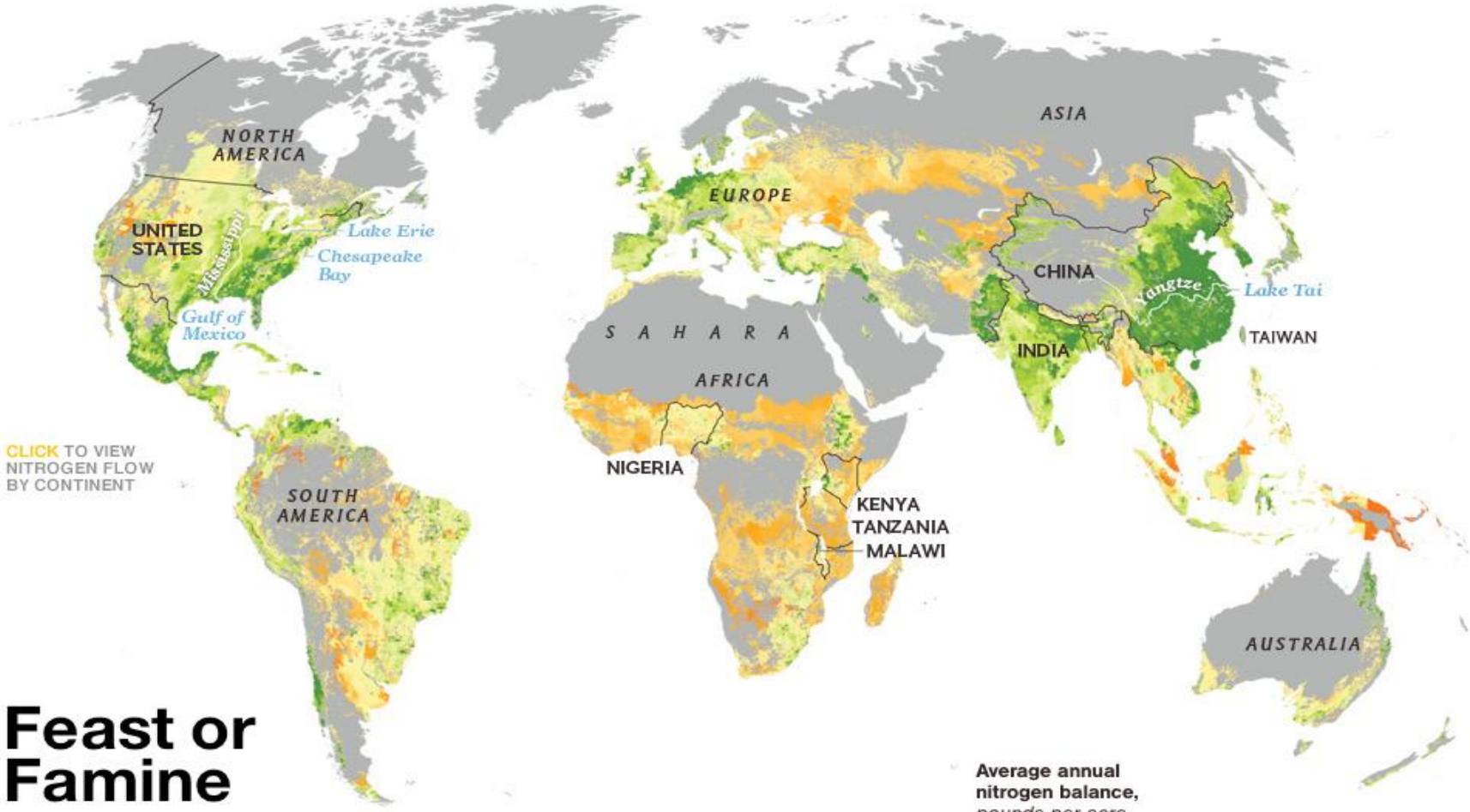
Root phenotyping: uncovering the ‘hidden half’

30 March 2015 Tobias Wojciechowski, PhD

Soil conditions



Feast or Famine

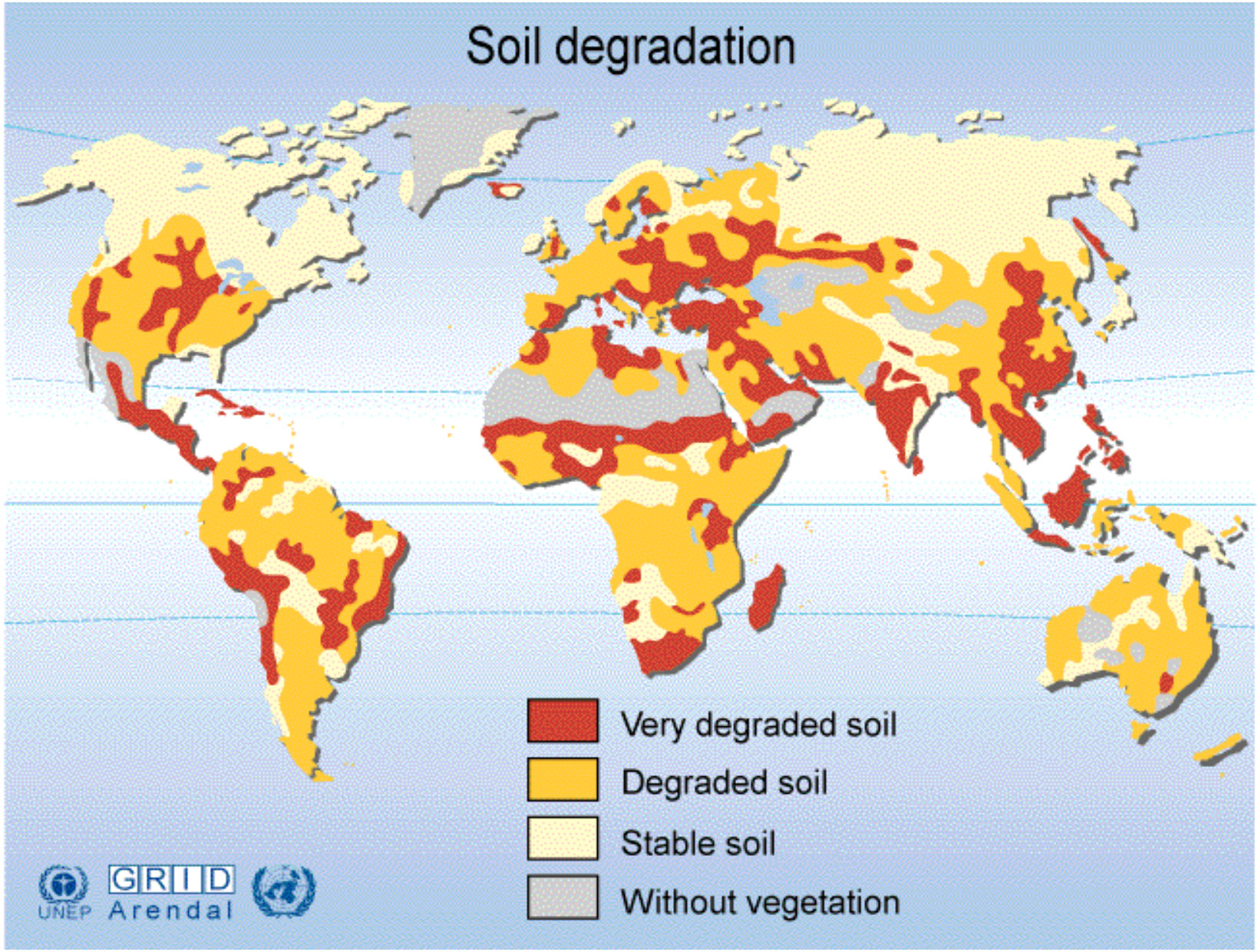
Nearly half the people on the planet wouldn't be alive if not for the abundant food made possible by nitrogen fertilizer. Yet its benefits have not reached everyone. In sub-Saharan Africa, where 239 million people go hungry in a year, crops fail as soil is stripped of nutrients, and farmers can't afford to buy fertilizer. Elsewhere overuse pollutes waterways and releases greenhouse gases.

JEROME N. COOKSON AND LAWSON PARKER, NGM STAFF
SOURCE: PAUL C. WEST, INSTITUTE ON THE ENVIRONMENT, UNIVERSITY OF MINNESOTA

Average annual nitrogen balance, *pounds per acre*

Zero means the crop used exactly the amount of nitrogen applied. The ideal range varies due to local conditions.

Soil conditions



What below-ground root architecture targets for breeding?

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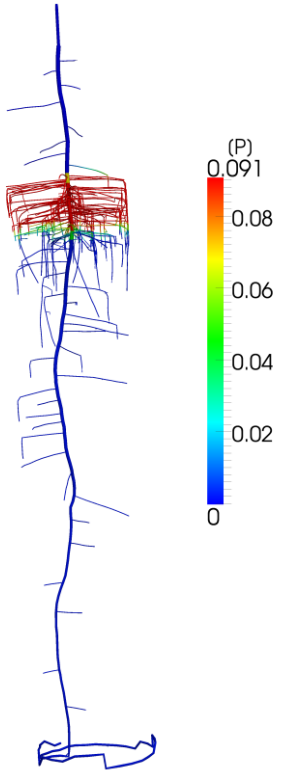
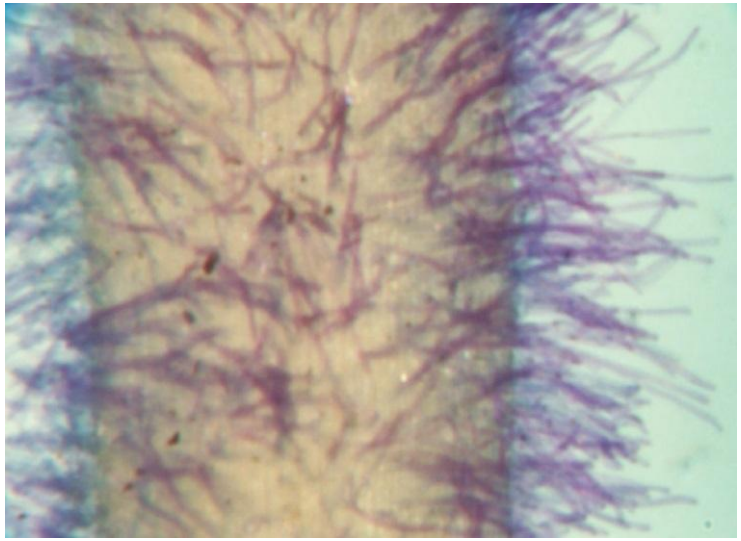
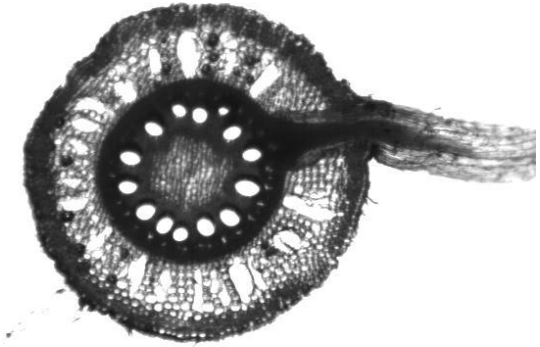
Nutrient foraging



Effective uptake of nutrients



Metabolic efficiency



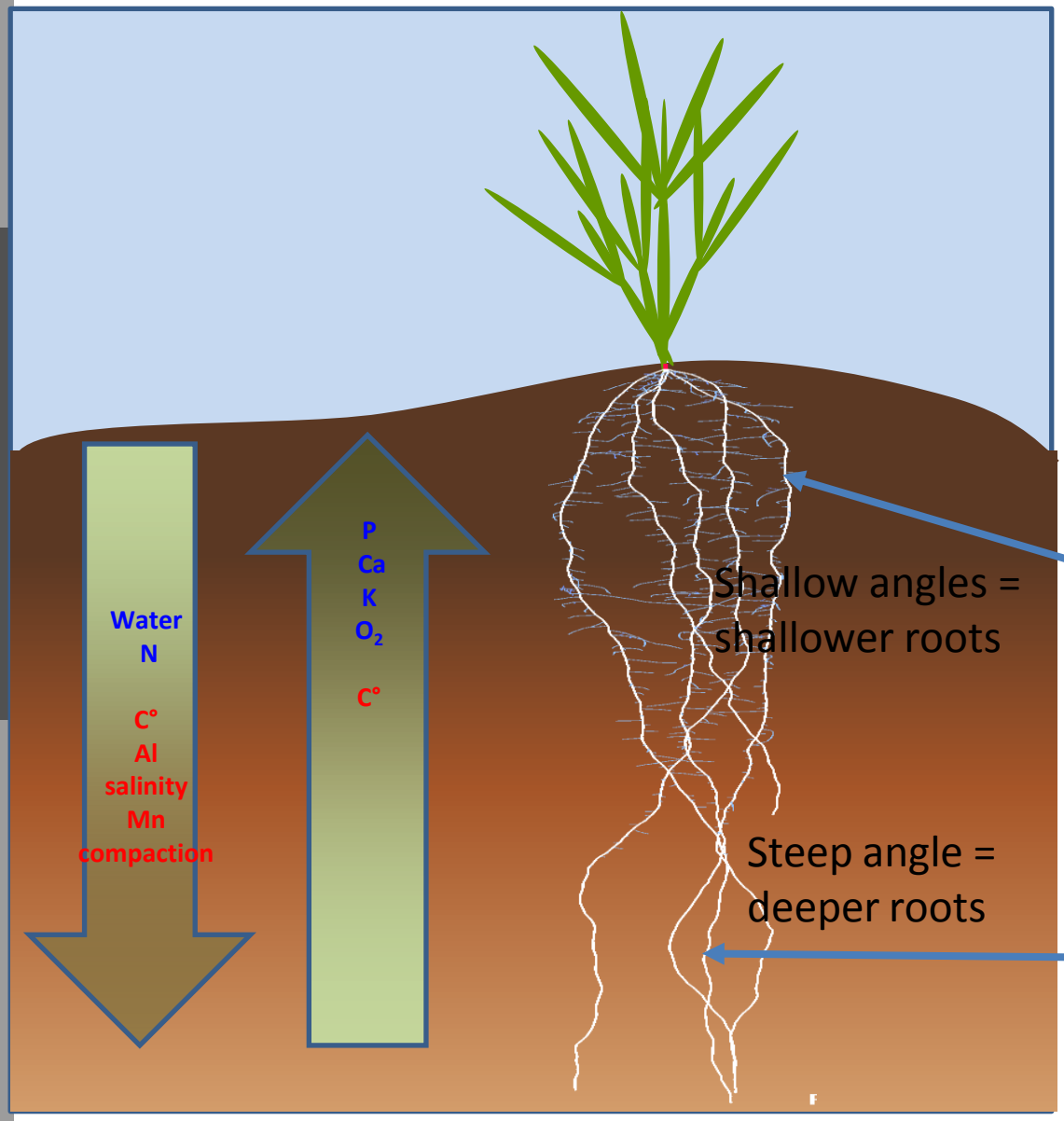
Root angle – steep vs shallow

Barley root system

Rooting depth is correlated with root angle: shallow angles – shallow root system

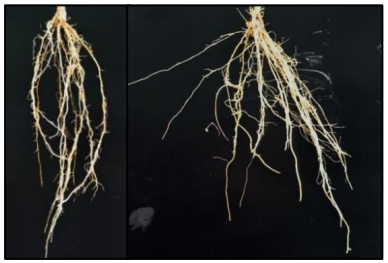
Maize root system

Soil constrains in top- and subsoils



- Plant roots encounter more constrains with depth and unequal distribution of nutrients
- Development of ideotypes e.g. shallow roots for P-acquisition in top soil

Zea mays



Hordeum vulgare

Root architecture in 2- and 3-D

FIELD

Partial root profiles

- Excavation
- Soil cores
- Trenches
- Minirhizotrons

CLIMATE CONTROLLED FACILITIES

Whole root systems and architecture

- Rhizoboxes
- Mesocosms
- Hydroponics
- Artificial media
- Growth pouches
- MRI
- Xray CT

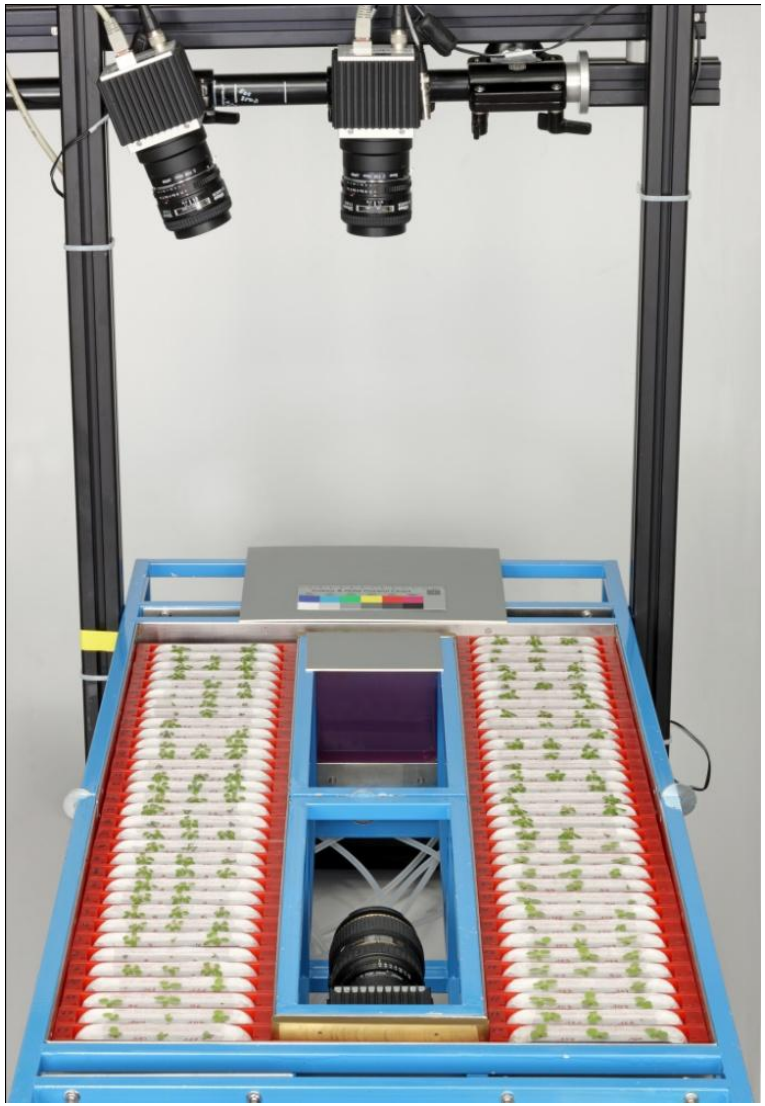
adult plants *seedlings*

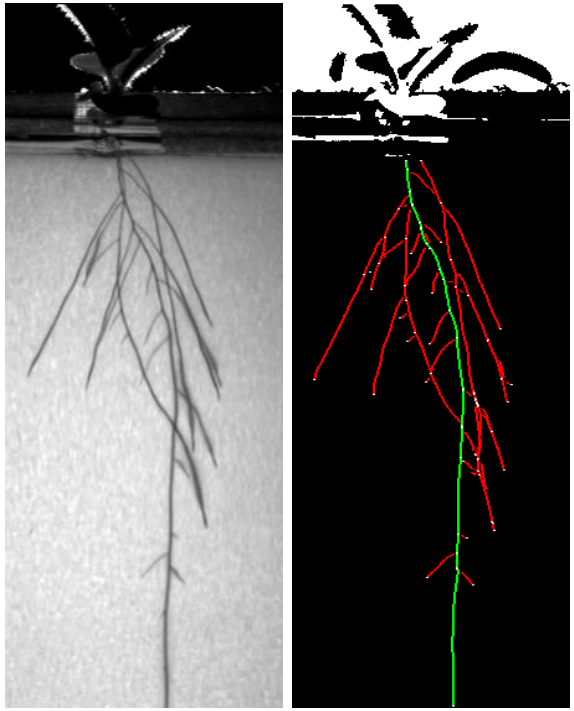
Spatial dimensions

Postma, Schurr, Fiorani (2013)

3-D imaging of roots

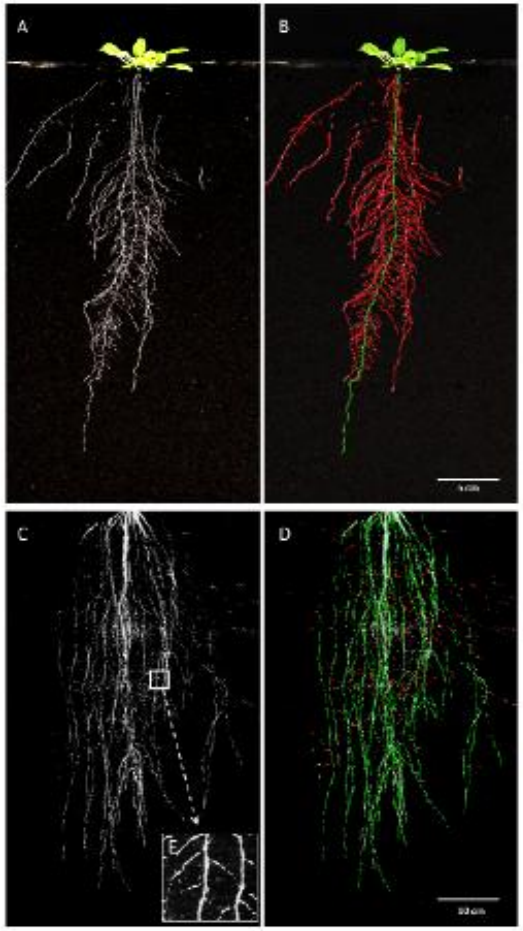
Root carousel (IBG-2)



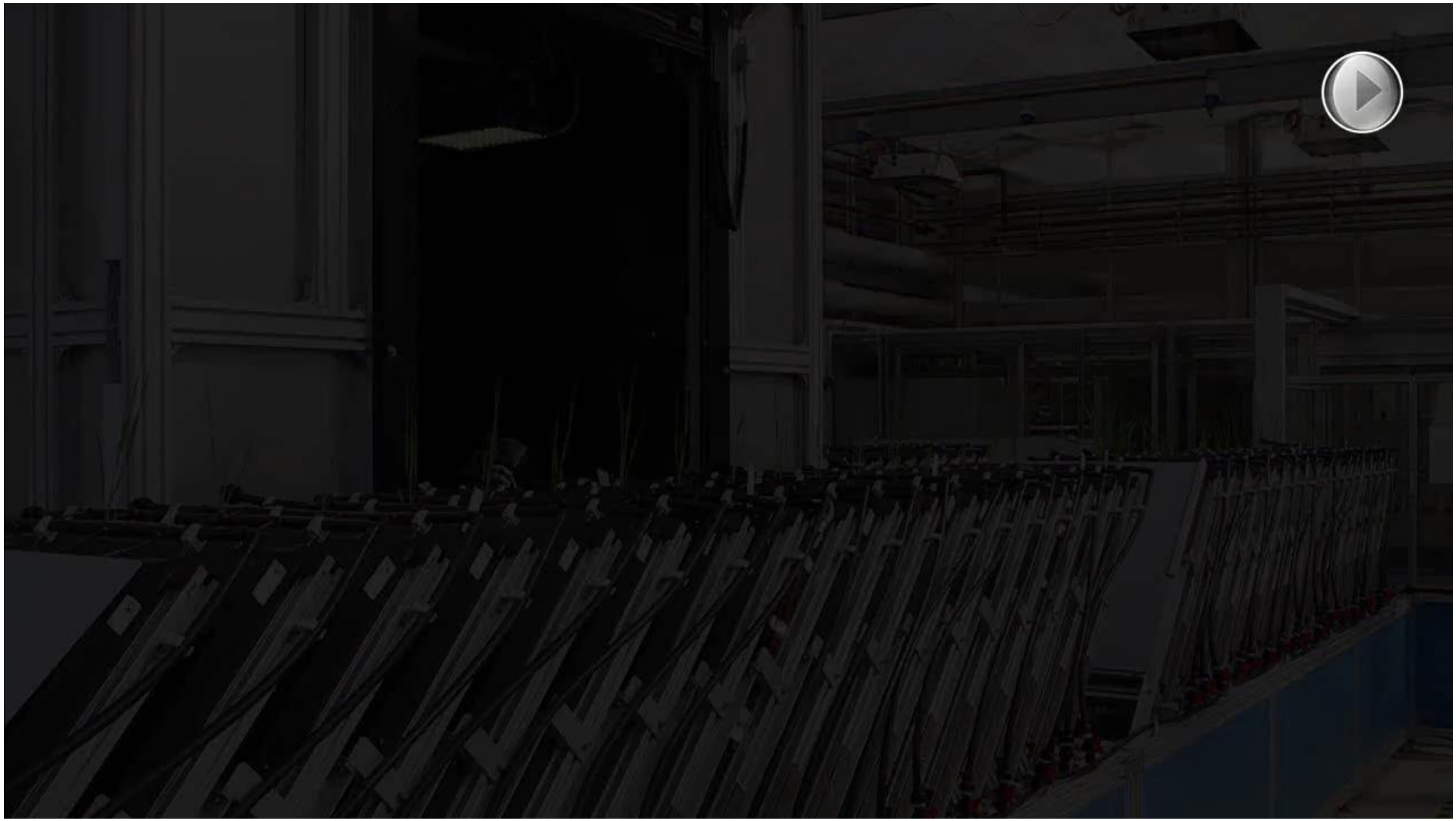


Nagel et al. (2009) *Functional Plant Biology,* 36: 947-959

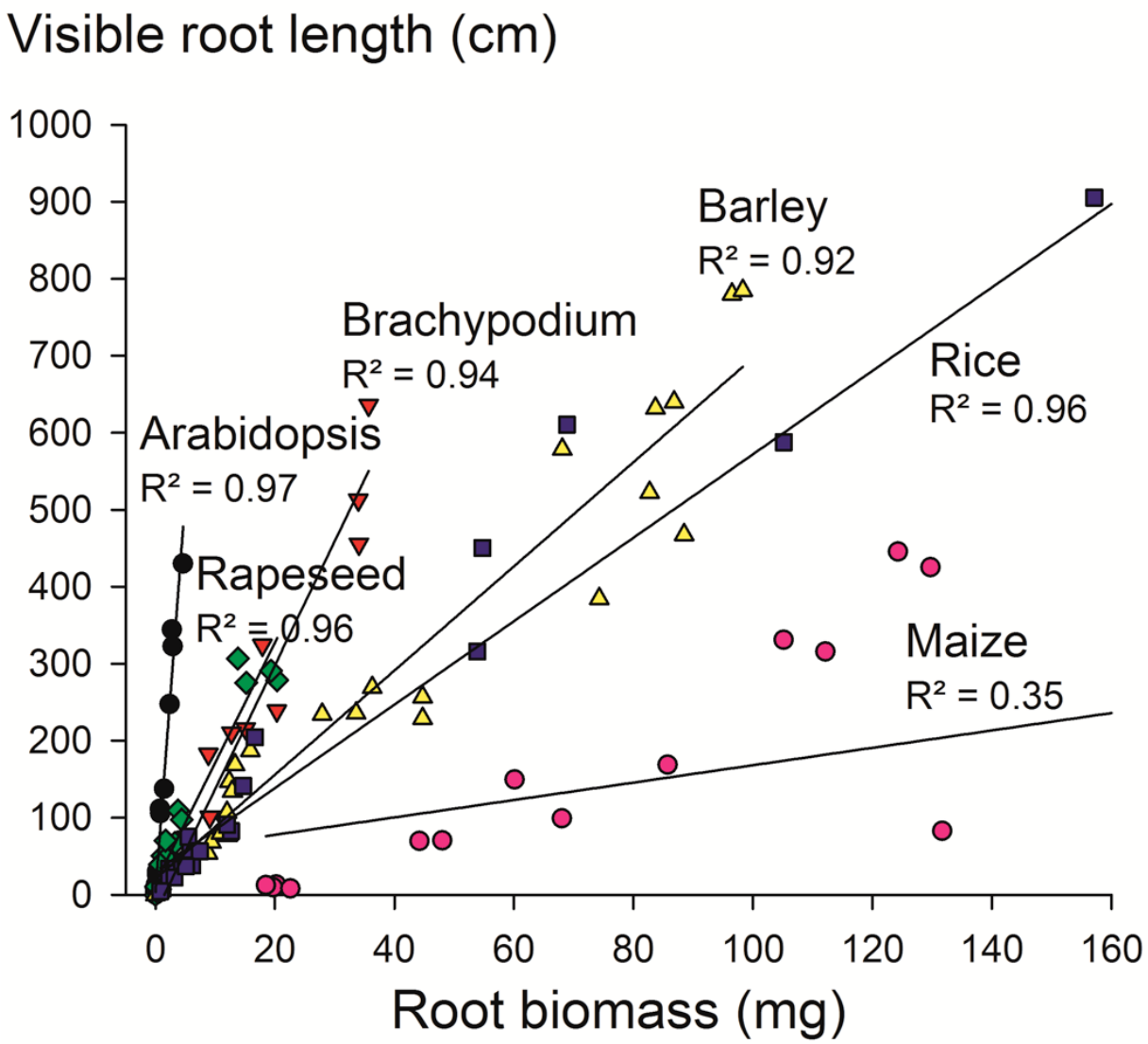
GROWSCREEN-RHIZO: a new automated system for 2D imaging of roots and shoots

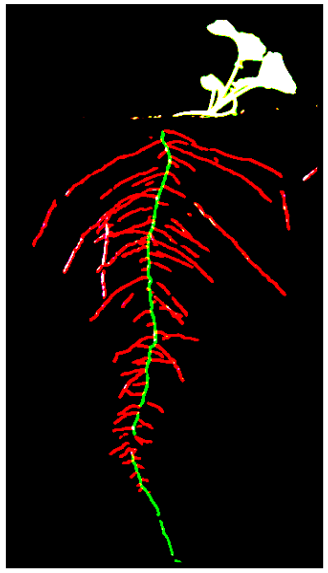


Nagel et al. 2012



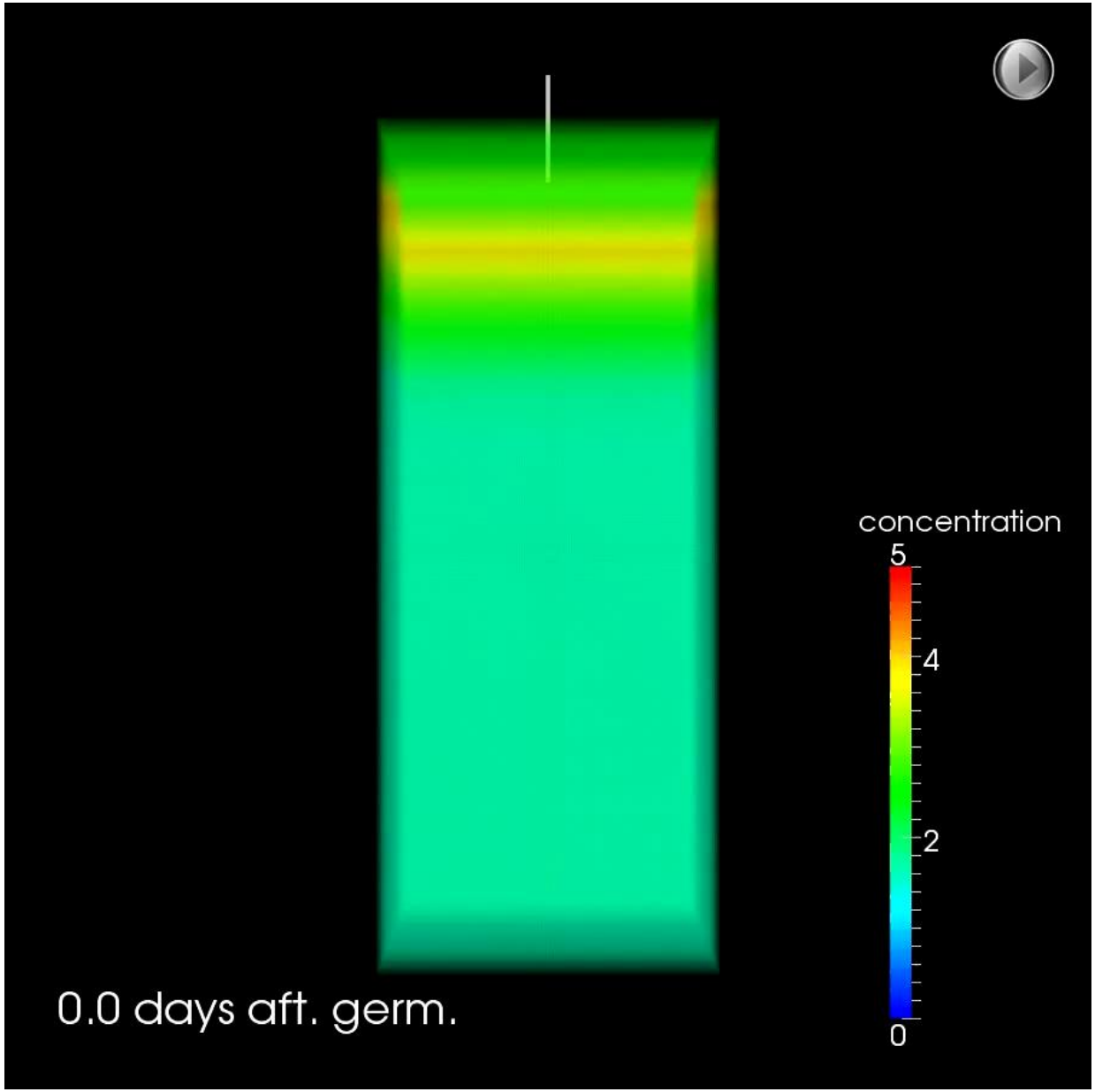
Visible root length correlates with global root parameters





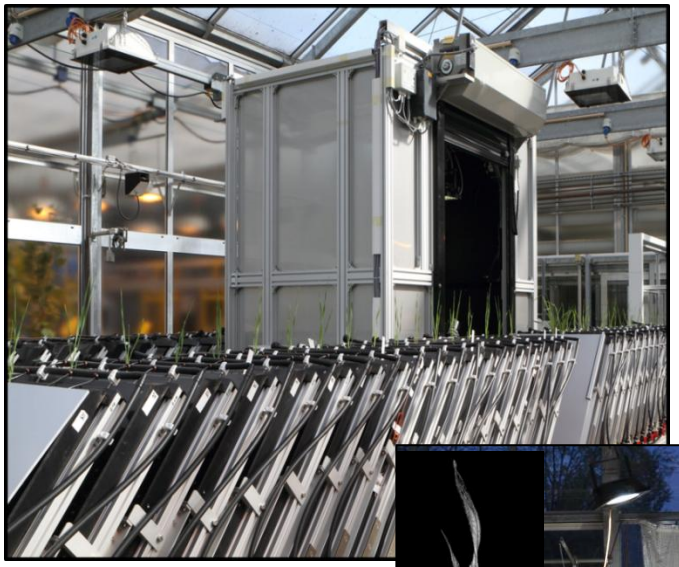
Nagel et al. 2012

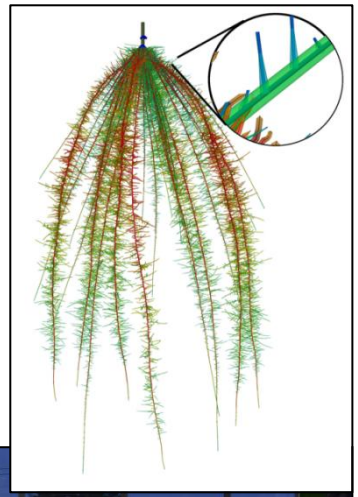
Dynamic modeling of root architecture and N dynamics

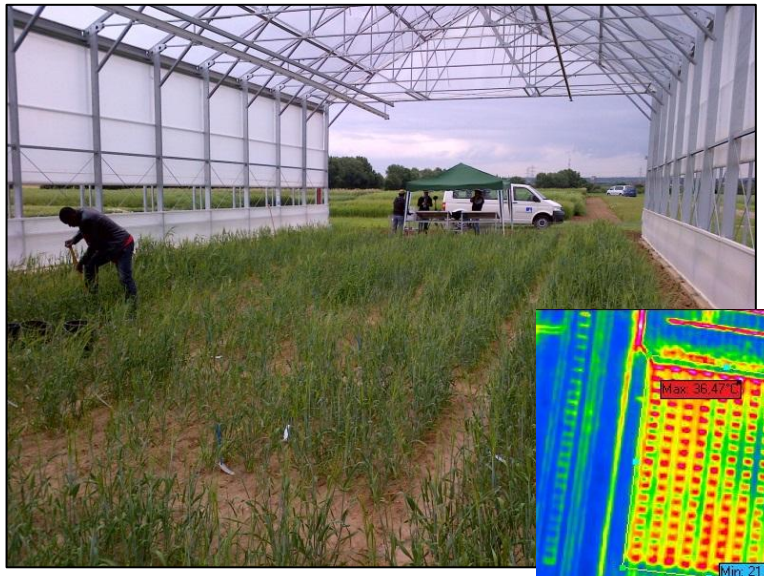


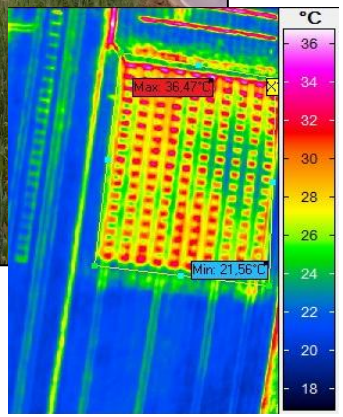
Field phenotyping of roots

- Integrates with technology at IBG-2
- Allows the screening of big plant numbers or populations (e.g. a barley diversity panel)









Field Phenotyping of roots

Plant Soil (2011) 341:75–87
DOI 10.1007/s11104-010-0623-8

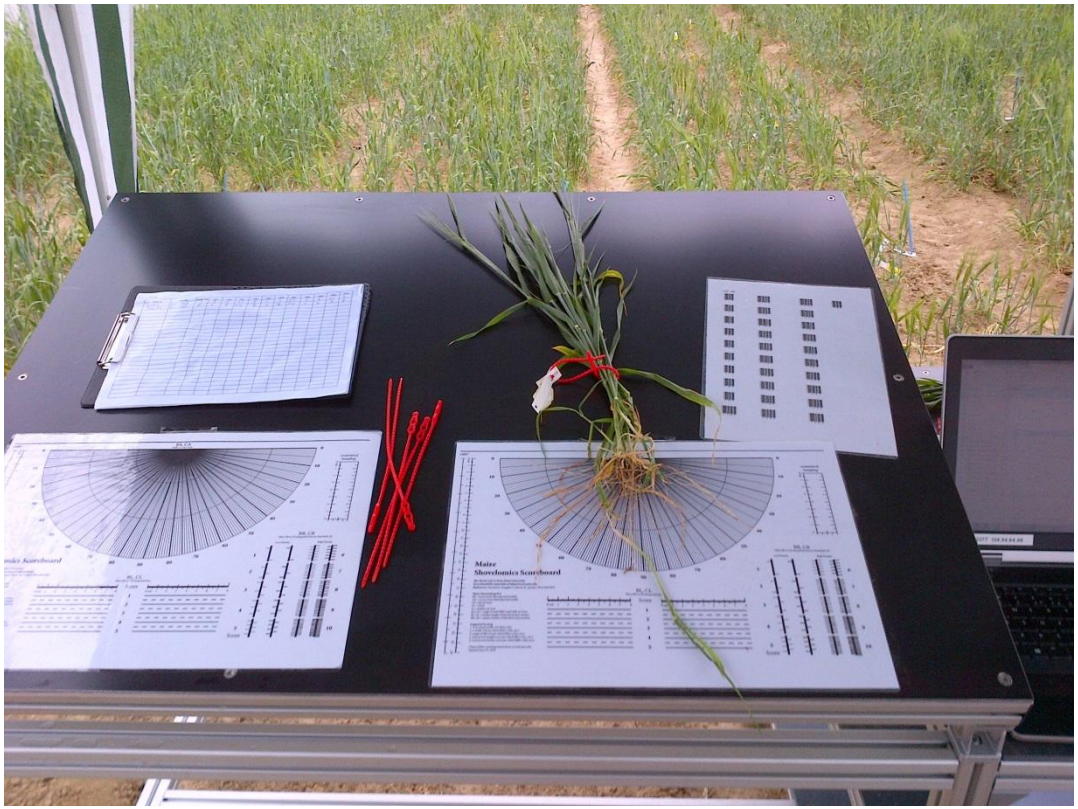
REGULAR ARTICLE

Shovelomics: high throughput phenotyping of maize (*Zea mays* L.) root architecture in the field

Samuel Trachsel · Shawn M. Kaeppler · Kathleen M. Brown · Jonathan P. Lynch

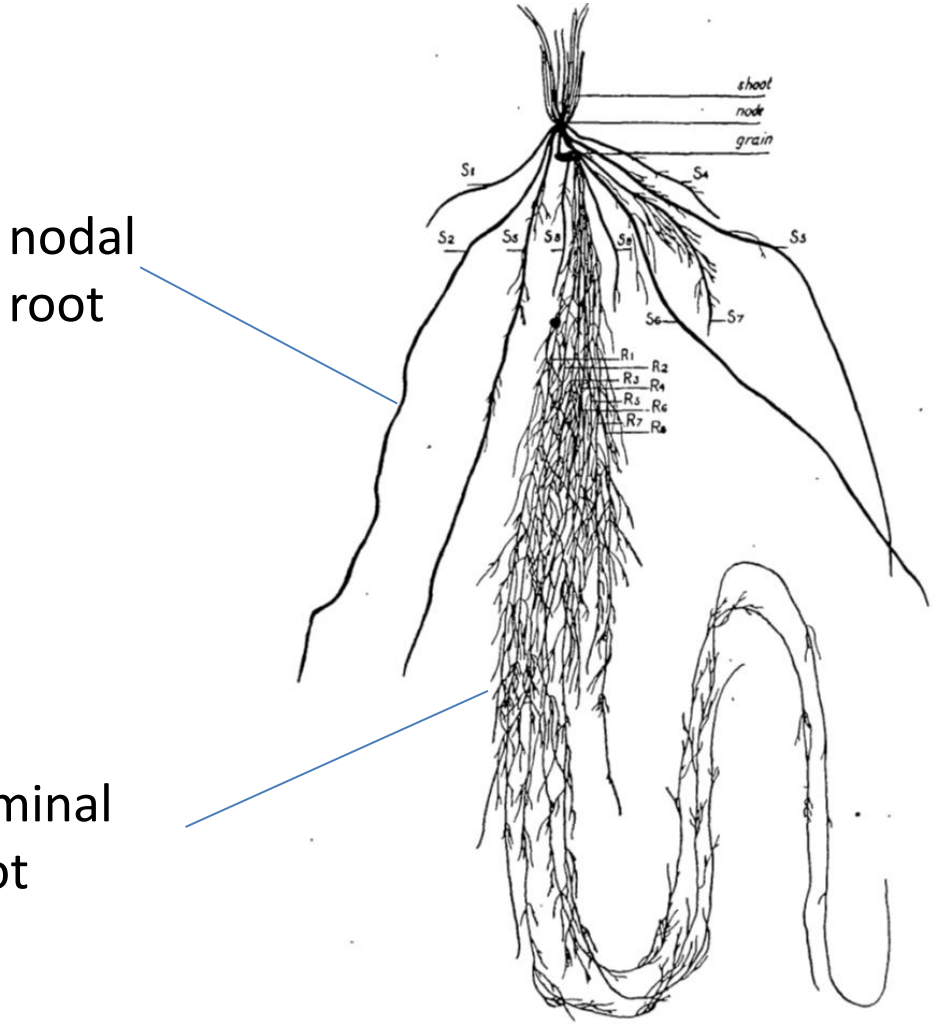
'Shovelomics' is a 'low-tech' high-throughput method, which allows to phenotype root crowns of single plants in great plant population of tropical and temperate grasses, legumes, and fobs

Manual Measurements

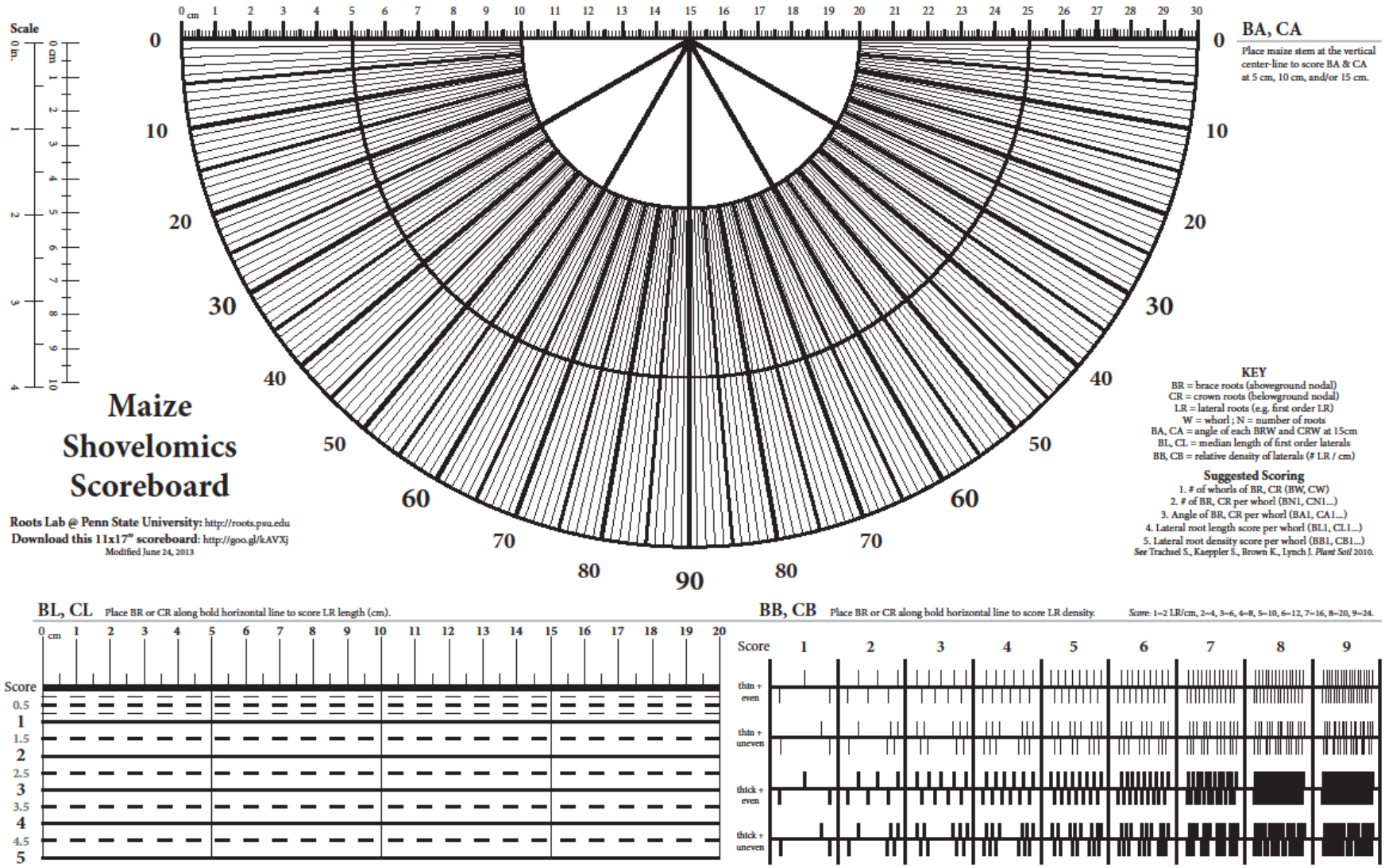


Visual scoring:

- Root classes (seminal and nodal roots)
- Root numbers
- Branching density
- Root angles

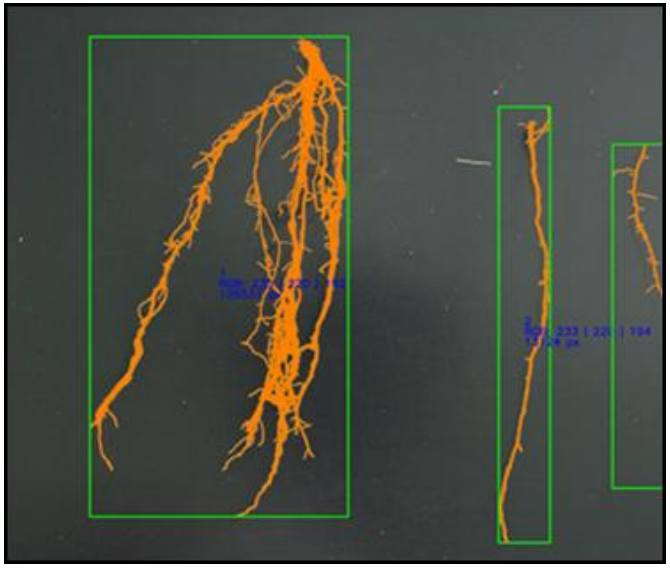


Score board

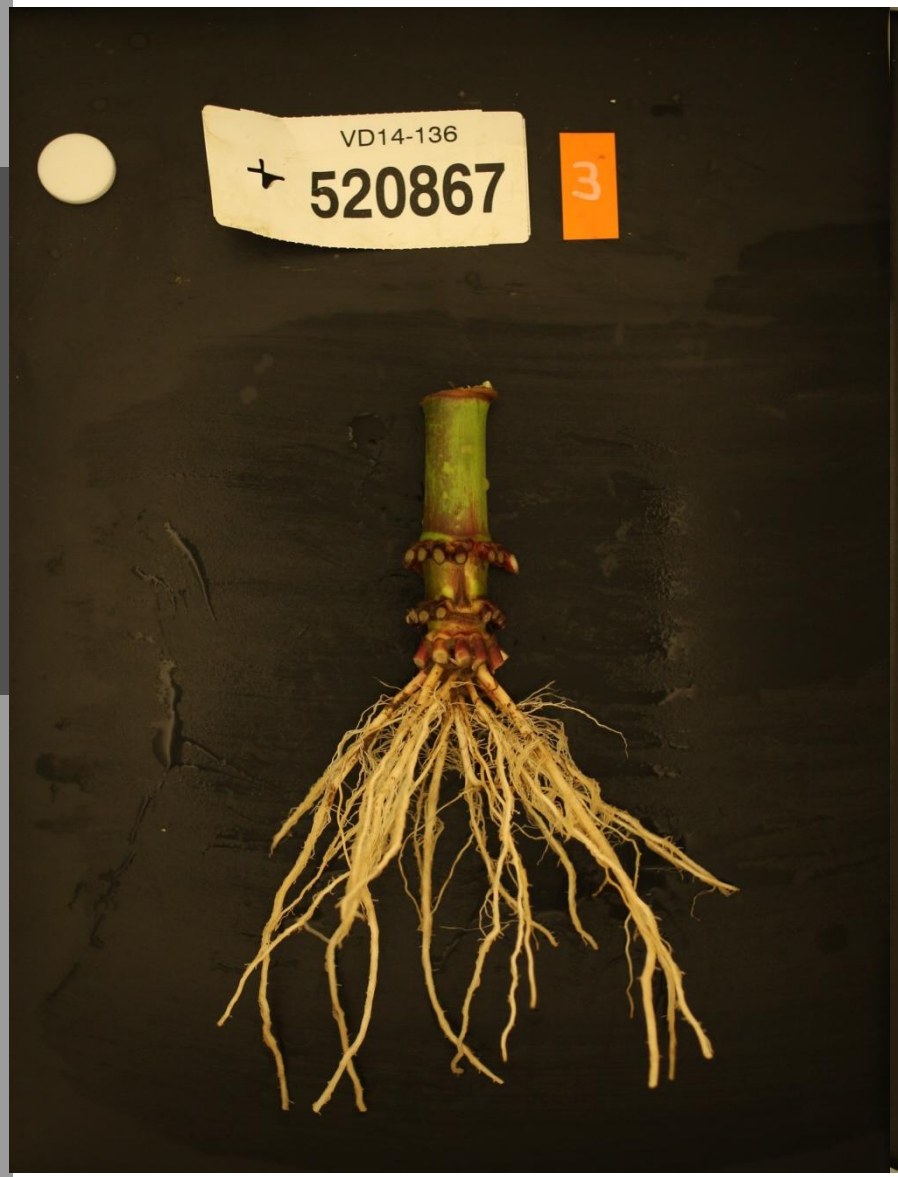


Manual Measurements

Measurement



Complex root system



Data evaluation using DIRT software

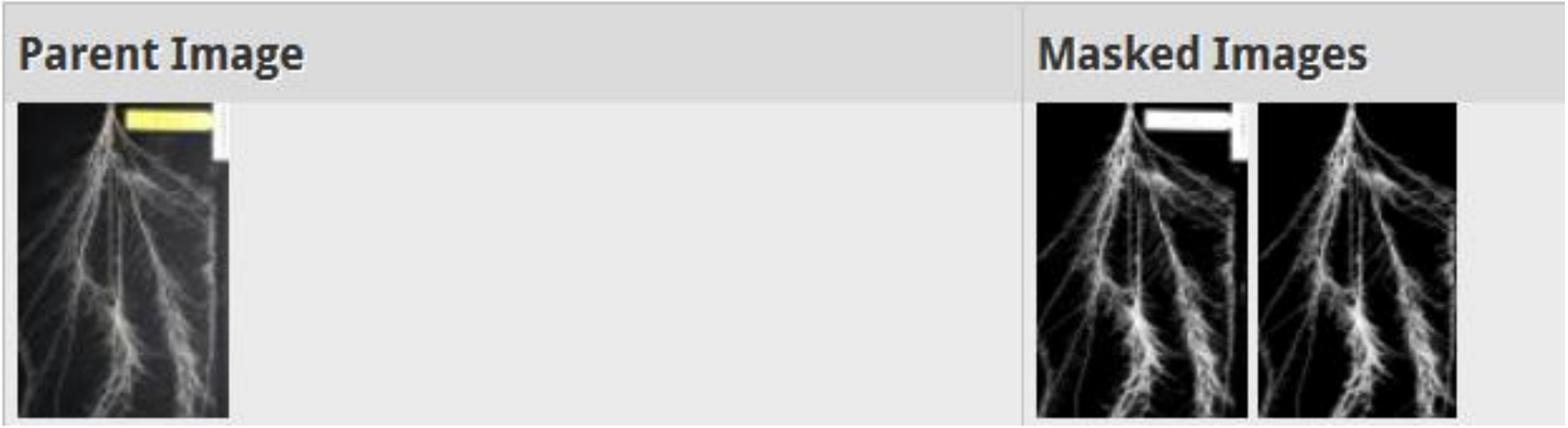
Breakthrough Technologies

Image-Based High-Throughput Field Phenotyping of Crop Roots[1][W][OPEN]

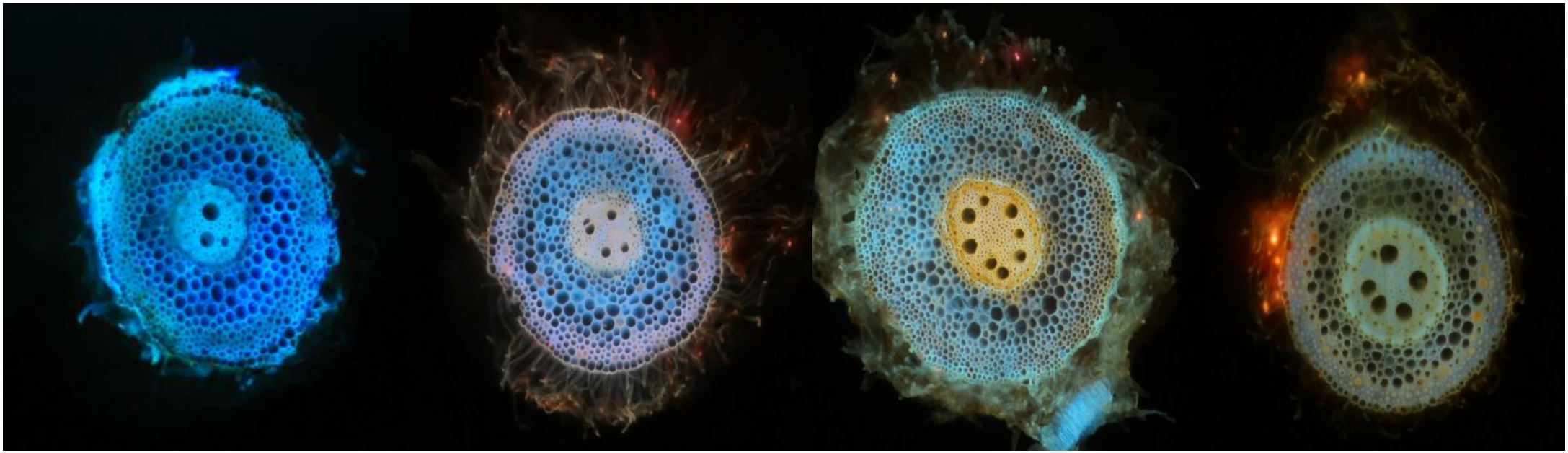
Alexander Bucksch[2]*, James Burridge[2], Larry M. York, Abhiram Das, Eric Nord, Joshua S. Weitz, and Jonathan P. Lynch

Schools of Biology (A.B., A.D. J.S.W.), Interactive Computing (A.B.), and Physics (J.S.W.), Georgia Institute of Technology, Atlanta, Georgia 30332; and Department of Plant Science (J.B., L.M.Y., E.N., J.P.L.) and Intercollege Graduate Degree Program in Ecology (L.M.Y.), Pennsylvania State University, University Park, Pennsylvania 16801

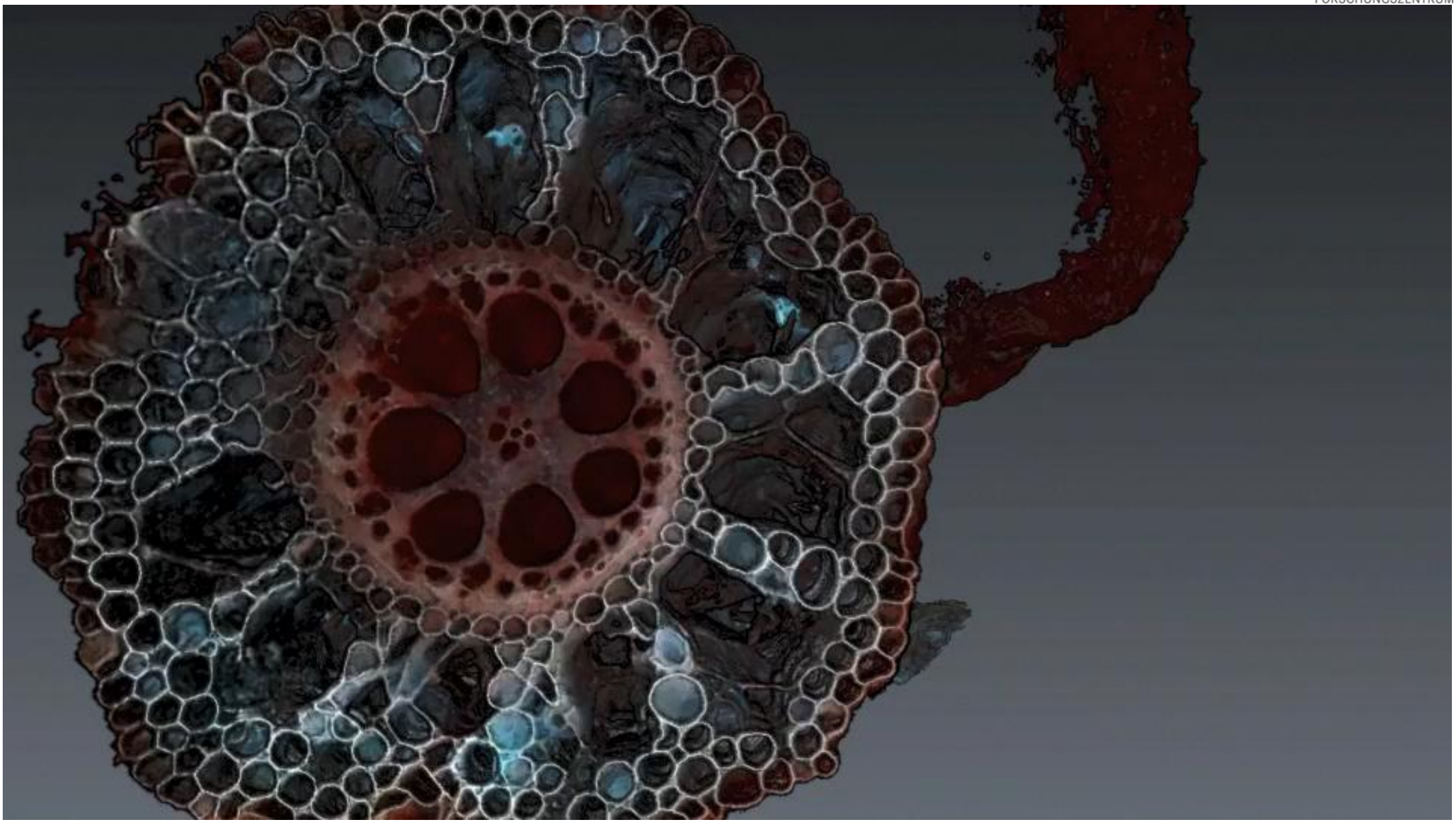
ORCID IDs: 0000-0002-1071-5355 (A.B.); 0000-0002-2593-3072 (E.N.); 0000-0002-3433-8312 (J.S.W.).



Variation of anatomical root traits



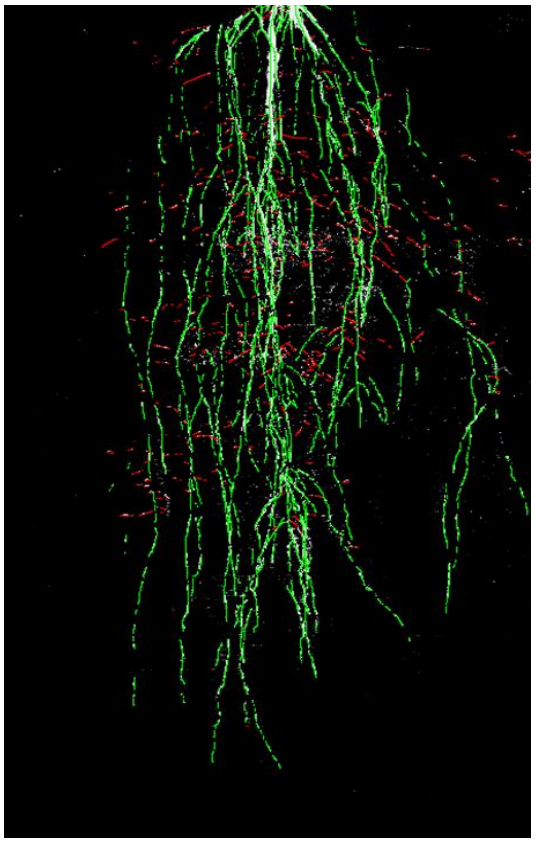
Nodal roots of barley plants
from a barley diversity panel



Laser ablation technology by PSU

Shoot traits

Root traits



Field proximal and remote sensing methods at IBG2

(presentation Francisco Pinto)

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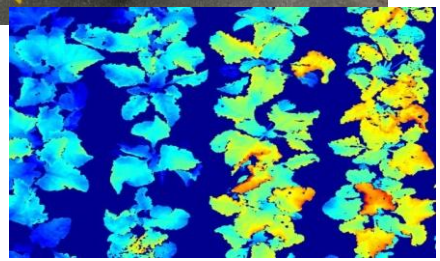
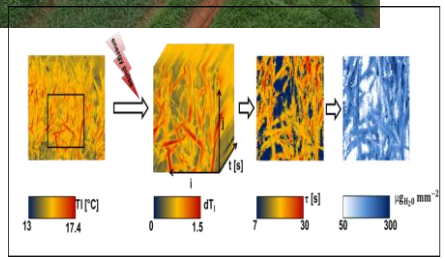
Field-Mobile

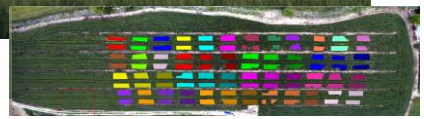


Field-Lift

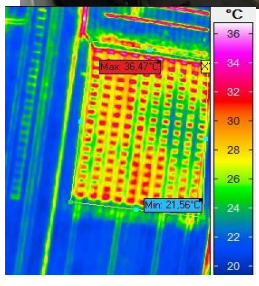


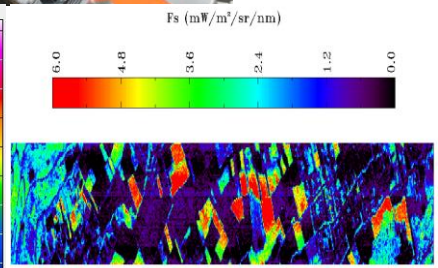
Field-Bee

Field-Ship

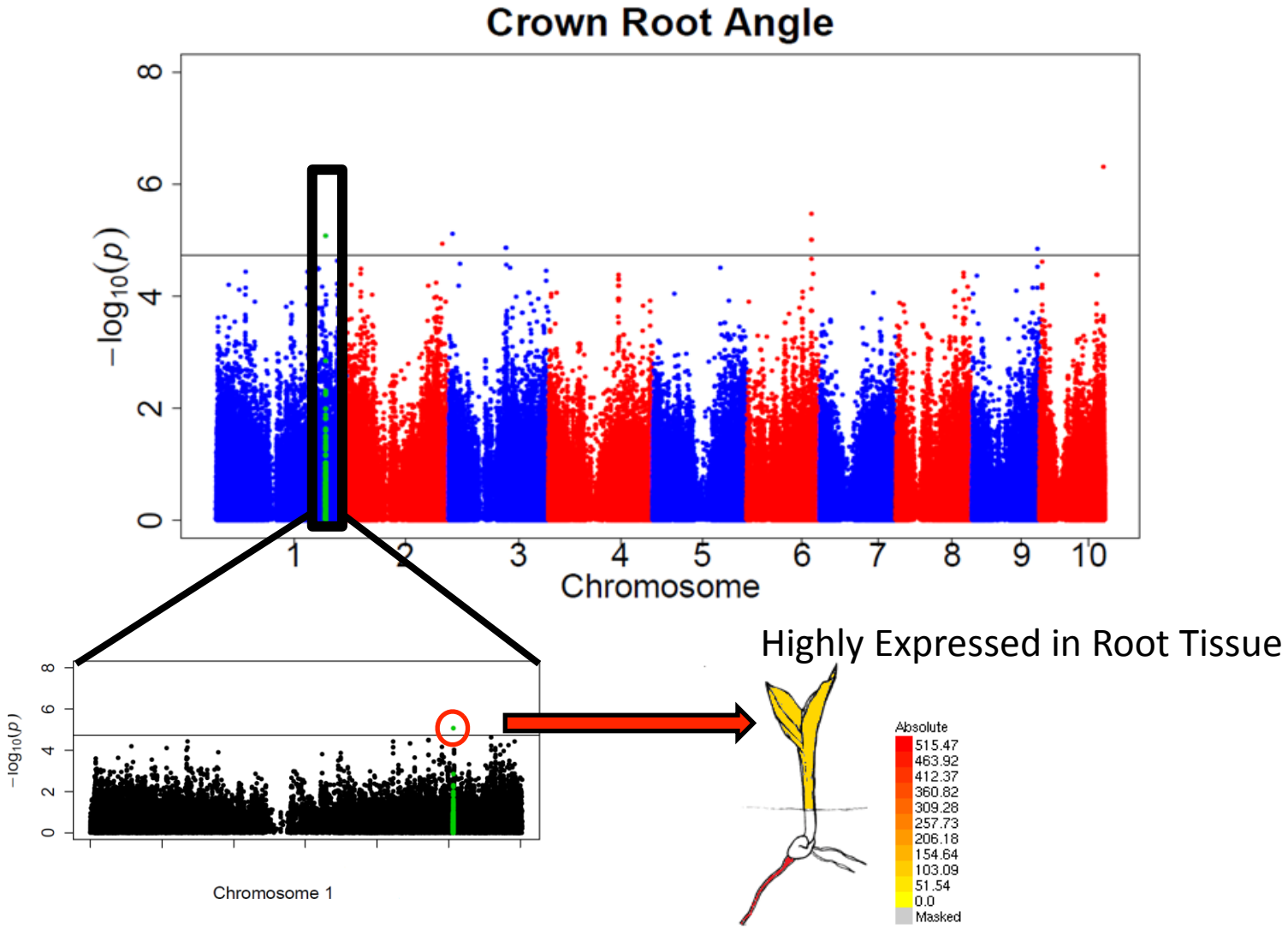


HyPlant



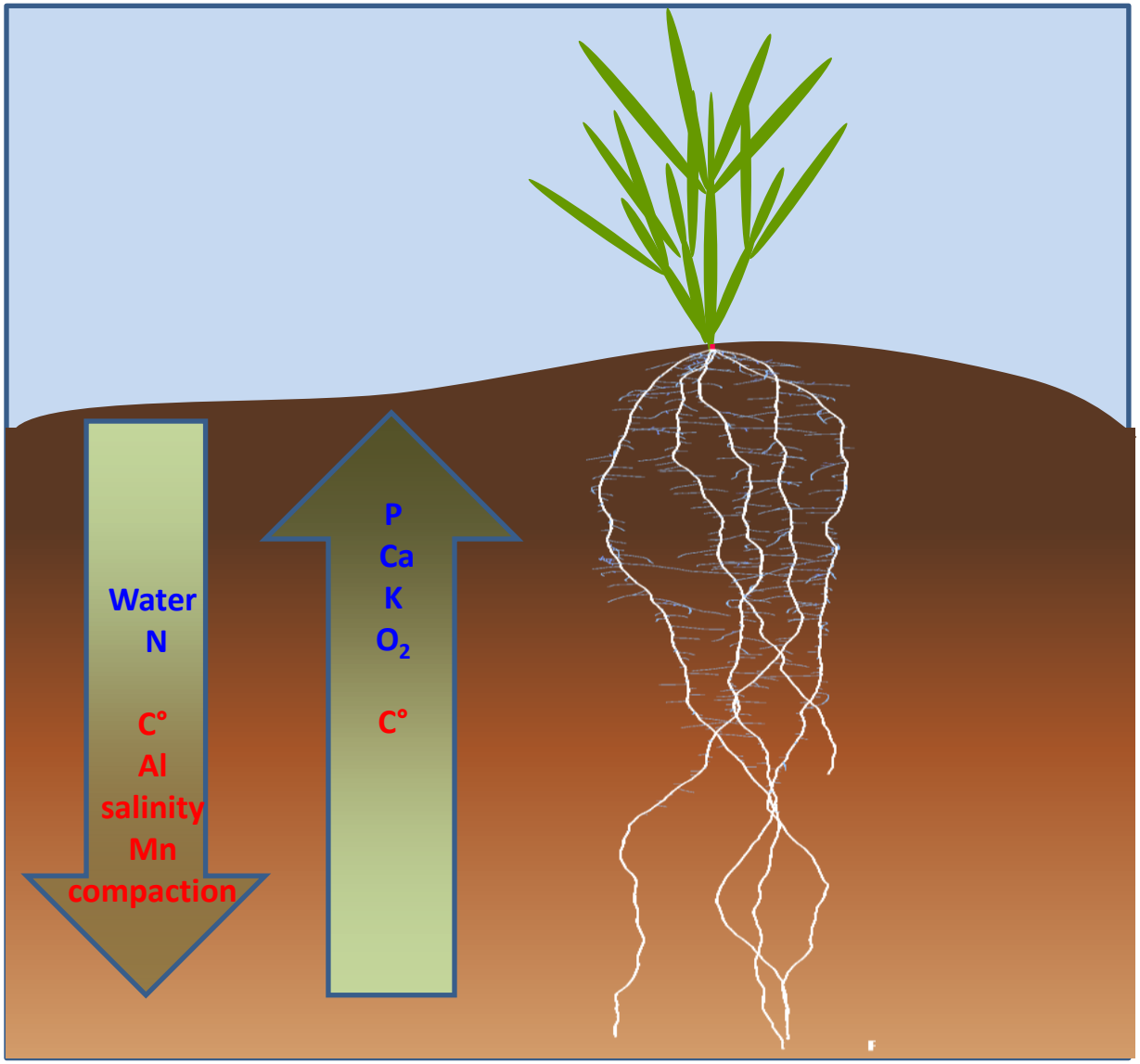


Gene / loci discovery



research of Hannah Schneider (FZJ / PSU)

Soil constrains in deeper soils



Plant roots encounter more constrains with depth and unequal distribution of nutrients

Pre-breeding example (root traits)

1987- 20 years (with several seasons/year) of screening elite lines for P efficiency failed to beat Carioca