JÜLICH
FORSCHUNGSZENTRUM

Root and rhizosphere traits for agricultural productivity:

Progress and possibilities with phenotyping

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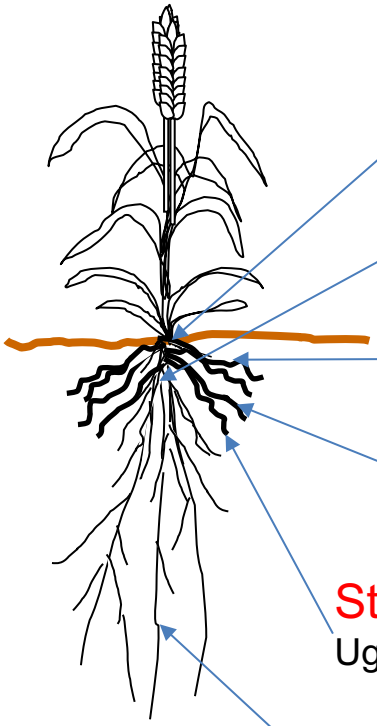
April 17, 2018 I Meeting of Austrian and European Plant Phenotyping Networks

Examples of root traits that have reached a public breeding process and roles of phenotyping



Root initiation in very low P, rice

Wissuwa, Heuer (2000- present), markers from field QTL

Water conserving root anatomy, wheat

Richard and Passioura, (1970-80s), anatomic selection

Shallow root angle for surface P acquisition in bean

Lynch (2000- present), phenotypic selection

Cereal Cyst Nematode resistance

Laguda (1990s- present), markers from pot screen

Steeper root angle for water capture in rice, wheat

Uga et al (2013-present), Hammer et al (2006-present), markers from lab screens

Al tolerance, Na exclusion

Delhaize, Ryan et al., Munns, James et al (1990- 2010, phenotypic screens, markers)

Deeper root length for water capture in wheat

Hurd (Canada, 1960s, 1970s)- Rhizoboxes for parents I

Reynolds et al (CYMMIT, 2010s)- Canopy temperature as selection in breeding

Wasson, Watt, Richards (India, CSIRO 2010s)- Field coring for parents

Features of these root trait selections

- All involved phenotyping for selection
- Controlled environment and/or field phenotyping
- Shoot phenotypes part of selection
- Single traits, developmental or functional
- Different levels and ways of impacting crop improvement breeding and pre-breeding, 10 to 20 yr delivery time

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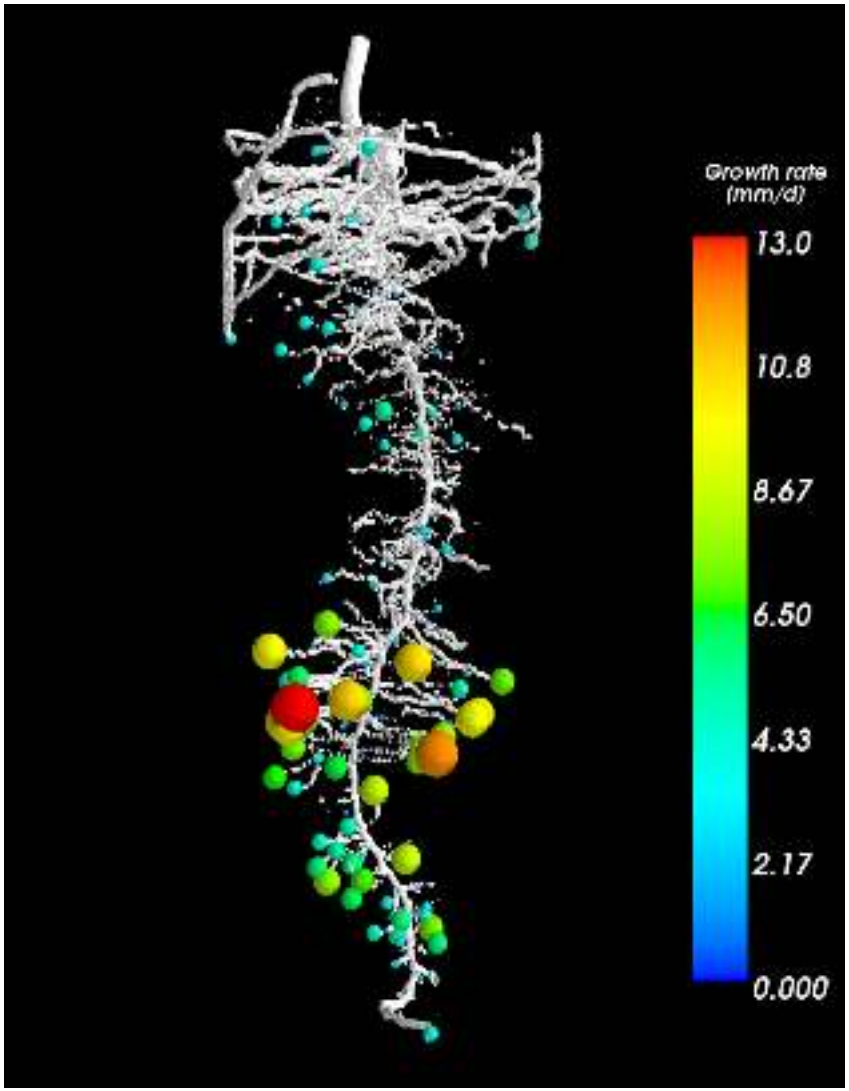
Dynamic/Functional phenotypes



Growth rates of maize roots measured over time in 3D- potential to look at dynamics and responsive traits

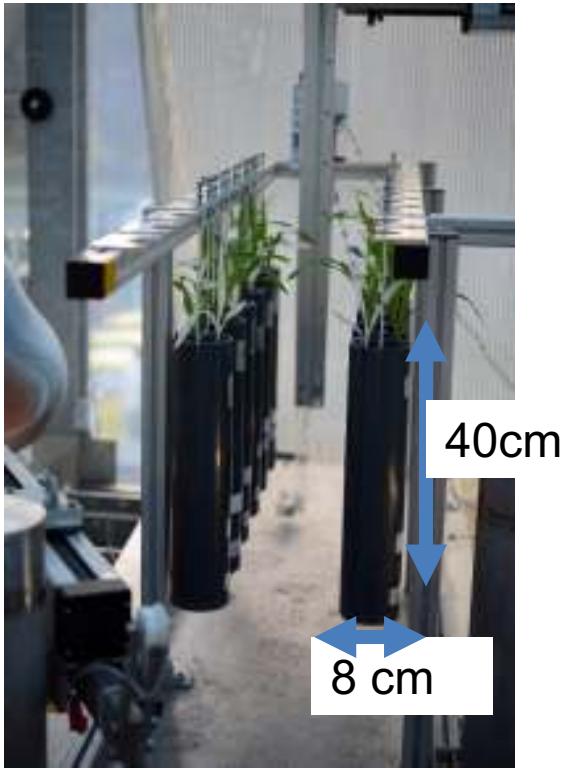
Imaged in soil with MRI, at 3 time points, indicating rates of elongation

D. Pflugfelder

Automated 3D imaging of plants for dynamic responses to soil environment

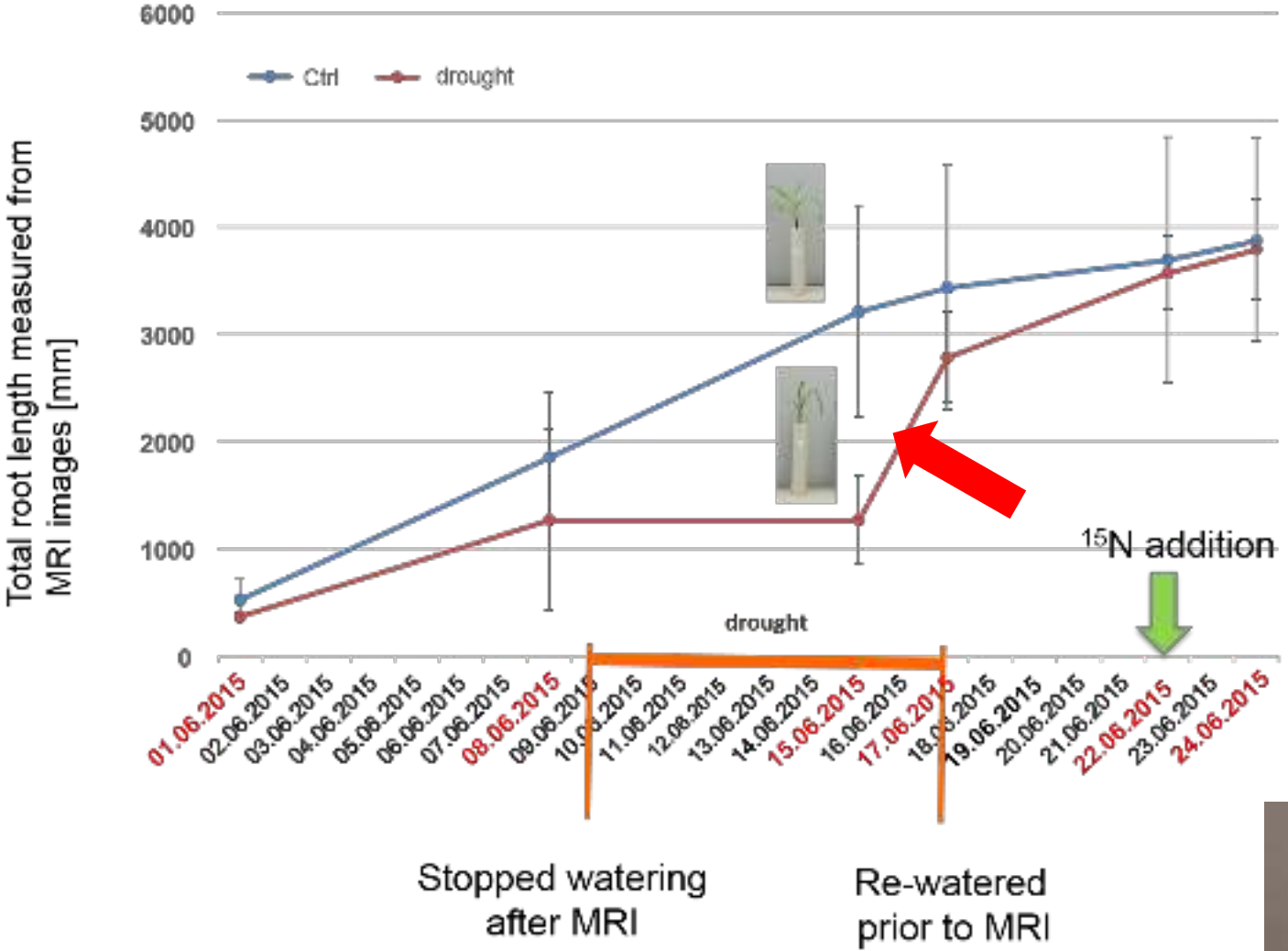
MRI-
Magnetic resonance

Robotic delivery
of plants into MRI



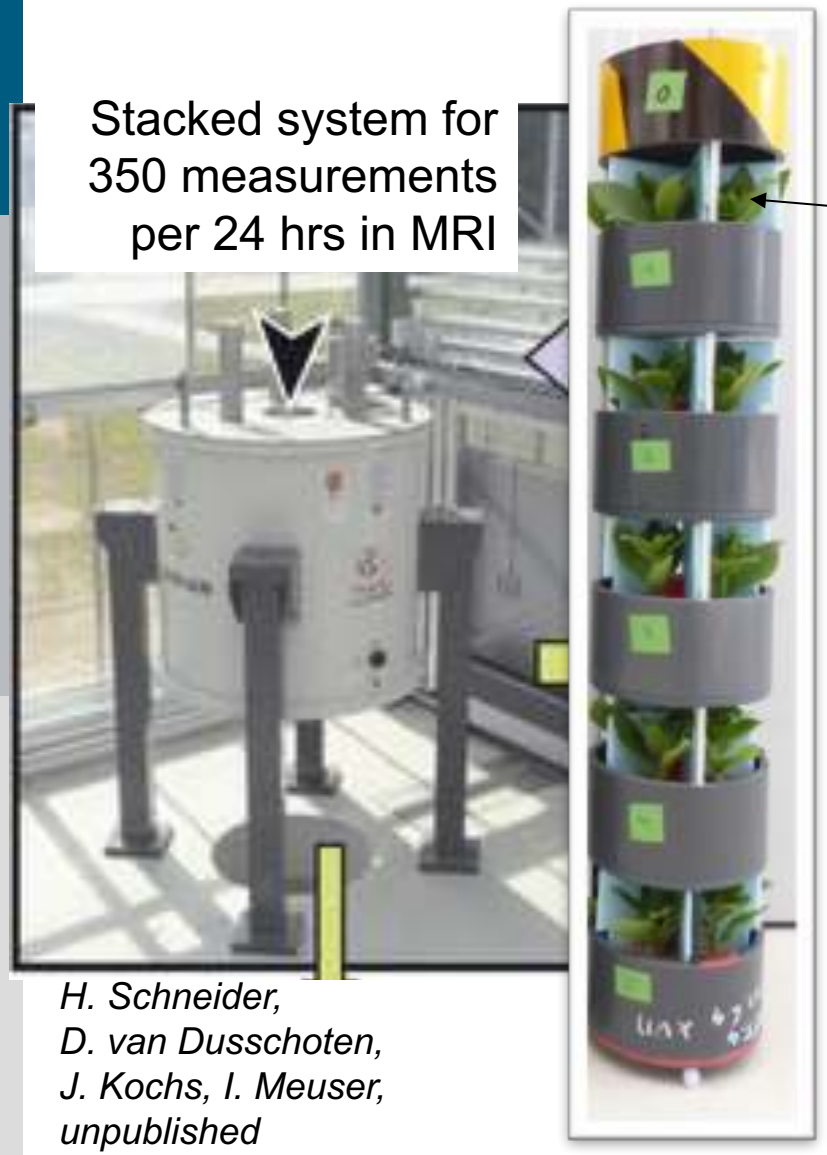
D. van Dusschoten et al., 2016, Plant Physiology

Dynamic phenotyping of *Z. mays* roots after drought and rewatering

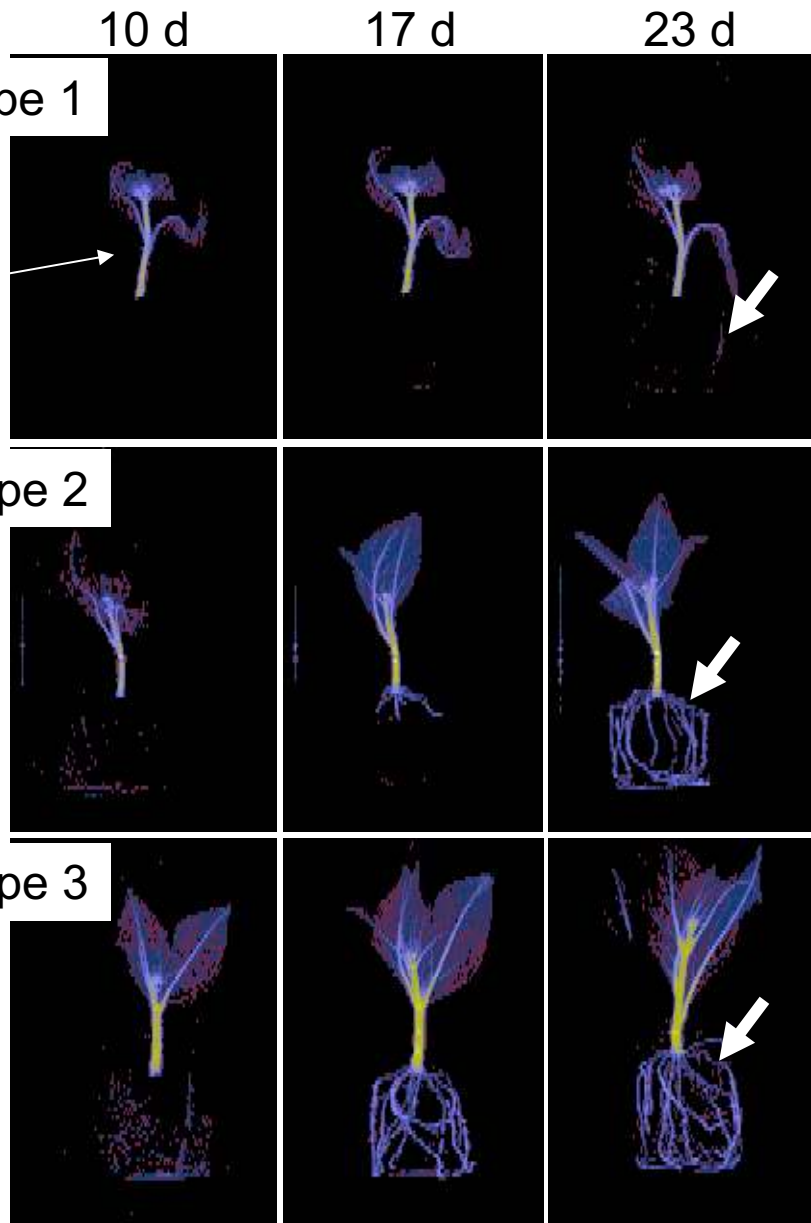


Robert Koller

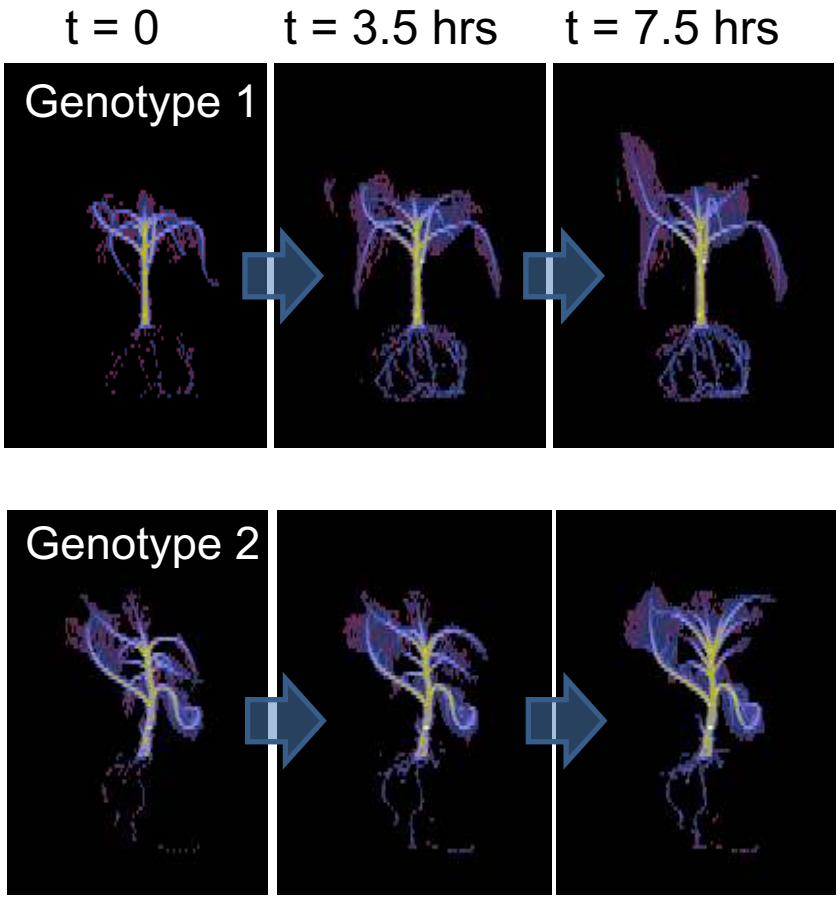
Dynamic, high throughput phenotyping of variation in rate of adventitious root growth

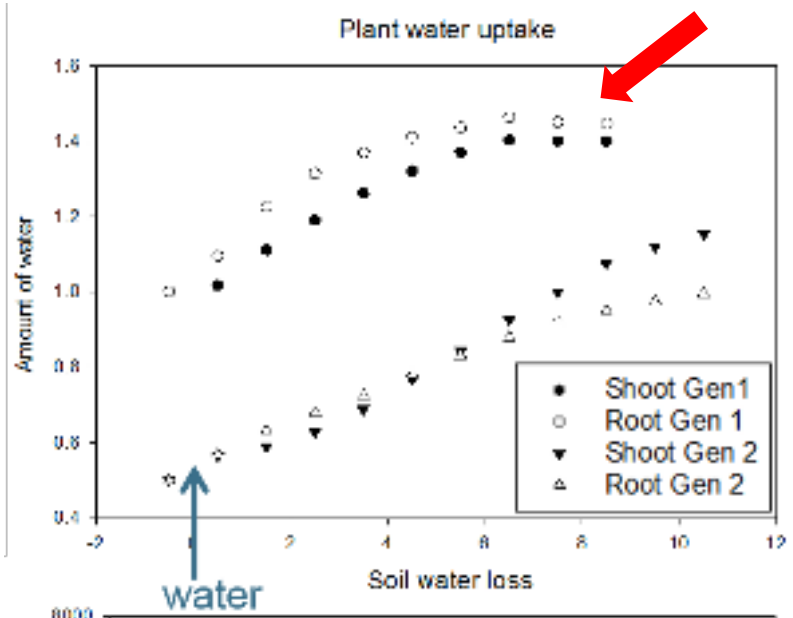


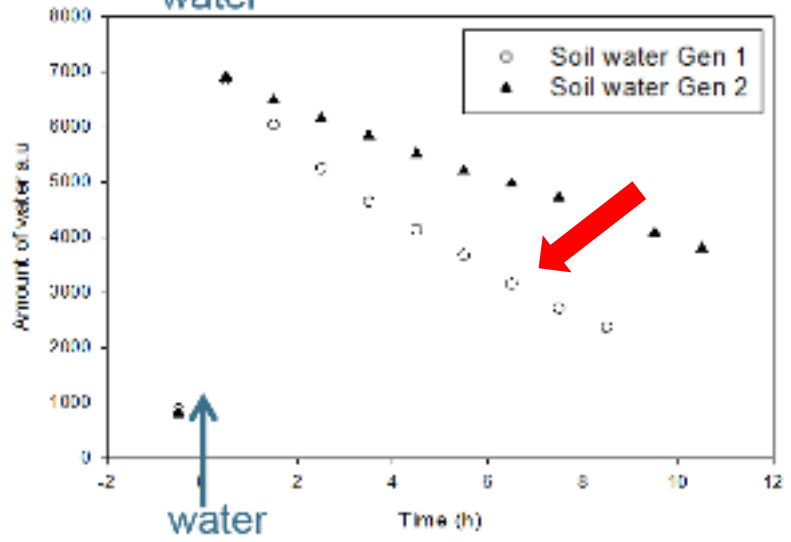
H. Schneider,
D. van Dusschoten,
J. Kochs, I. Meuser,
unpublished



Dynamic, high throughput phenotyping of drought recovery (roots, shoots and soil water uptake)







Genotype 1 draws water faster from soil into roots and shoots

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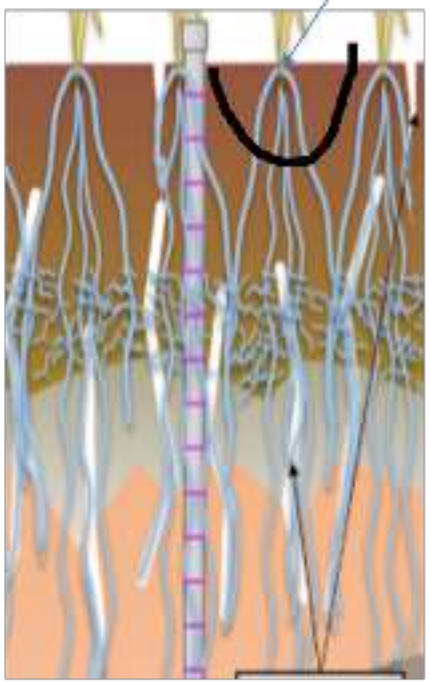
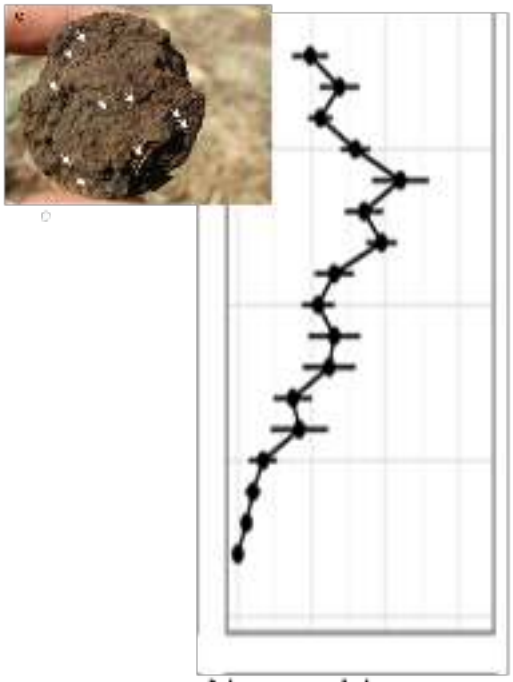
Direct field phenotyping of roots- two methods for ~250 plants per day for deep roots or root crown



Drawing: Anton Wasson

Core data
root number cm^{-2}



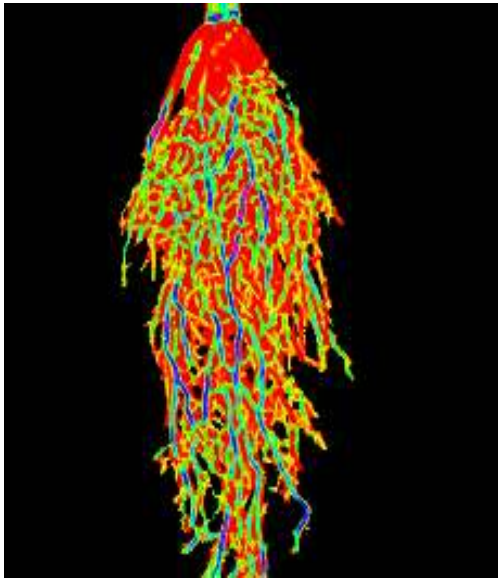
- No washing
- Deep
- Transect through root profile

Shovel data
Parameters from images

- Washing
- Shallow
- Crown with stem: connection with stem, shoot

Recent technological advances for field

Portable root crown phenotyper

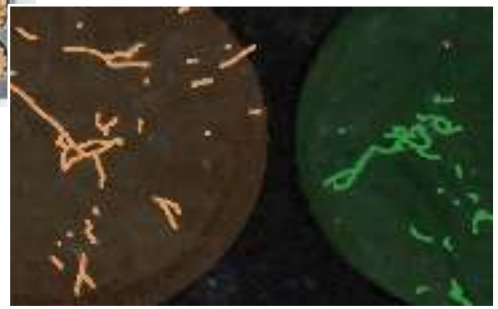


- Portable box with optimised light
- Rotation with motor, and video images
- New software
- Multi species including Cassava

T. Wojciechowski et al, Juelich

Recent technological advances for field

Portable Blue Box to image core faces



Wasson et al., 2014, 2016, 2017

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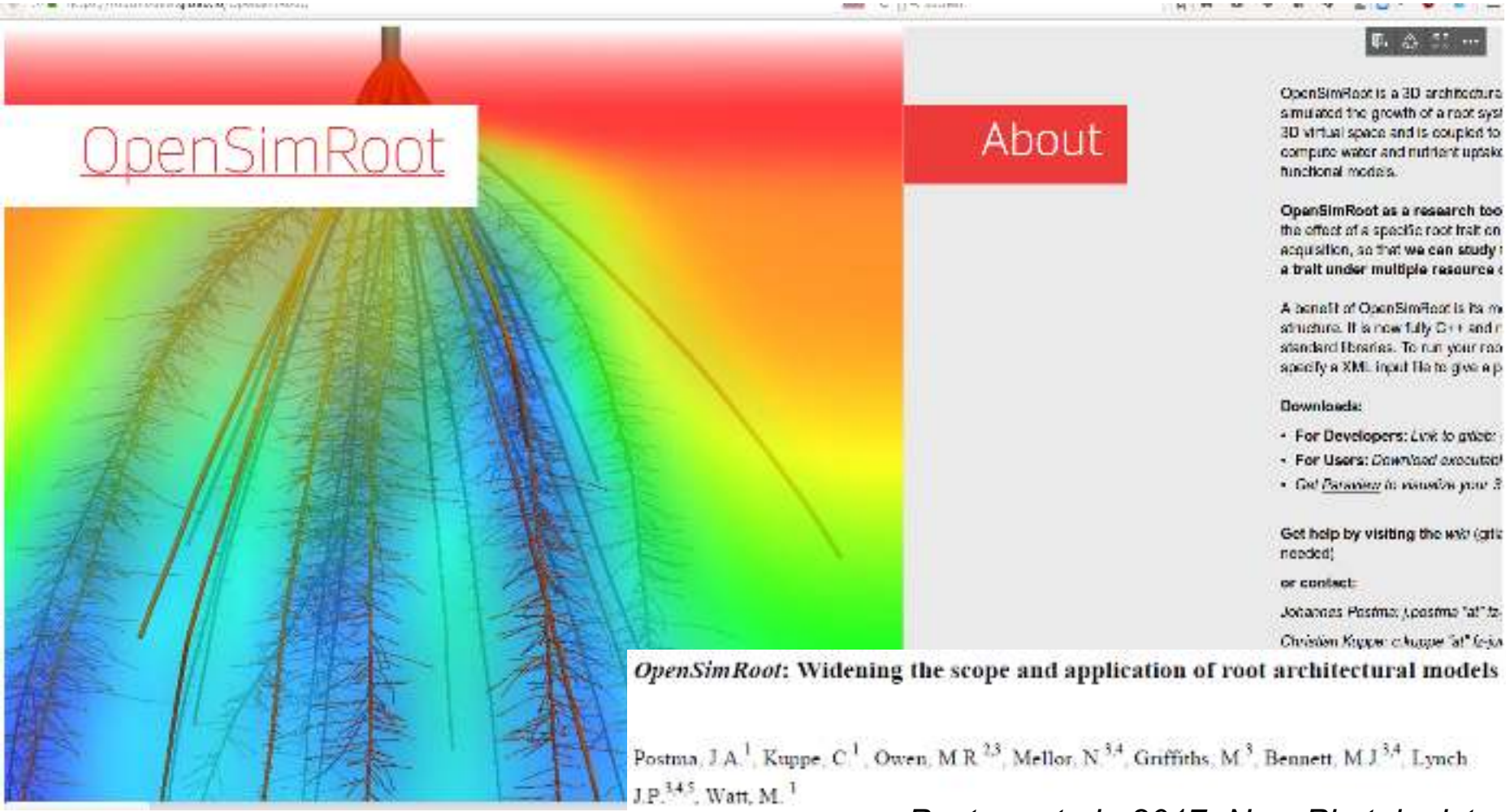
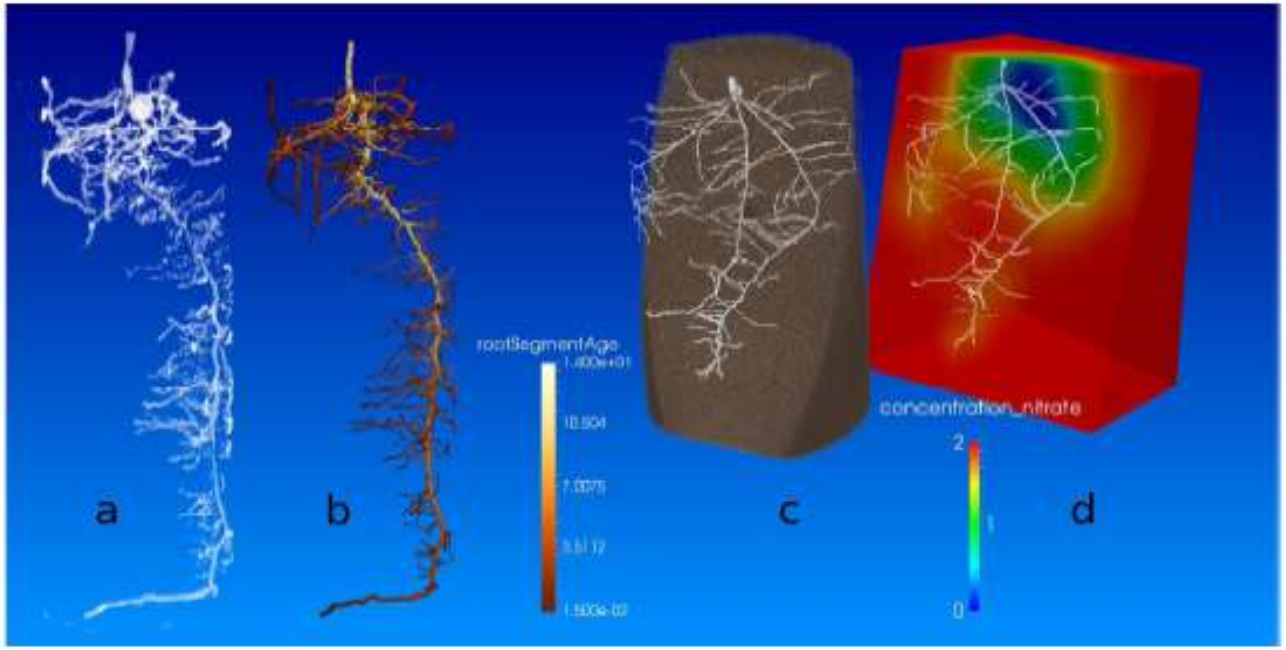
https://rootmodels.gitlab.io



Postma et al., 2017, New Phytologist

OpenSimRoot for integrating phenotypes with soil environments and predicted functions



A. MRI acquired image of a 2 week maize root system, D. van Dusschoten, Juelich Plant Sciences
C. X Ray CT acquired image of 10 day wheat root system, D. Wells, U of Nottingham Hounsfield Facility

(Postma et al., 2017)

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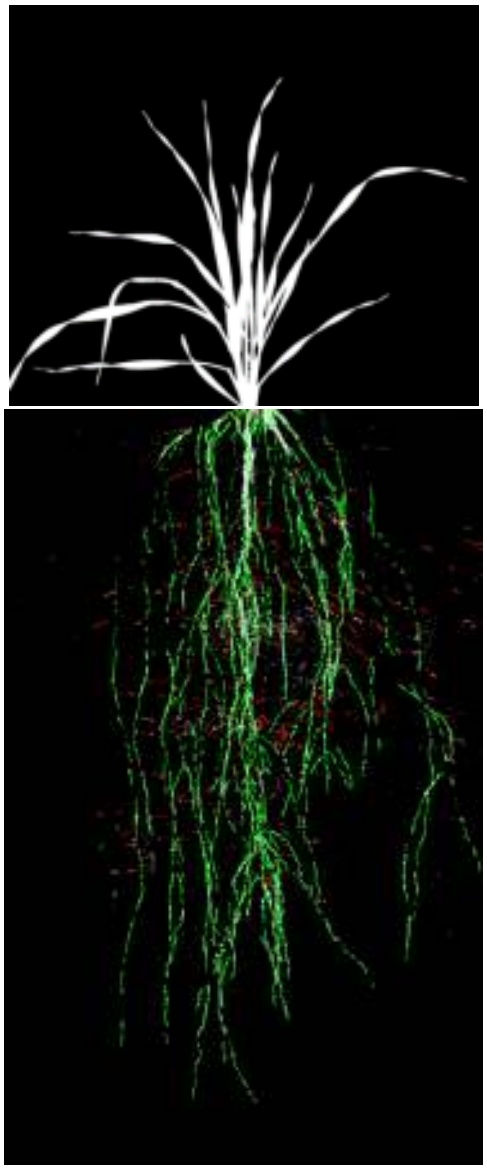
Root-shoot phenotypes



Signals
Transport

2. Modulate shoot growth and harvested product

Root growth and architecture
Rhizosphere processes

1. Capture soil resources

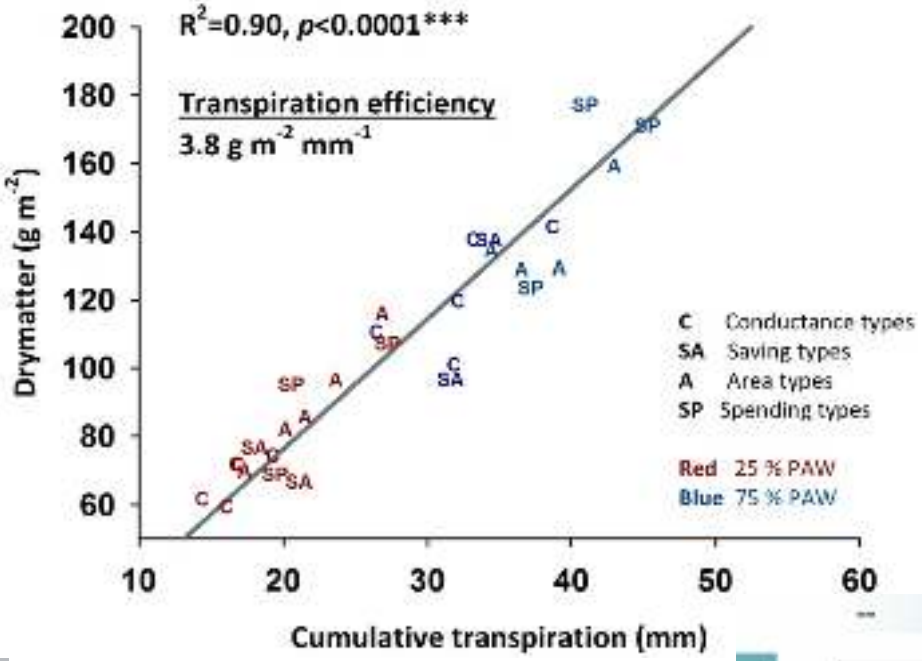
Shoot and below-ground phenotypes for water use

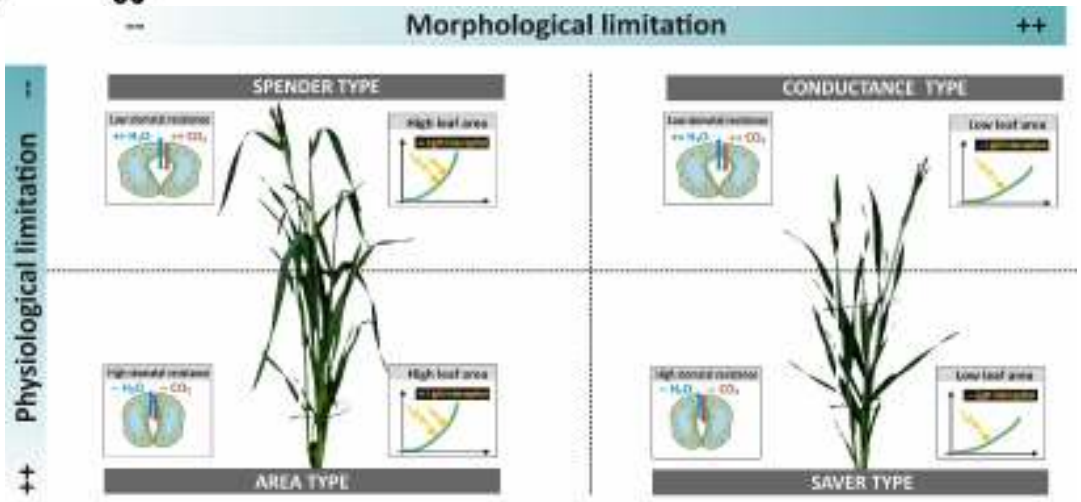
15 durum wheat landraces and cultivars

Two conditions: 25% and 75% plant available water

- Projected area by imaging
- Evapotranspiration (gravimetric)
- Dry mass destructively
- Relative water content
- Gas exchange and stomatal conductance
- Chlorophyll fluorescence

Four water use ‘types’ identified, each with a combination shoot and soil water phenotypes





Fiorani and Group,
Nashforok et al., 2016, Frontiers Plant Science

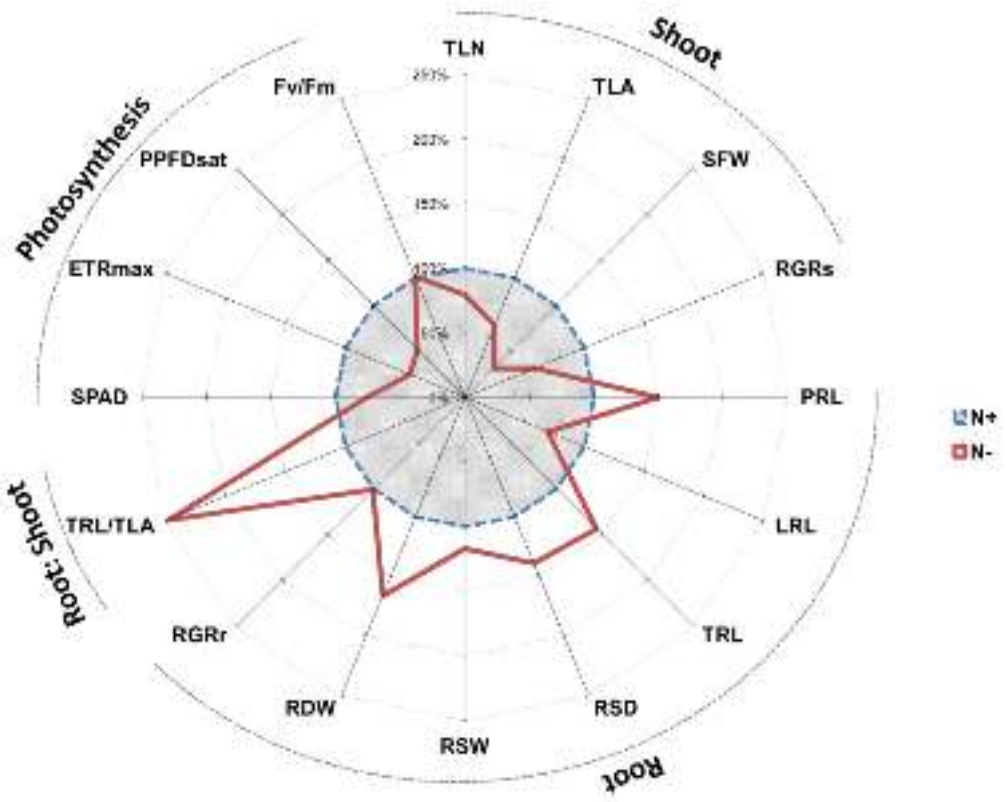
Root-shoot phenotypes for N use

GrowScreen-Rhizo to image roots and shoots overtime

Throughput: up to 240 plants – 60 min

Nagel et al. 2012, Functional Plant Biology

Among durum wheats, shoot and root phenotype expression depended on N supply and domestication



Gain through root and shoot phenotyping?

Gioia et al. 2015, Journal of Experimental Botany

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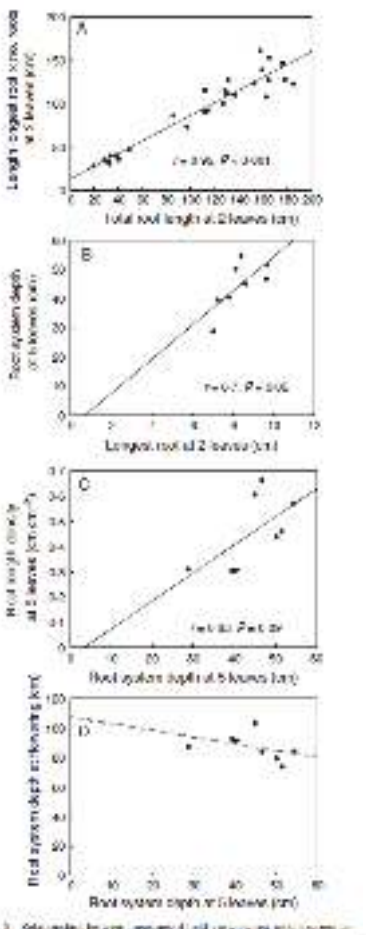
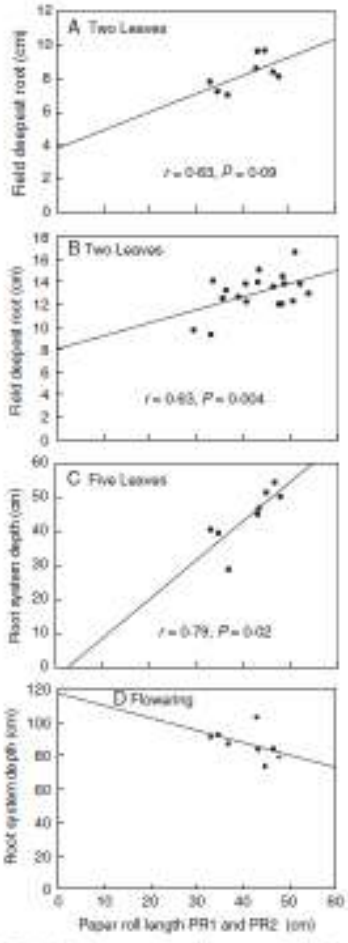
Root phenotypes in the field: young plant stage predicted in lab but not flowering stage

Lab vs field



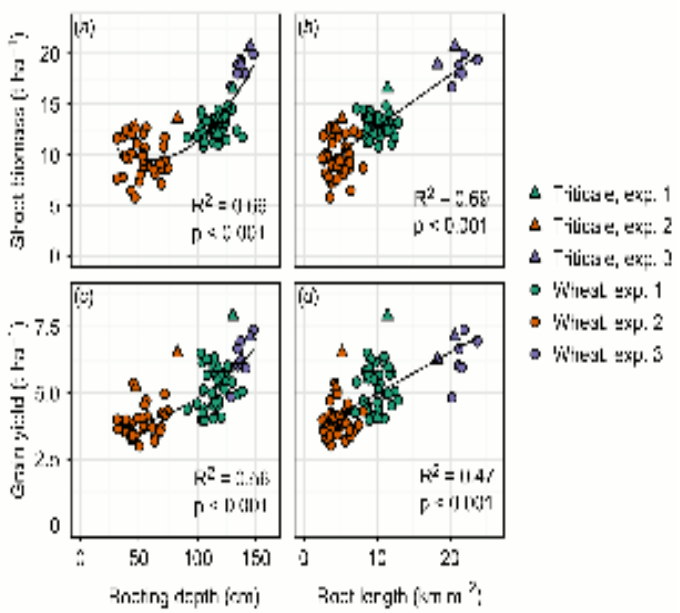
Field vs field



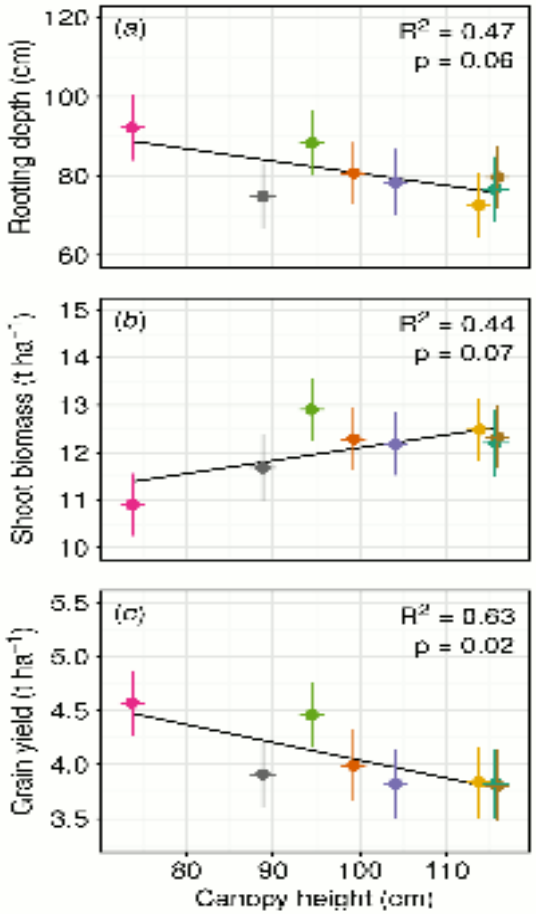
Watt et al., 2013

Root phenotypes in the field: hard to predict from shoots

General relationships….



Break down in some cases…



Severini, PhD thesis, 2016 (in preparation)

Acknowledgements

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Root Dynamics Group

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B Arsova

A Kuhn

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C Mohl

T Ehrlich

J Nestler

A Shi

J Correa

V Hecht

Join Root Phenotyping Working Group in the International Plant Phenotyping Network!

https://www.plant-phenotyping.org/root_phenotyping

Twitter @RootScientists

EUROPEAN UNION

RI AT CZ

Interreg

Austria-Czech Republic

European Regional Development Fund

International Plant Phenotyping Network

IPPN

A Functional Structural Plant model with emphasis on root architecture

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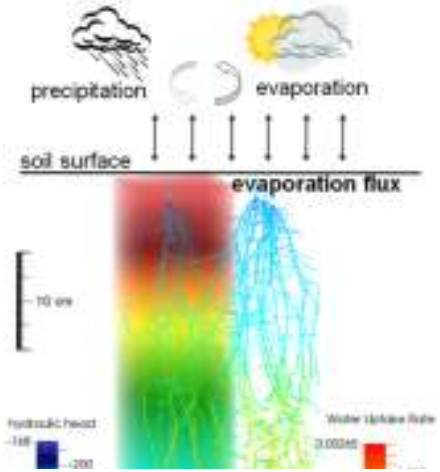
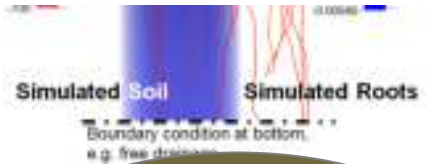


(RUE)
Radiation use efficiency based
Crop model

Carbon source sink

- Barley, Maize, Bean, Squash, Lupine
  - New Wheat, Rice, Cassava, Sorghum *in progress*
- New architectural 3D-root coupled to 3D-soil
- Coupled to simple shoot model

Nutrient deficiency & growth plasticity



3D soil for Water, solutes & mineralization

Nutrient transport & uptake