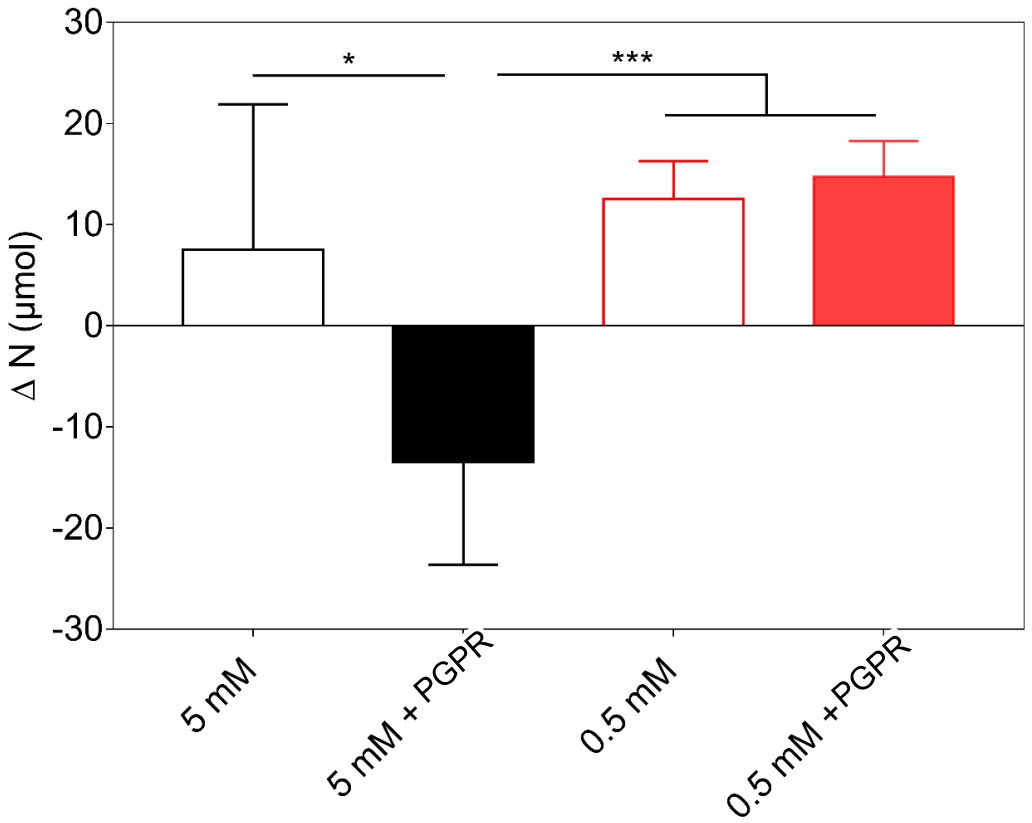
Kuang *et al*, in preparation

# N balance calculation

**dN= input (seed and medium through time) – N contained in plant at day 28**

Dr. Weiqi Kuang




- At 5mM the inoculated plants contain more N than was supplied through the seed and medium.

## Hypothesis: multiple mechanisms at work, depending on condition

- Longer roots and higher leaf area in inoculated plants at 0.5mM N indicate better NUE (more biomass per unit N)
- -dN in inoculated plants at 5mM may indicate contribution through N fixation

**qPCR data for transcripts of N metabolism is under analysis**

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# Summary - Nitrogen

- Controlled eco-systems (e.g. EcoFab) now allow non-invasive monitoring of root and shoot phenotype through time, in the study of plant-microbe interactions, including a mass-balance calcualtion of specific nutrients.

- Phenotype and molecular response can be linked once a proper time-point point has been determined (to avoid bypass reactions, and identify first molecular response).

# Acknowledgements

## Root Dynamics Group

ECRs' contribution to presentation on 5.5.2020

University of Cologne

A. Zuccaro

D. Sarkar

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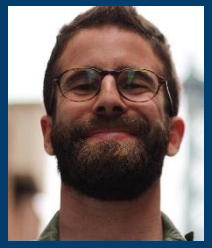
Michelle Watt

Ute Roessner



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