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4PMI: Plant Phenotyping Platform for Plant and Microorganisms Interactions Phenotyping innovations, opportunities and challenges

Christophe Salon, Céline Bernard, Mickaël Lamboeuf, Christian Jeudy

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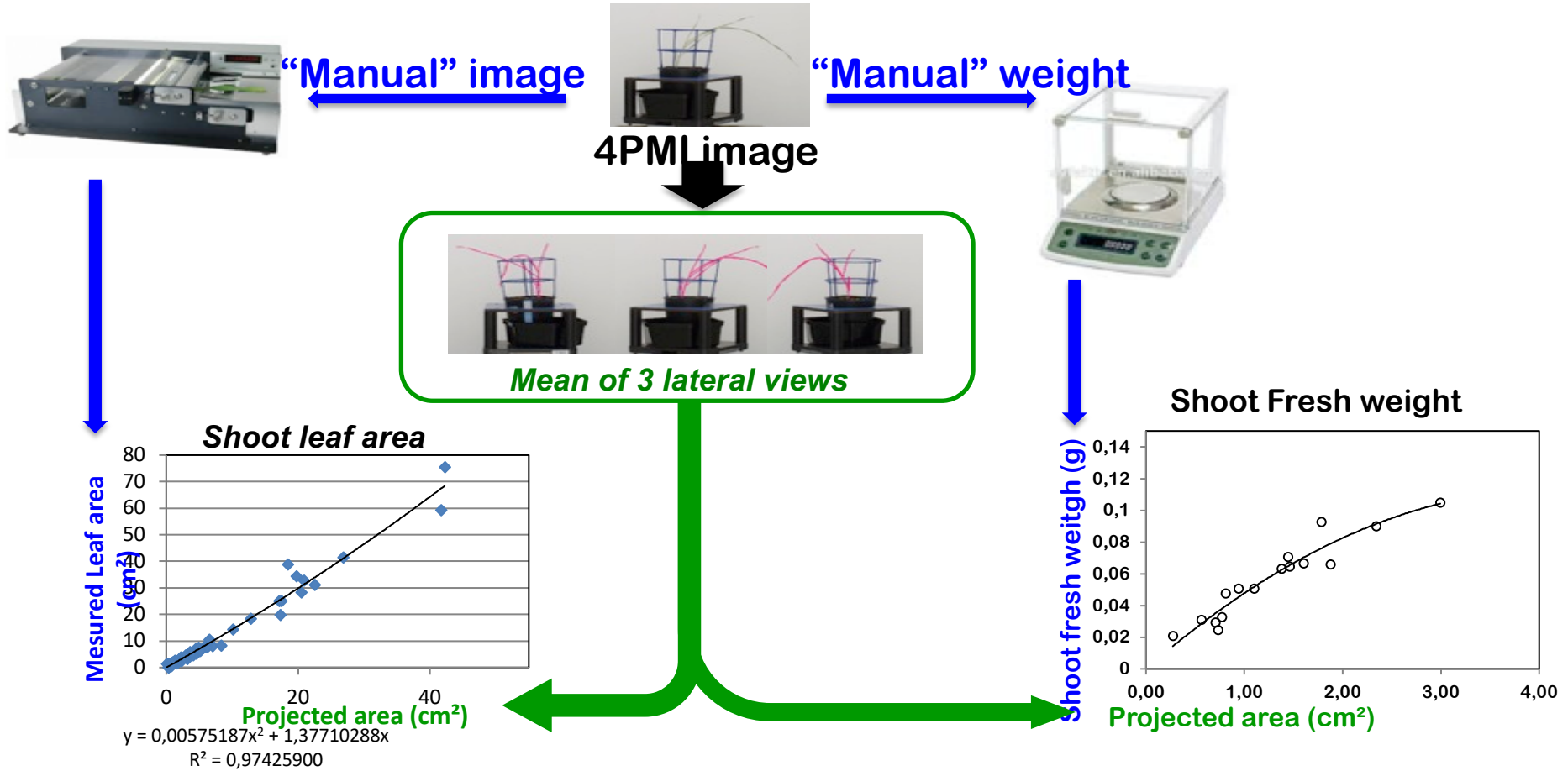
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4PMI: Plant Phenotyping Platform for Plant and Microorganisms Interactions

**Phenotyping innovations, opportunities and challenges
(Christophe Salon, Céline Bernard, Mickael Lamboeuf, Christian Jeudy,
UMR Agroécologie, INRA, Dijon, France)**





Choice of best image acquisition model !

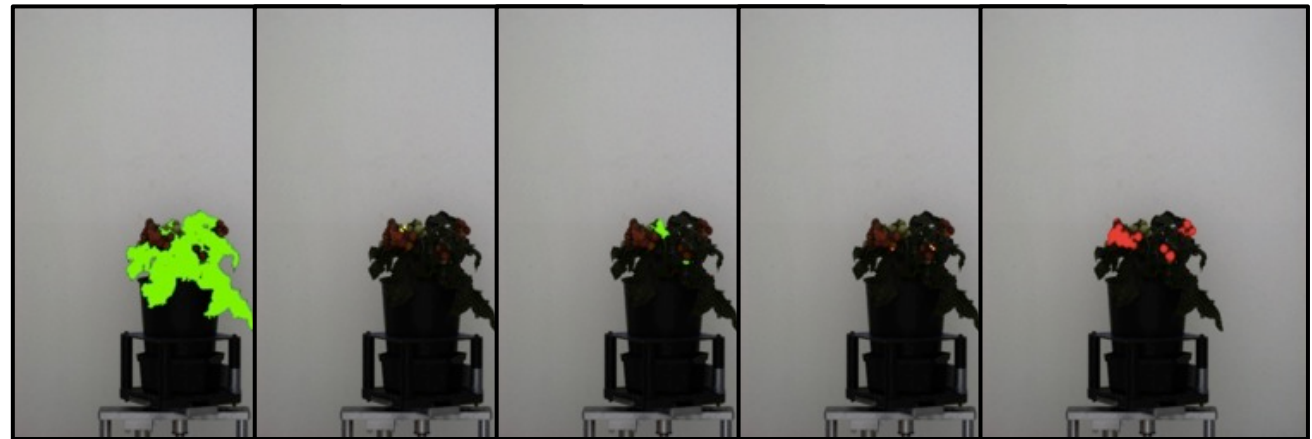
Micro tom phenotyping, coll. C Rothan (BFP Bordeaux, France)



Tomato in pots



Original image



Segmentation

Leaf

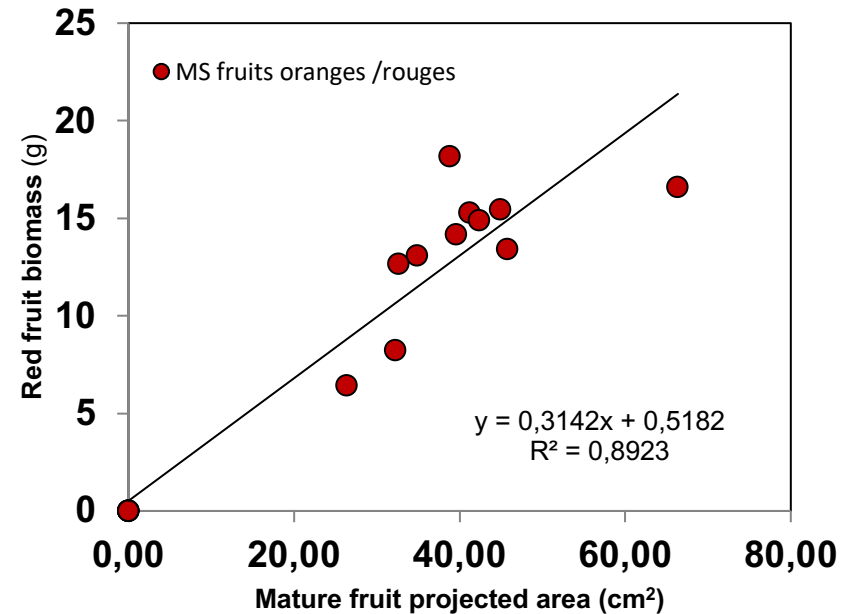
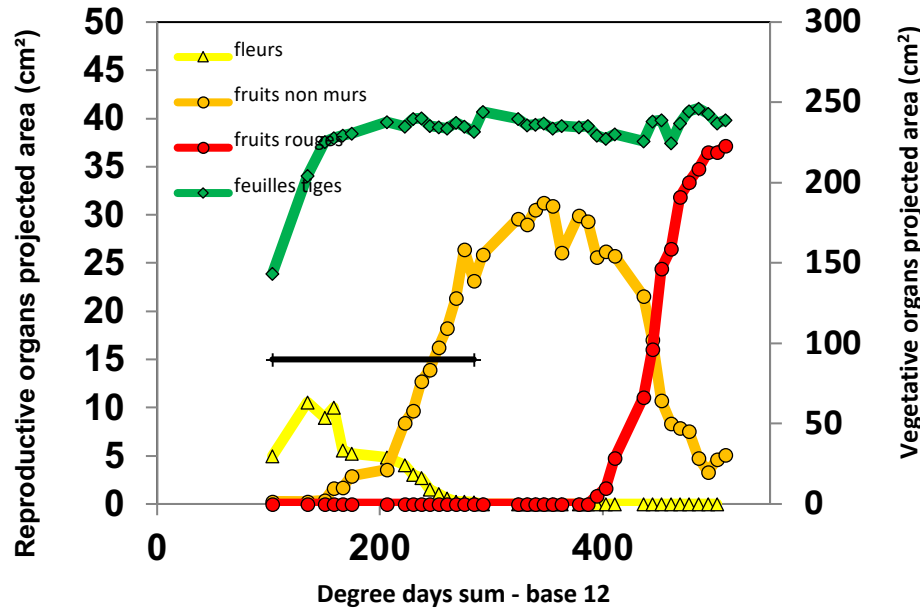
Flowers

Green fruit

Orange fruits

Red fruits

Micro tom phenotyping, coll. C Rothan (BFP Bordeaux, France)



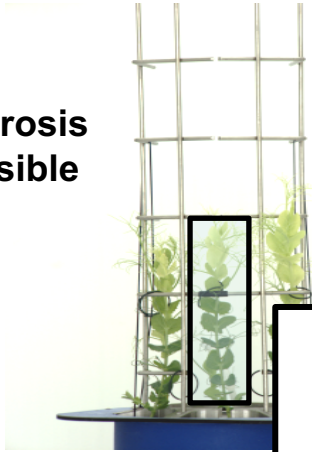
- Phenology and fruit maturing followed non destructively from image analysis.

- Fruit detection realized = f(image analysis).

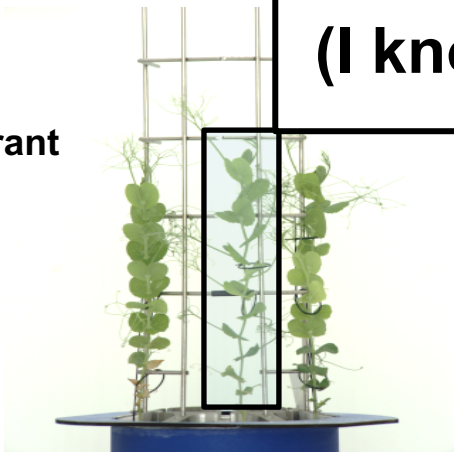


PEA plants

Chlorosis
Sensible



Tolerant



1800 plants capacity !
 (I know..., that's less than Trevor's PF..)

Algorithms to identify symptoms on 300 genotypes

Root phenotyping: why go into trouble ?

➤ **Crop breeding programmes:** root traits rarely used as selection criteria, a focus on adaptation to high-input systems,



Improve crop resource-use efficiency through:

- (i) physiological utilization of acquired resources,
- (ii) resource acquisition

➤ **Technical difficulties:**

- Access to roots ,
- Root diversity,
- Plasticity of RSA (abiotic and biotic factors including plant and microorganisms interactions) in order to enhance its efficiency.

We wish:

- To visualize (harvest) roots, at high resolution, dynamically and non destructively, for a large number of biological units, various species.
- To estimate structural (and functional?) traits, avoid shading roots, oxygen shortage and pH, nutrient unregulated conditions
- To study plant-plant and plant-microorganism interactions

...and access various descriptors of RSA:

First priority

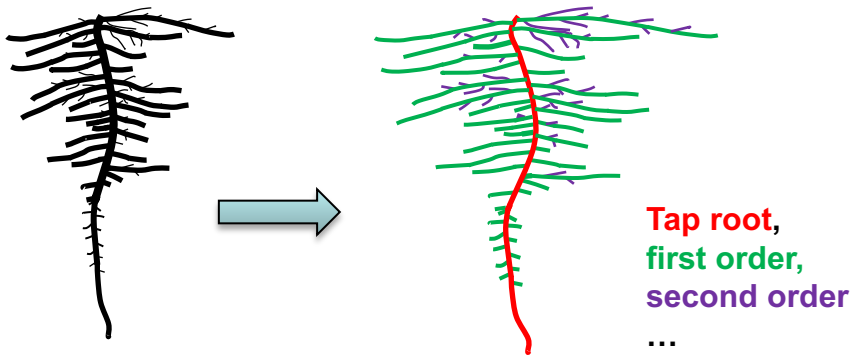
Root projected area
Nodule projected area
Nodule number
Total root length
Root depth, prospection

then

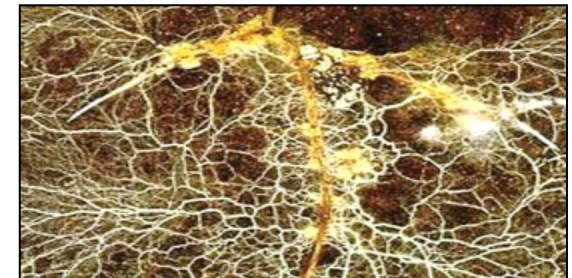
Main and lateral root length
Number of lateral roots, of secondary roots on lateral roots
Number and position of nodules on each root
Apical diameter of roots

Notes:


Number: total, by segment-segment length
Projected area: individual, by class
Position: individual, by class
Nodule efficiency: individual, by class
Estimated biovolume: a root \neq cylinder
Biomass estimation: calibration



Also structures arising from plants and microorganisms : nodules, mycorrhiza



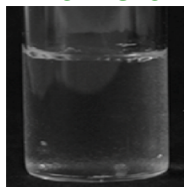
Soil



Growth pouches



Artificial



Downie et al. 2012
DOI: 10.1371/journal.pone.0044276

Agar plates, petri dishes



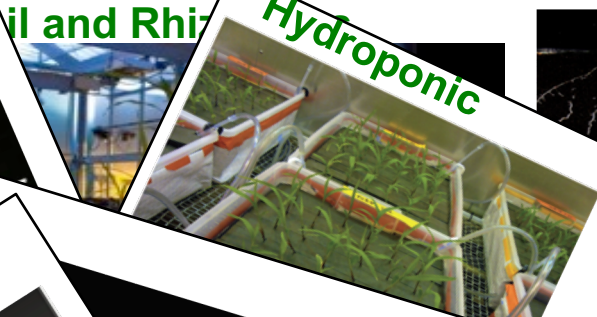
Hargreaves
Plant and
297.

X Ray tomography



Mooney et al. 2012. Plant Soil, 352:1-22
Moradi et al. Plant Soil (2009) 318:2

Hydroponic

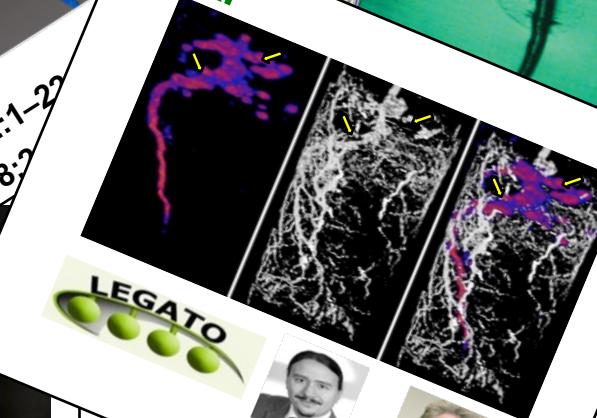


Tube




P. 10:1096-1108

MRI



LEGATO

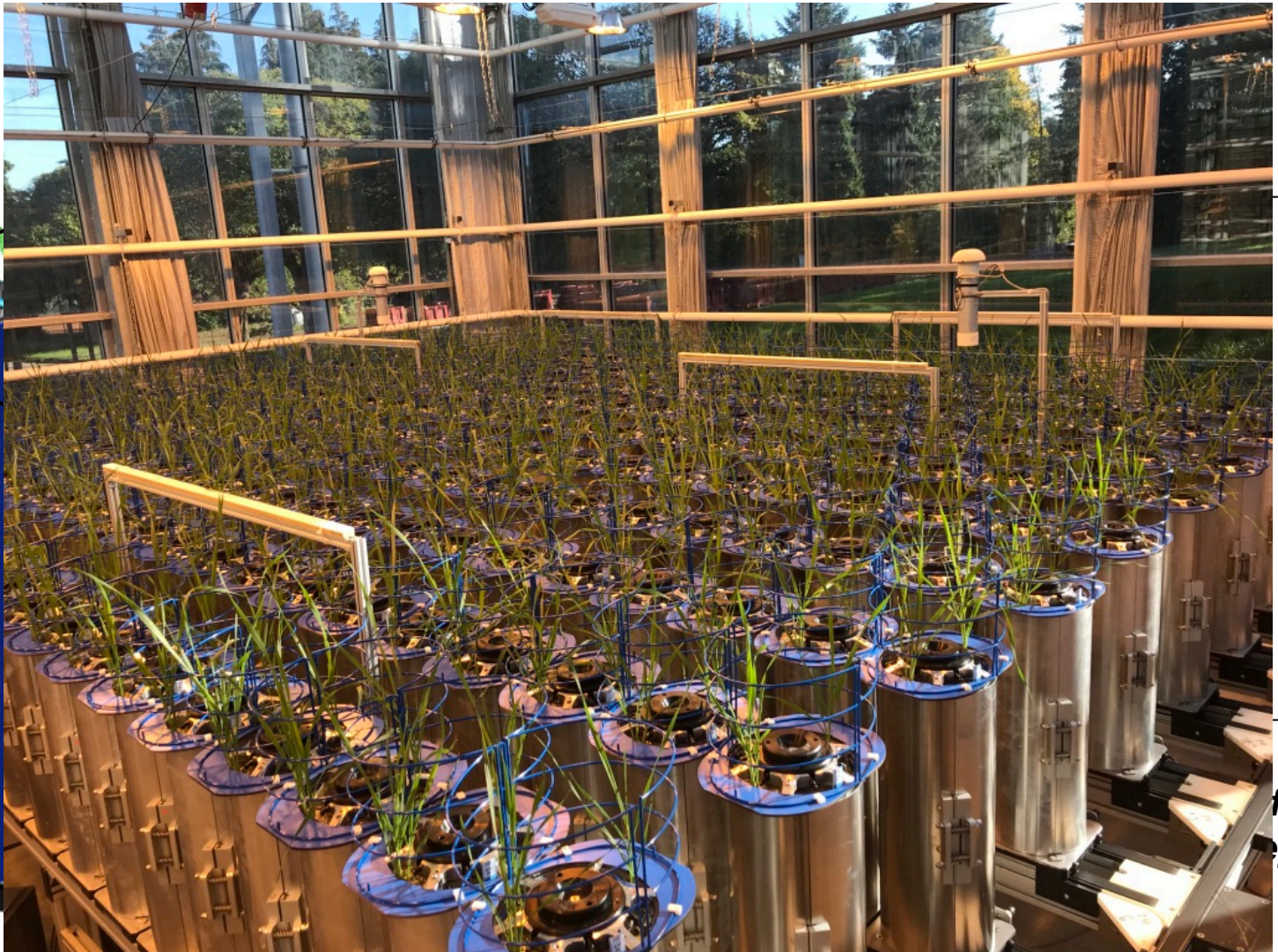


C. Windt R. Metzner

Clark et al. 2011. P. 156:455-465.

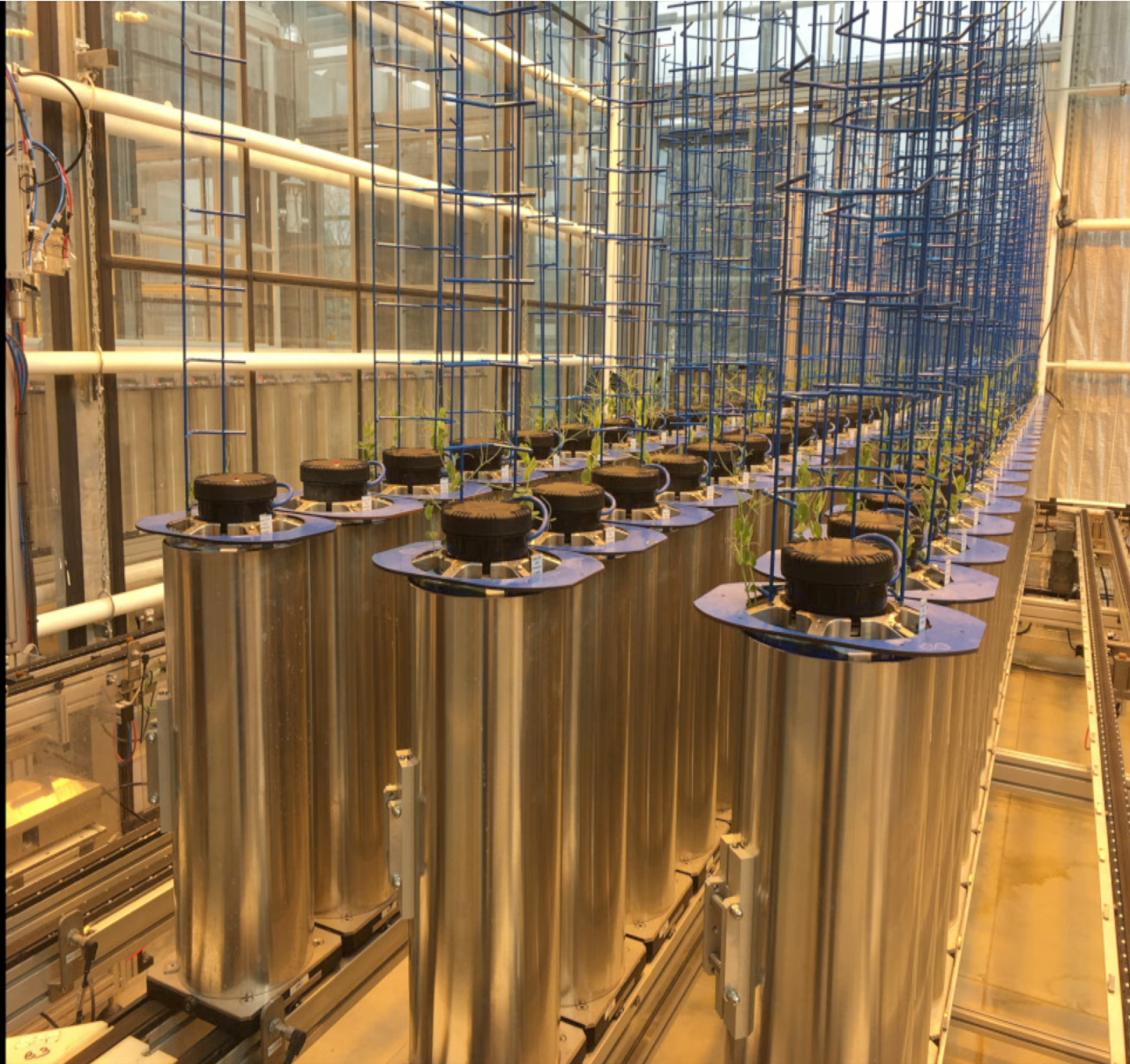
I give up counting slides...

RhizoTube: the concept

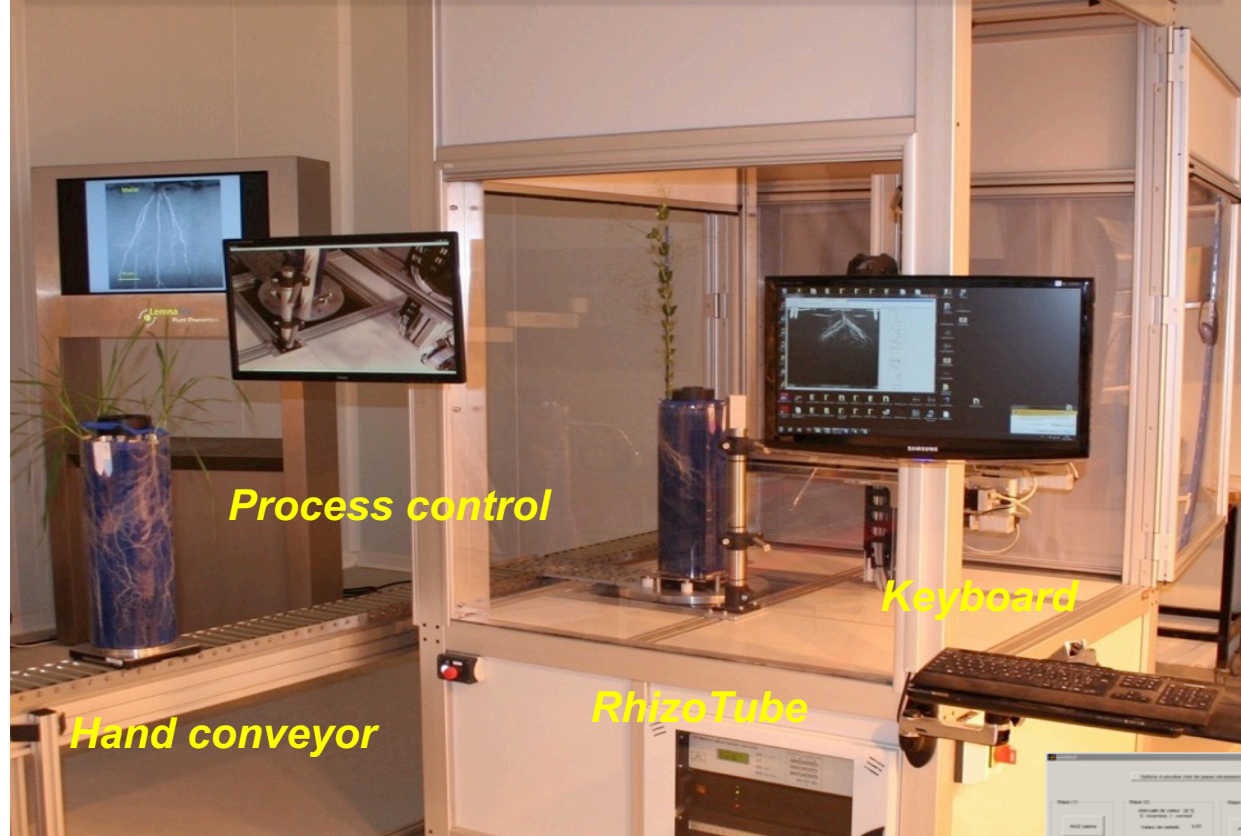


S

for
eyors



Patent INRA-InoviaFlow-Shakti

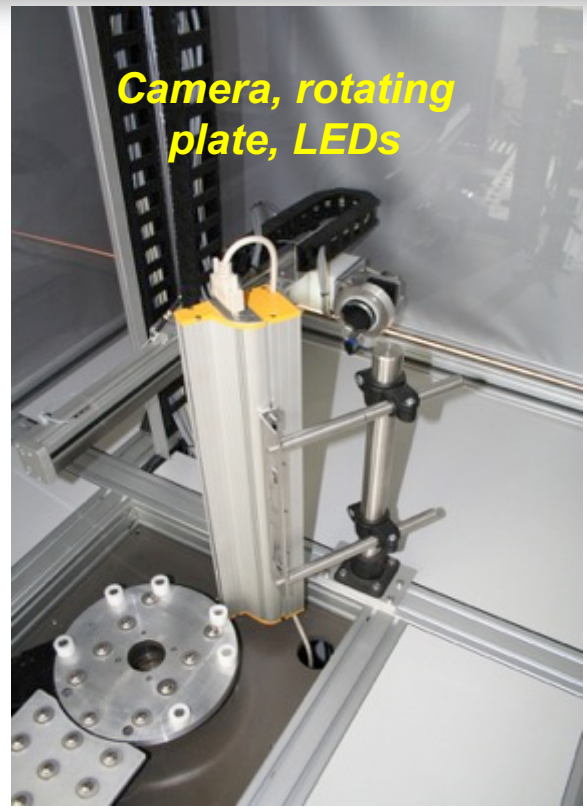


Process control

Keyboard

Hand conveyor

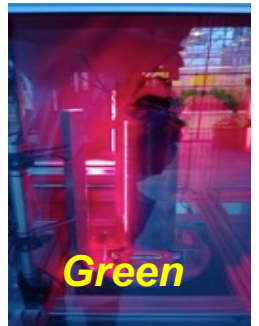
RhizoTube



Camera, rotating plate, LEDs



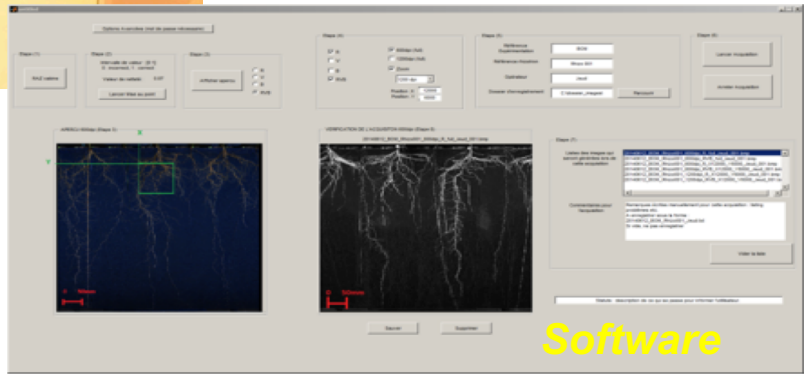
Red



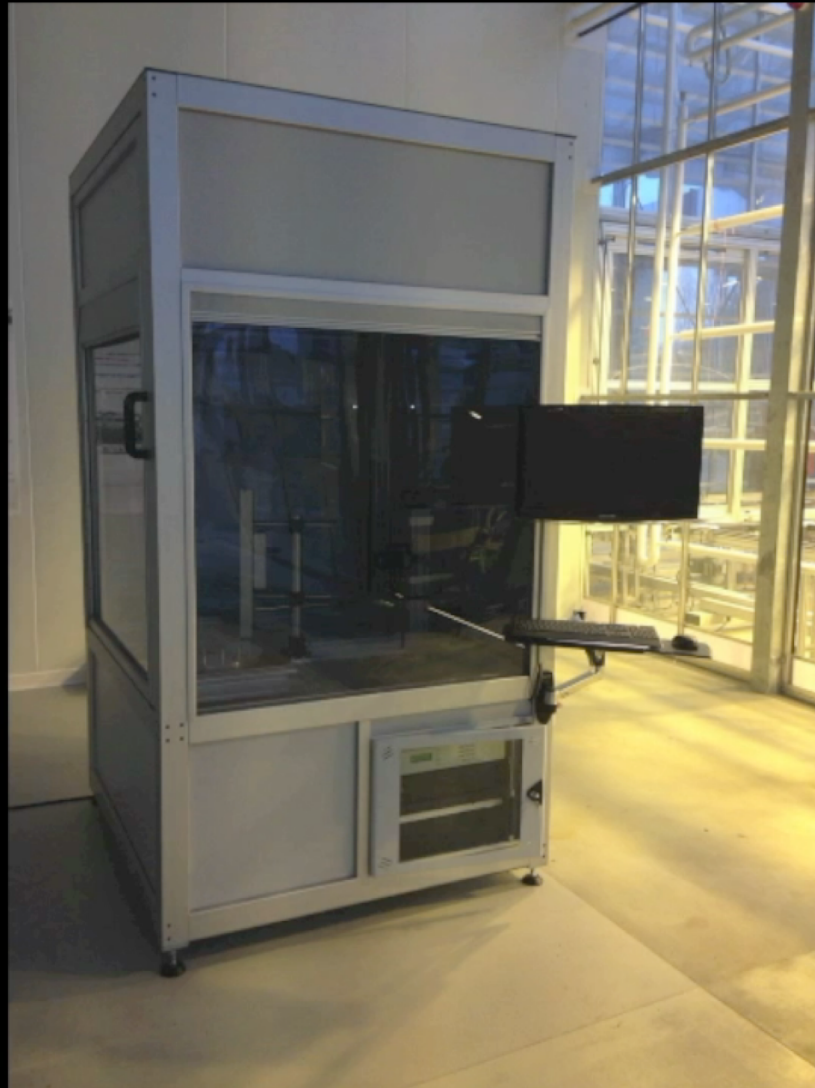
Green



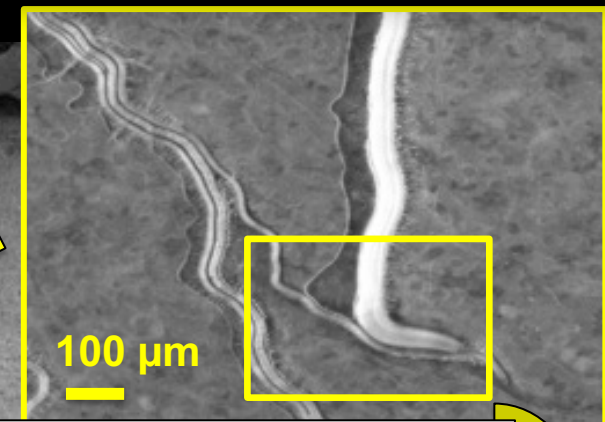
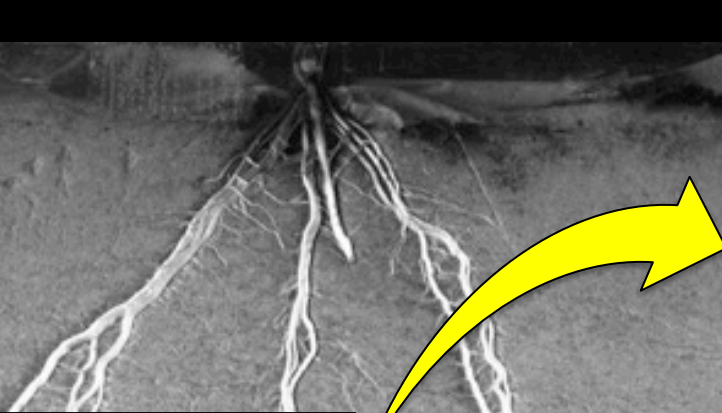
Blue



Software

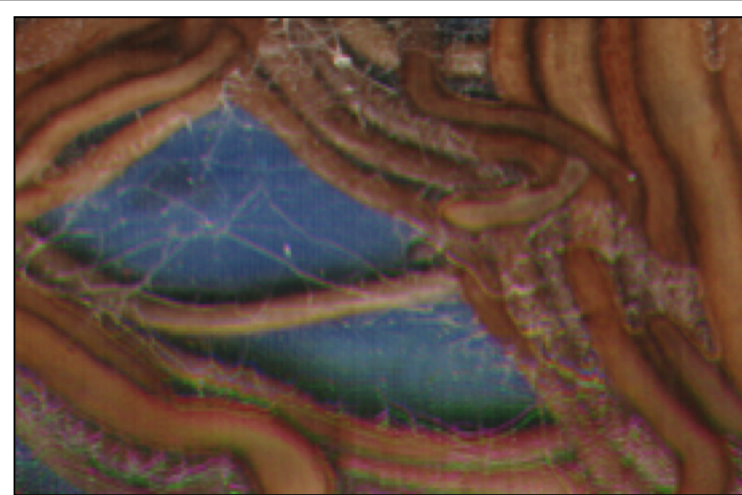


Maize



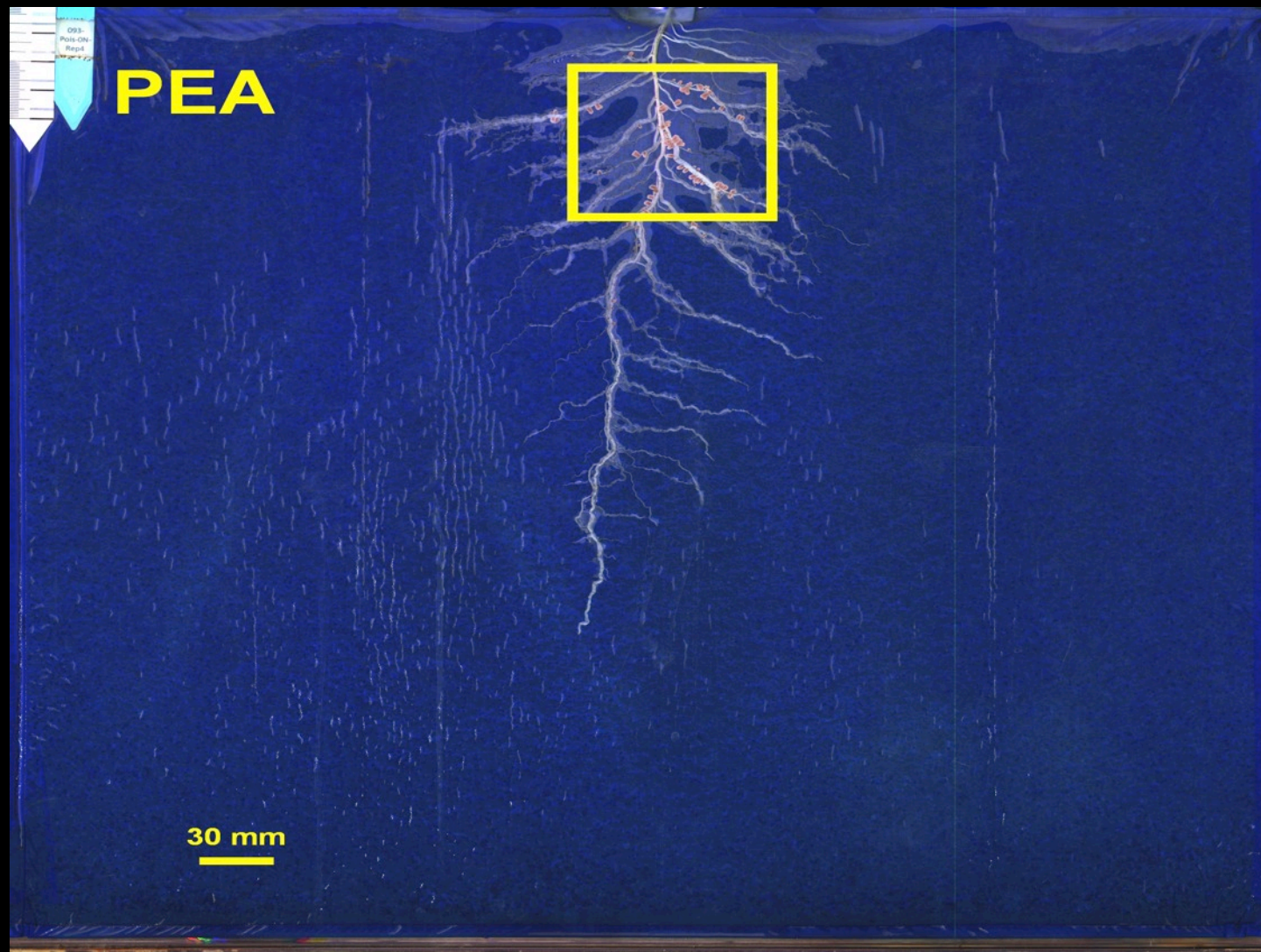
Nodules

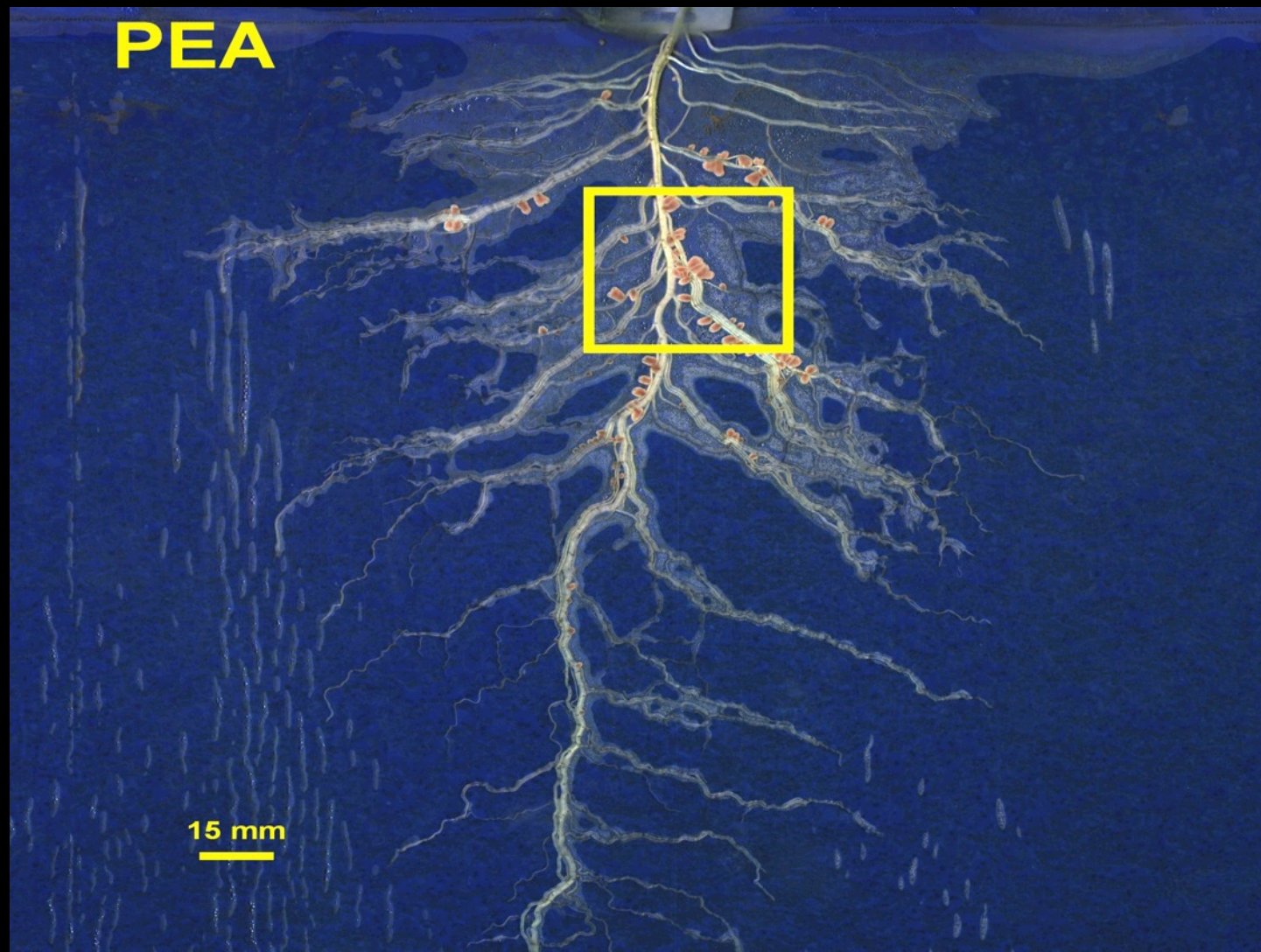
10 cm

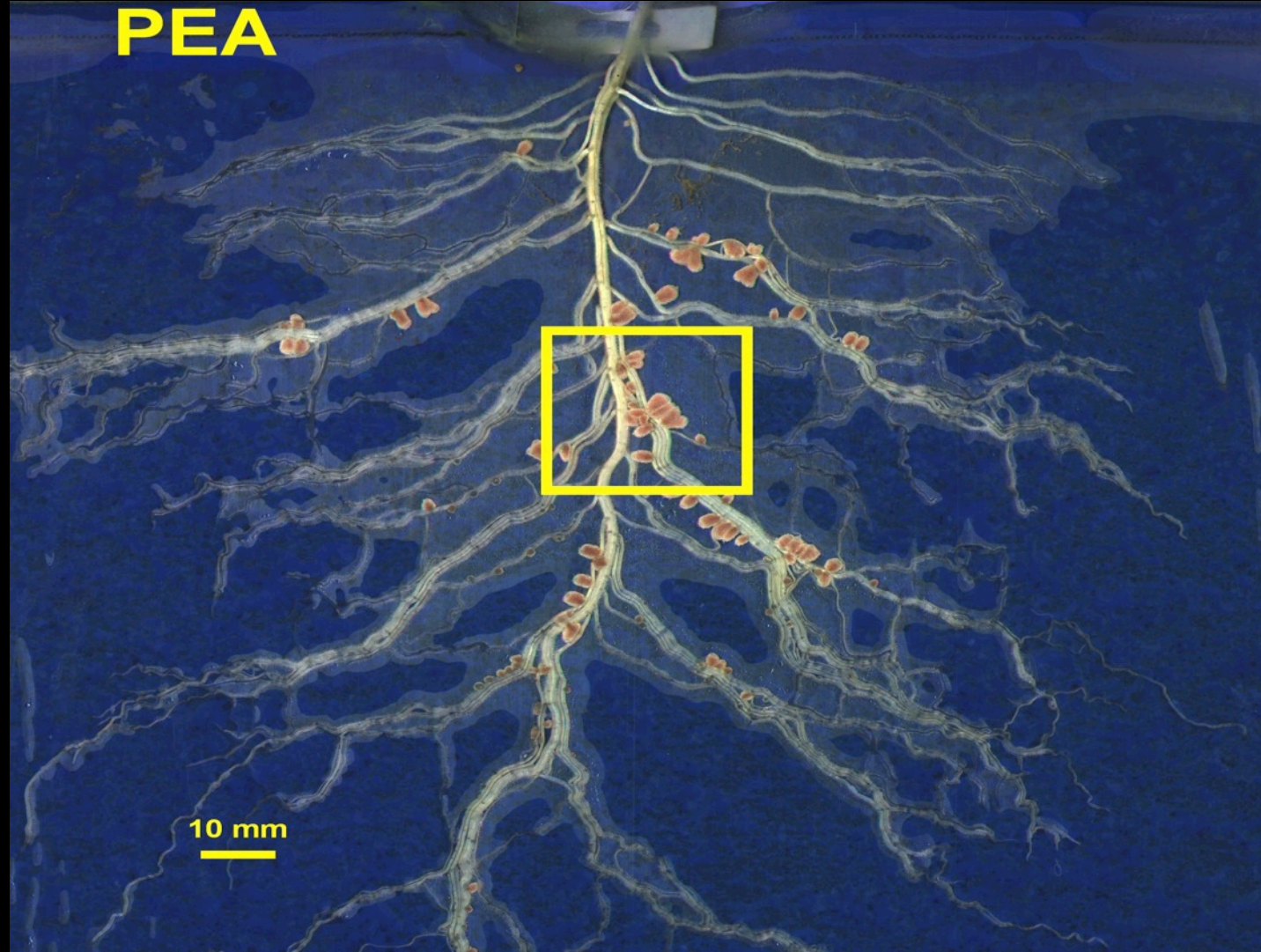


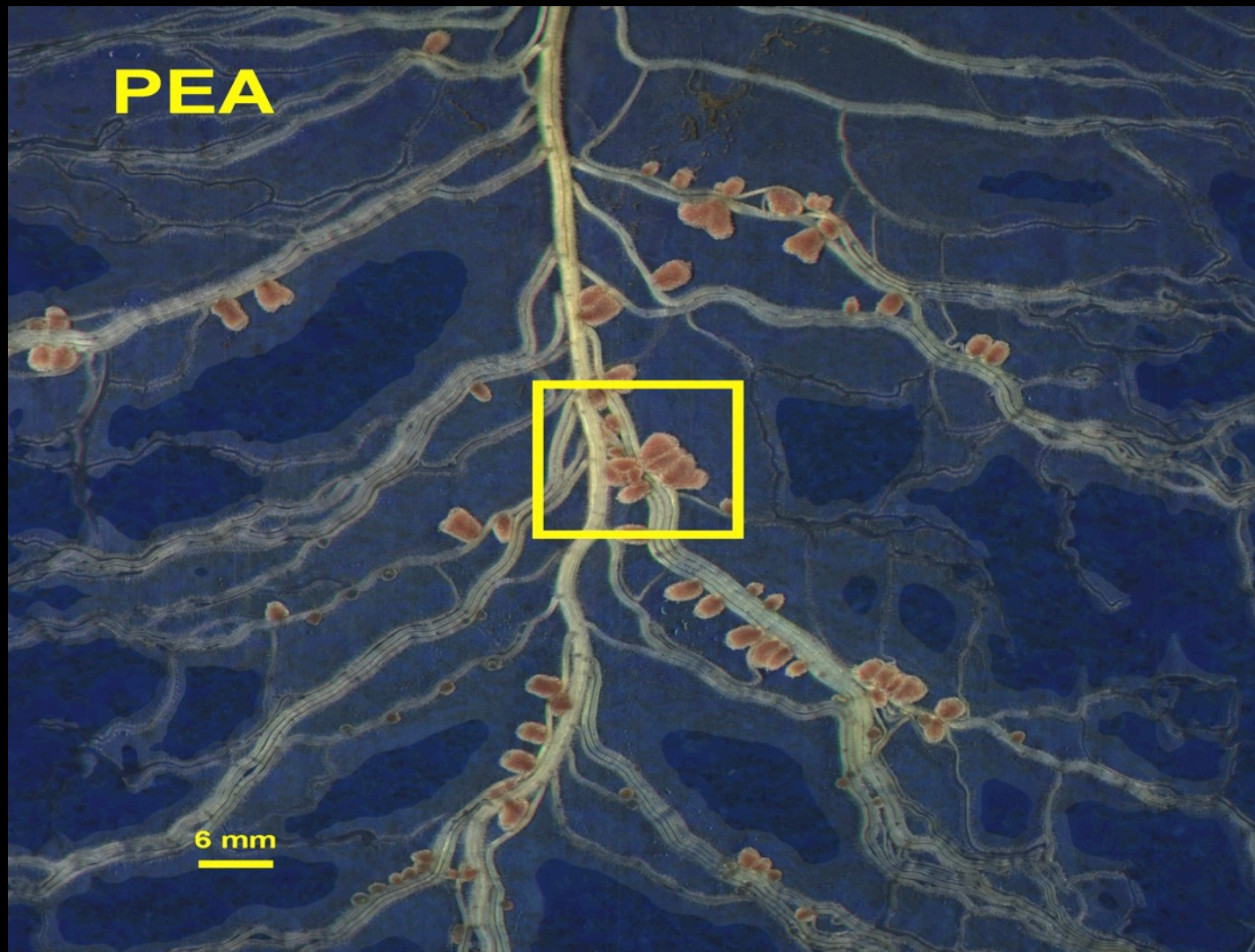
Hyphae

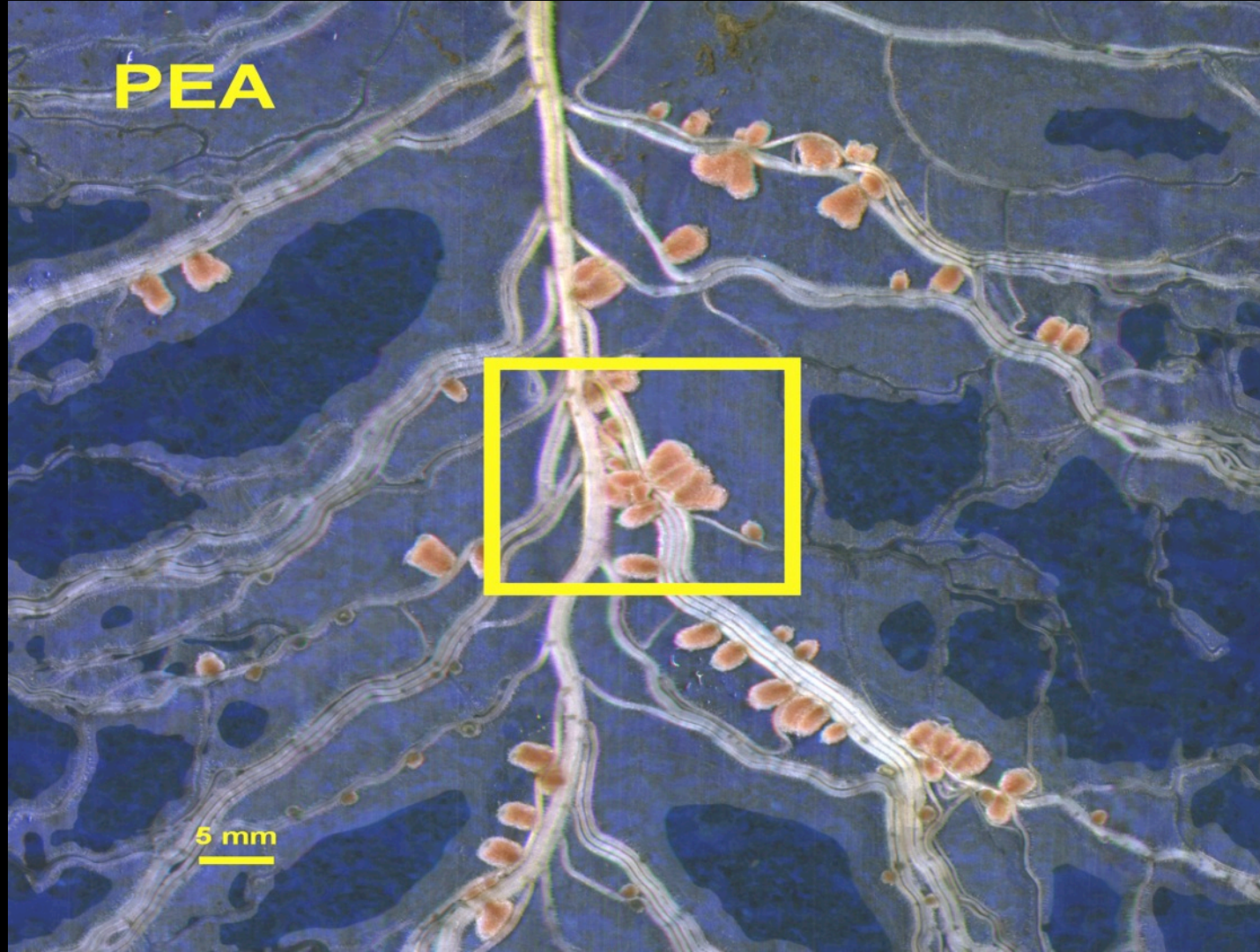
10 µm

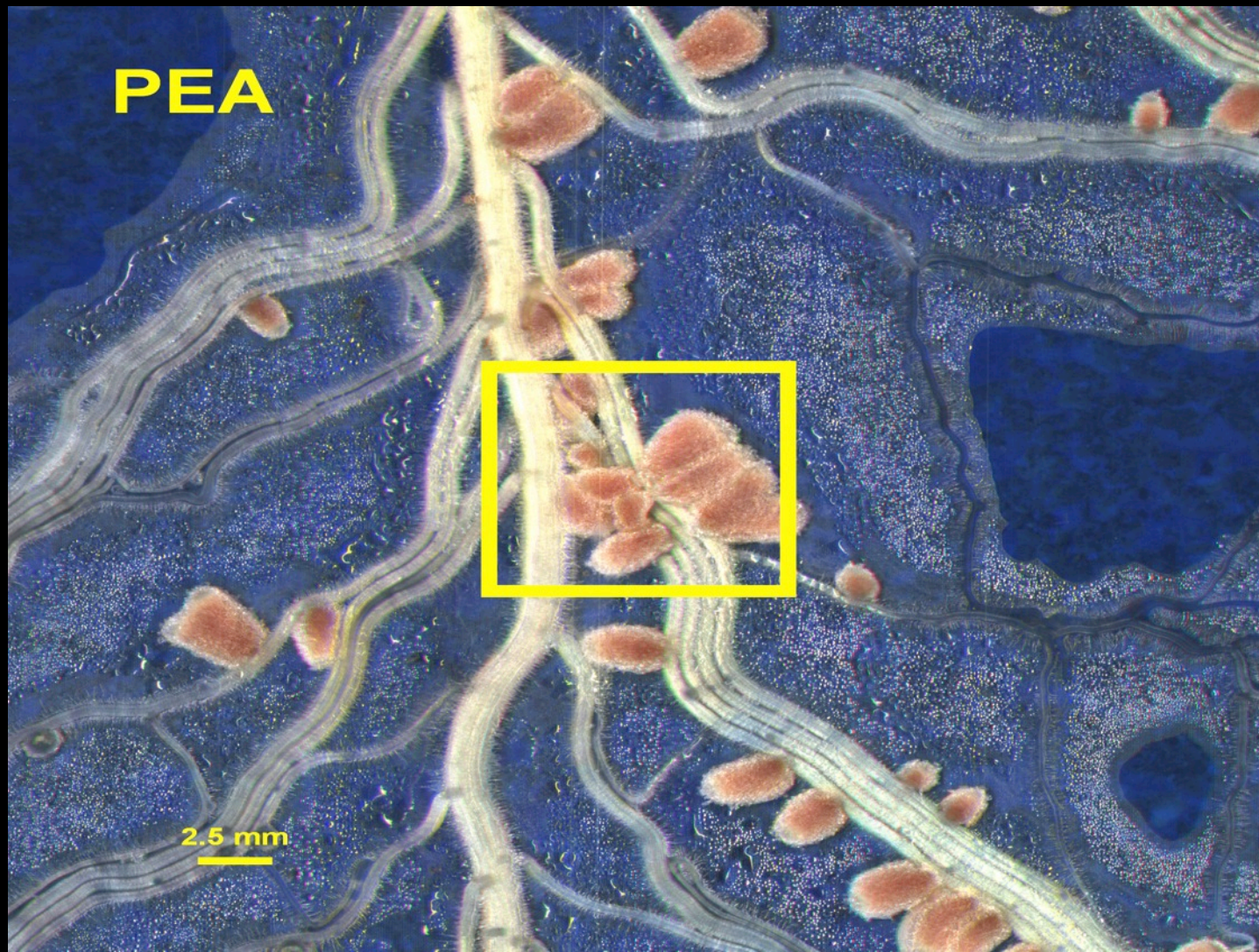




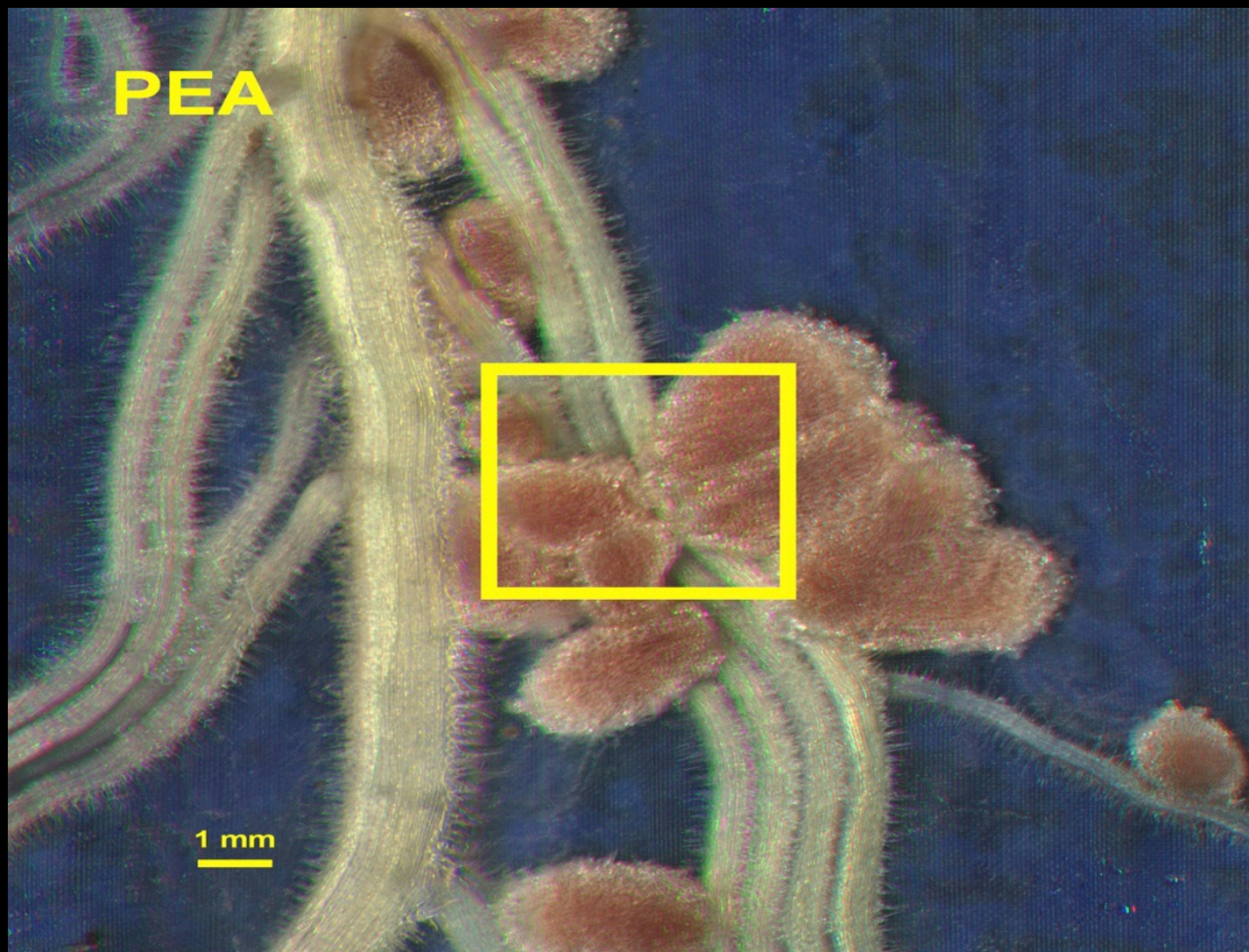




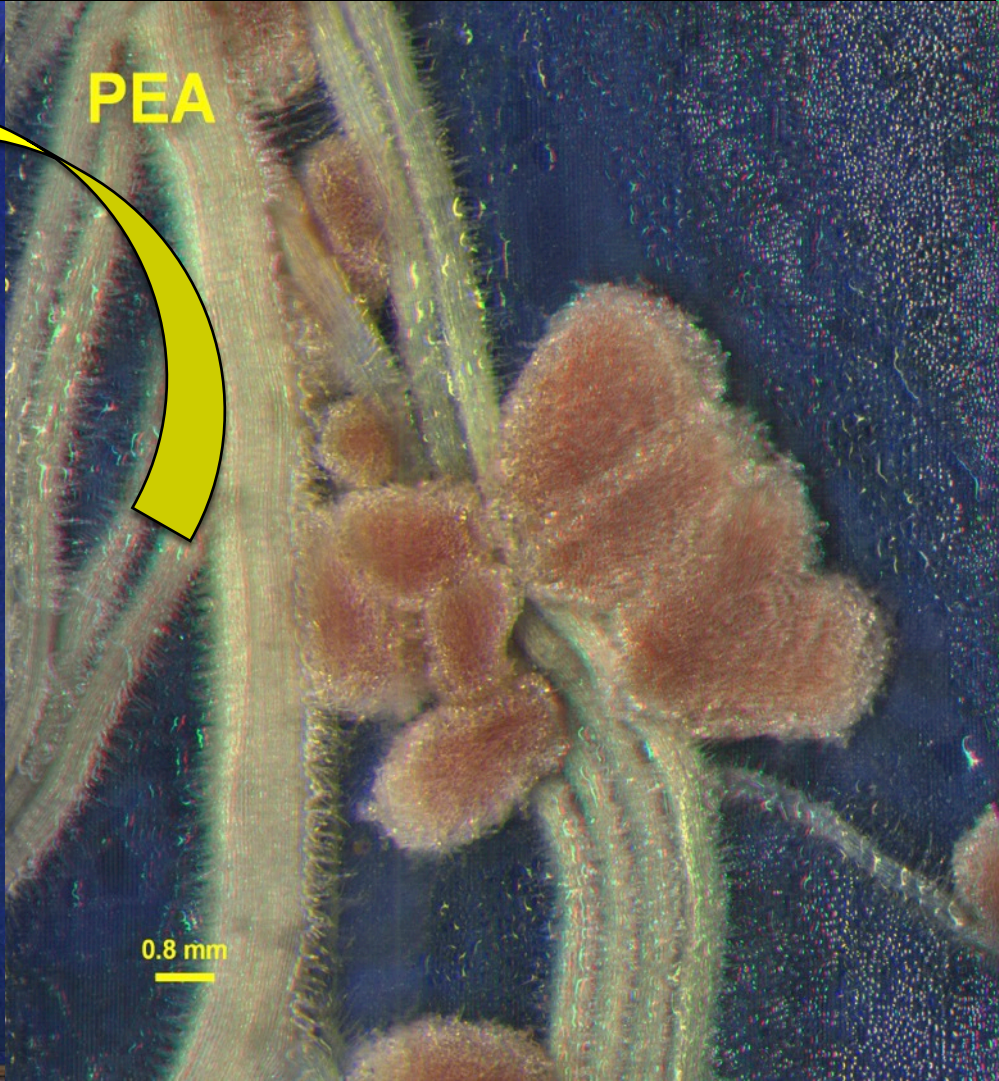
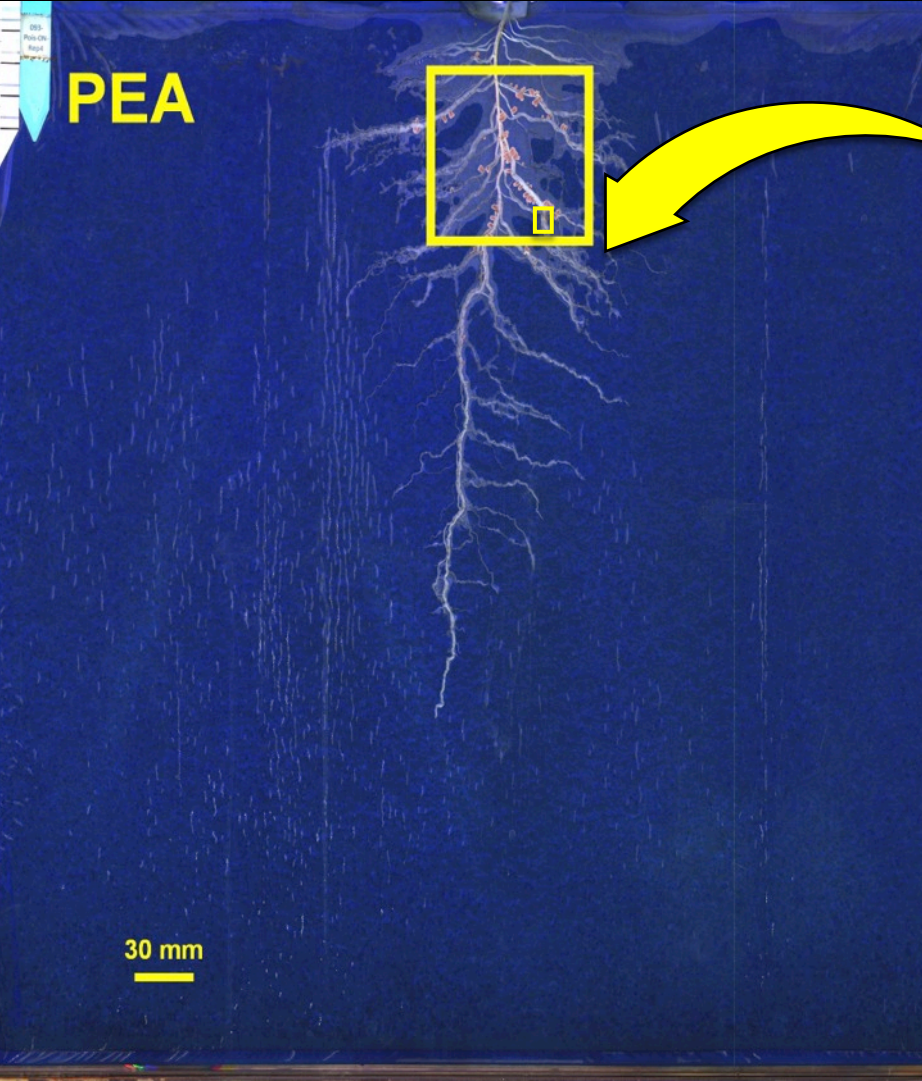














InoviaFlow



INRA
SCIENCE & IMPACT



SHAKTI

**World wide
distribution**



PhenoTrait

Trademark



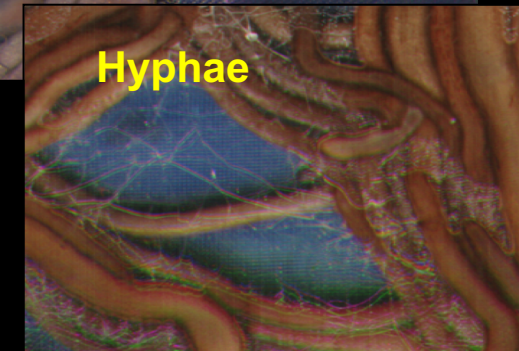


RhizoCab HR

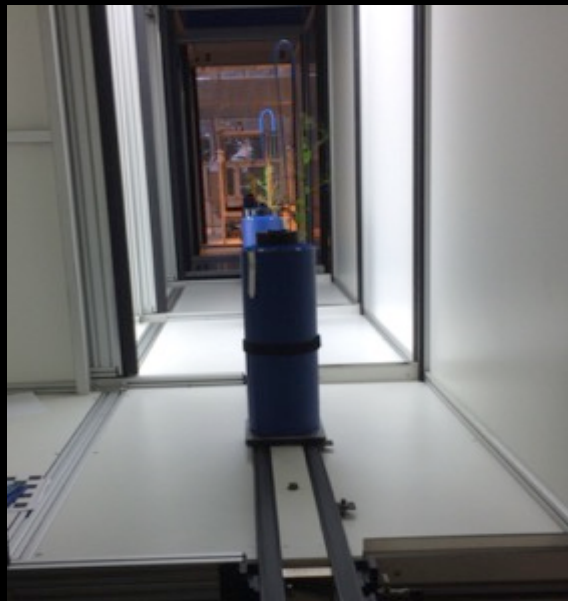
Medium throughput:
100 RT/Day, 5-60s/day/WL
Very high resolution (7 μm)



Nodules

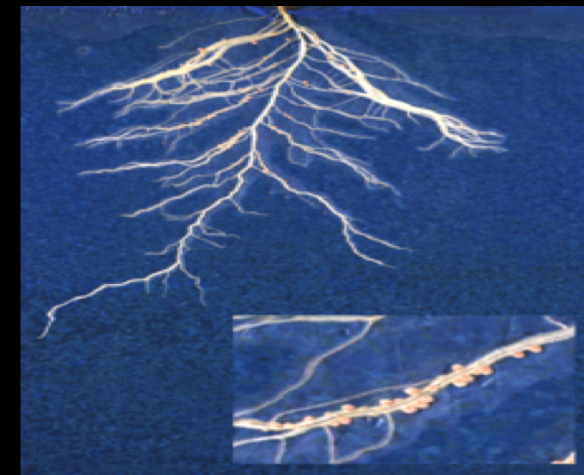


Hyphae

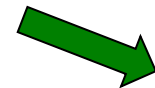
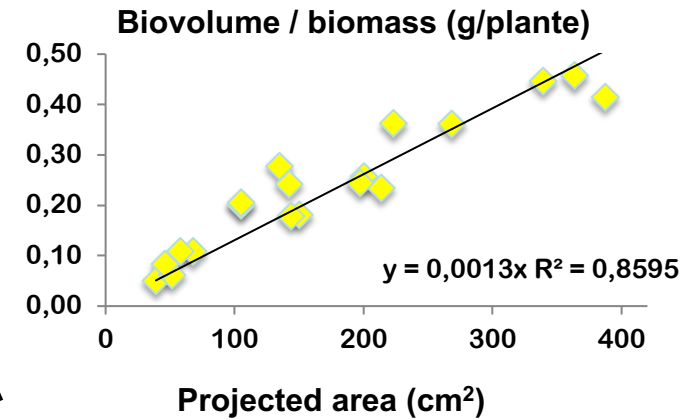
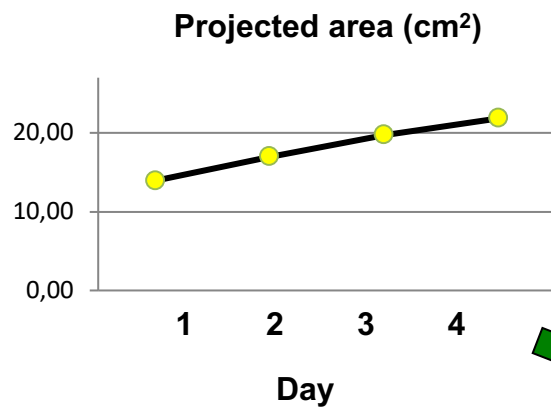
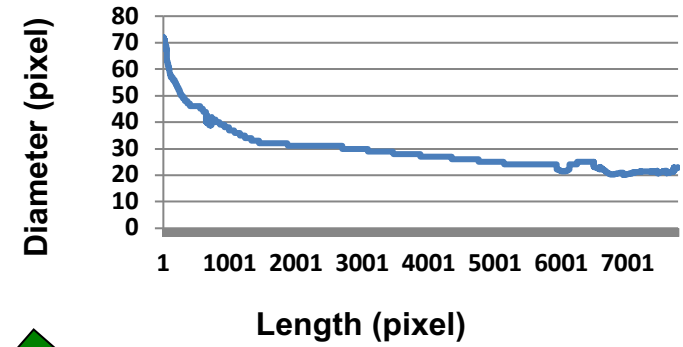
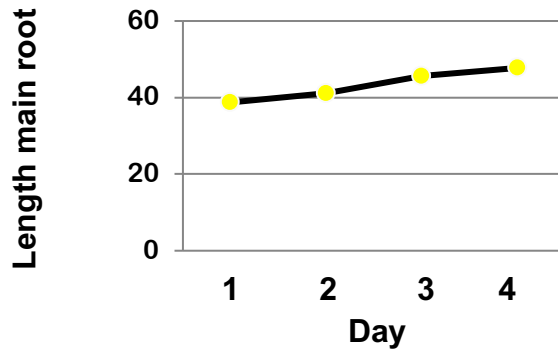
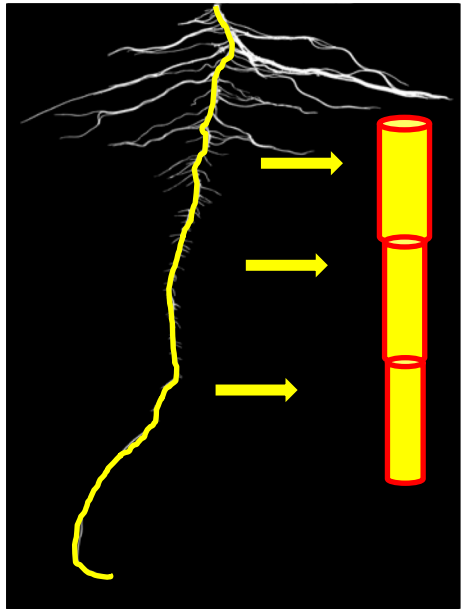


RhizoCab HT

High throughput:
1000 RT/day, 5s/RT/WL
Medium resolution (42 μm)

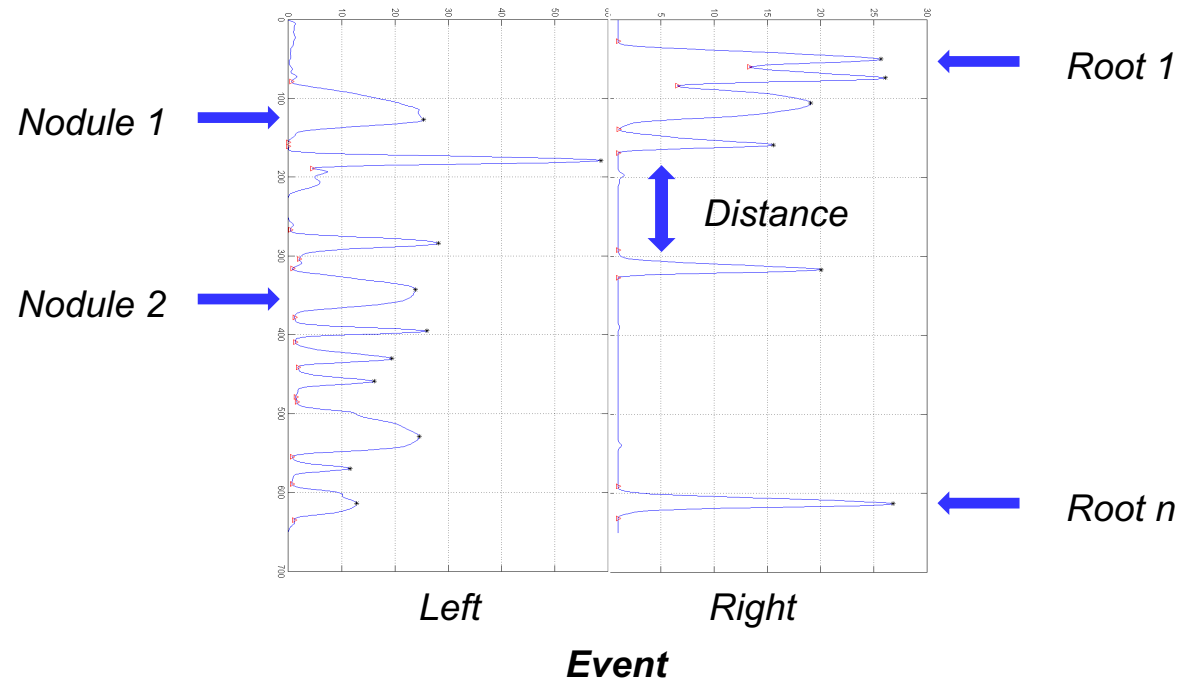
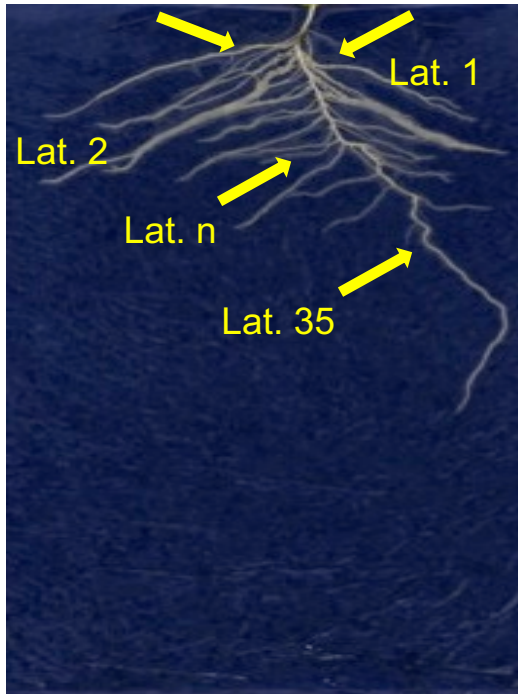


Roots: Length, diameter => projected area => biovolume



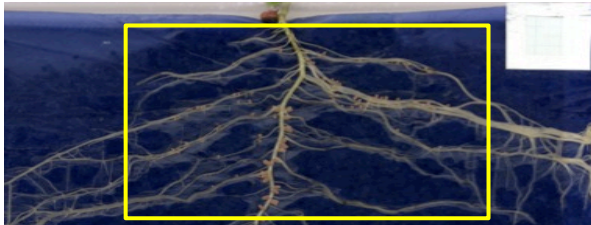
Dynamic trait characterization

Roots, detect events: lateral roots and nodules detection

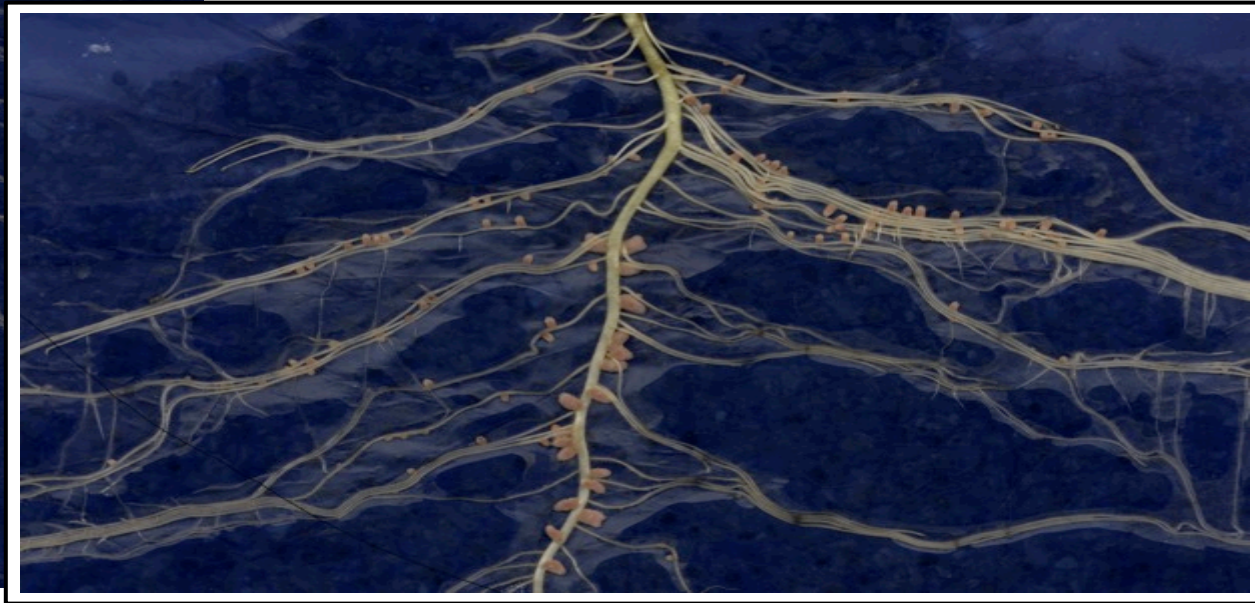


Nodules and lateral roots detection

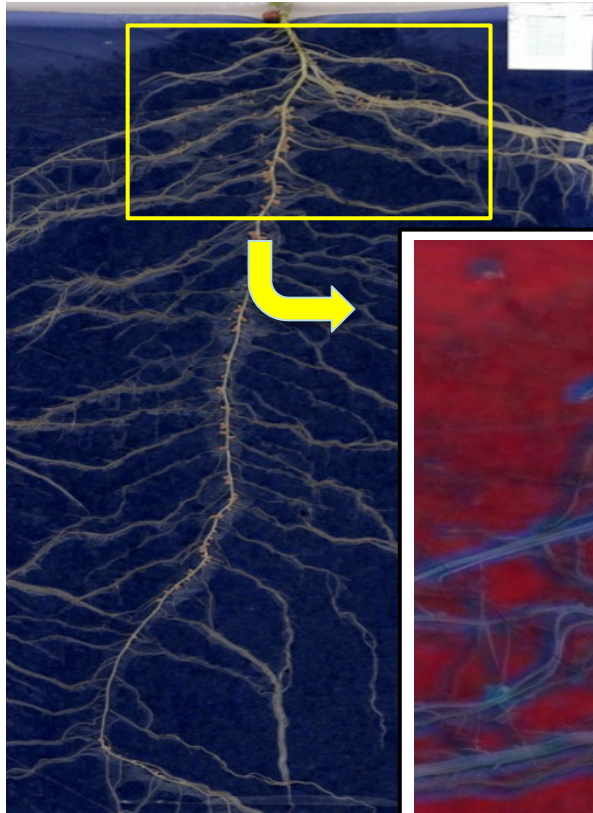
Nodules: Number, projected surface, position, color



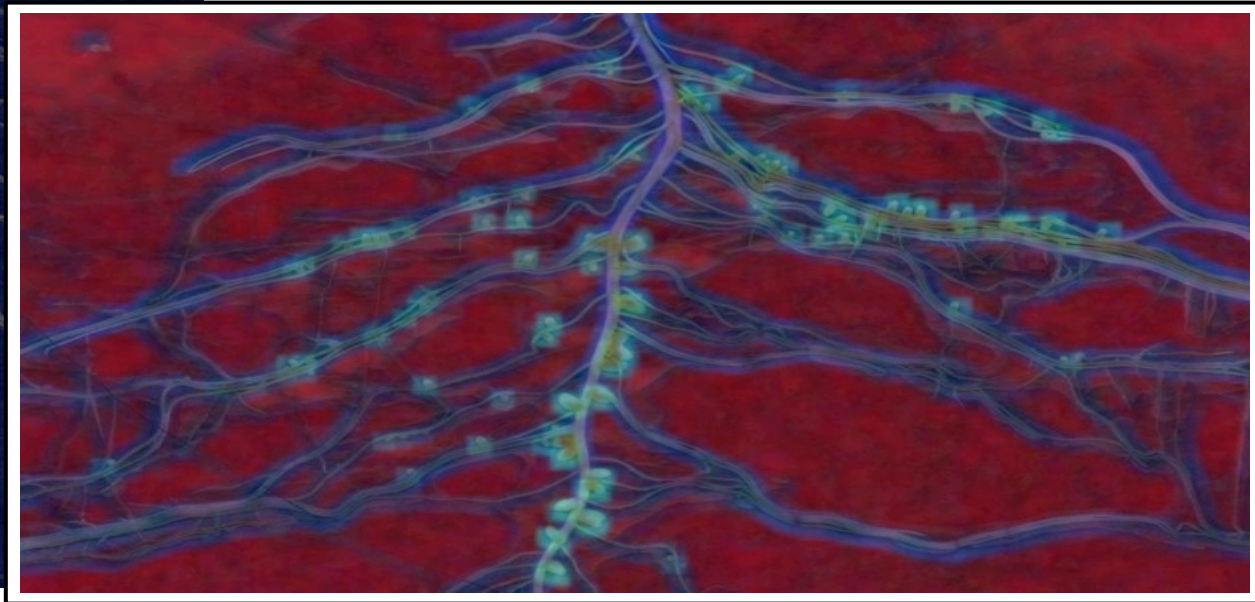
Focus on image



Nodules: Number, projected surface, position, color



Hybrid spaces (color + texture)
(Cointault et al, 2008)



Nodules: Number, projected surface, position, color

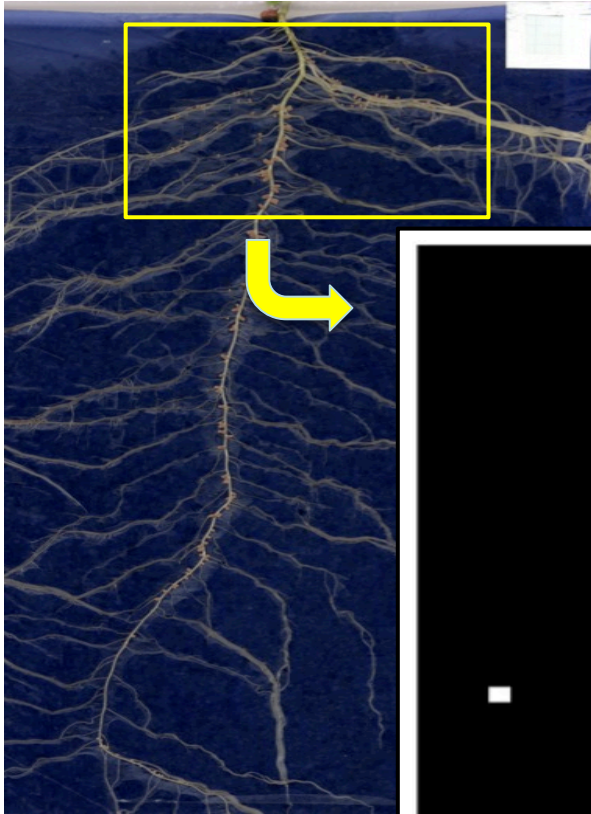
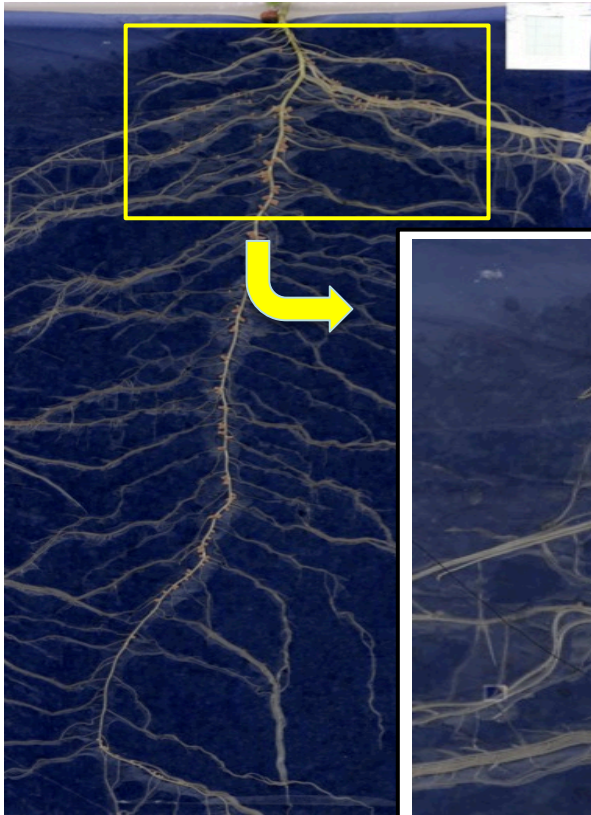


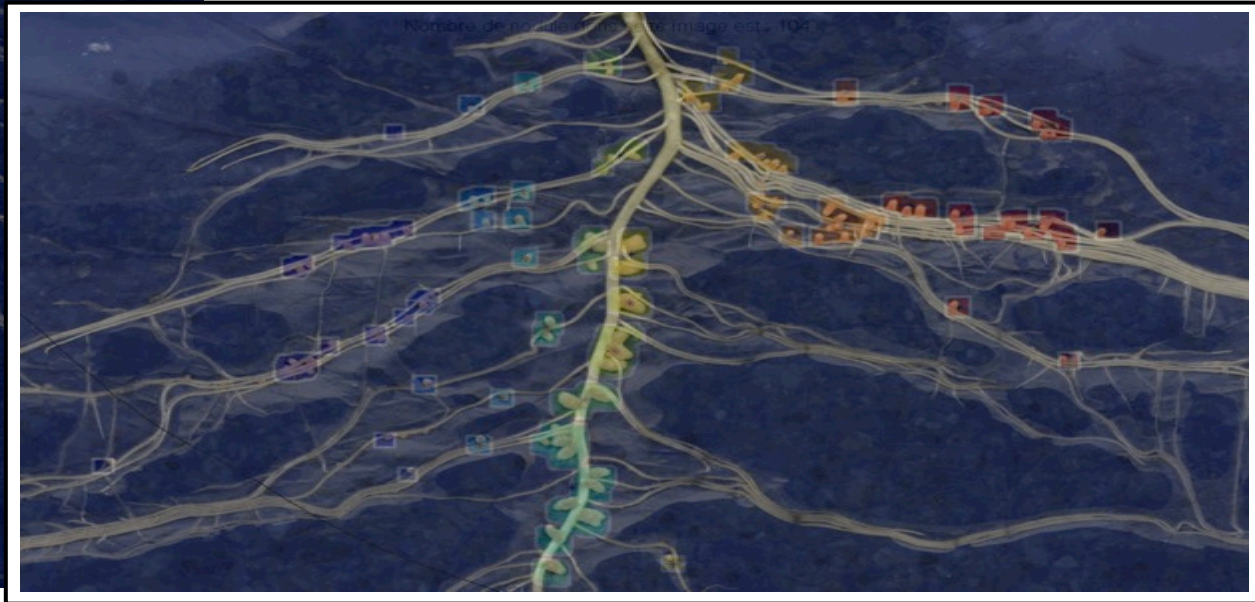
Image with nodules



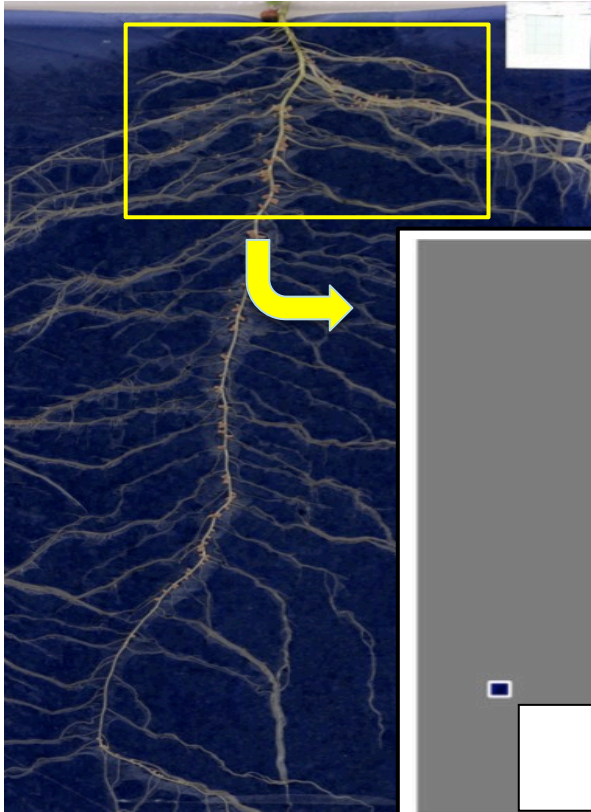
Nodules: Number, projected surface, position, color



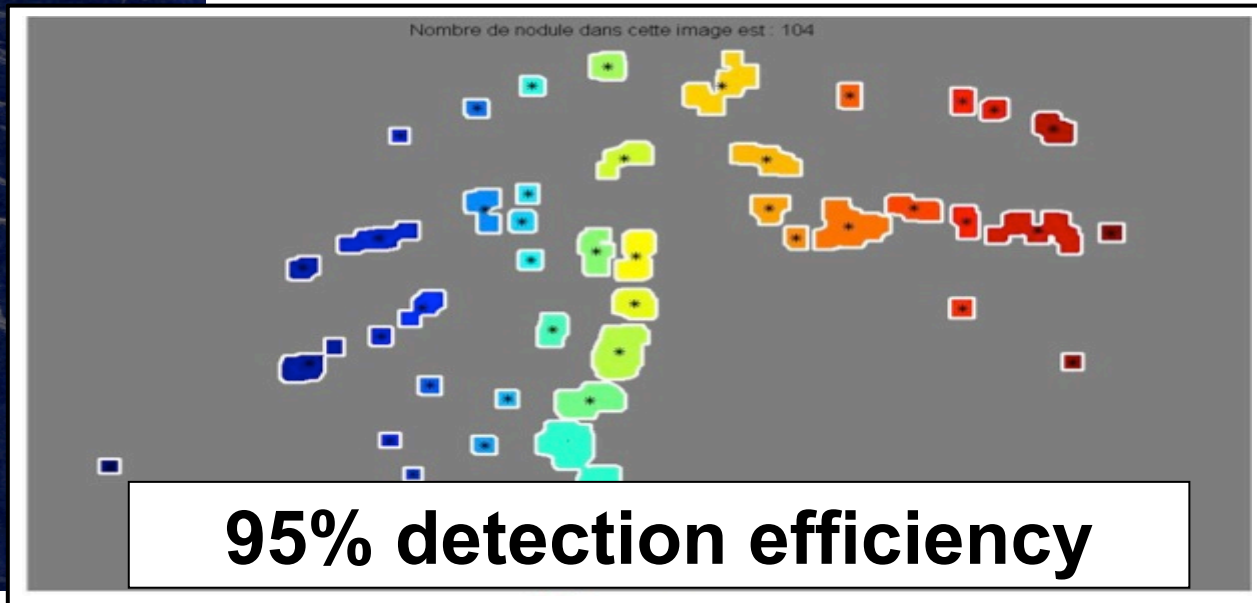
Original image + superimposed nodules



Nodules: Number, projected surface, position, color

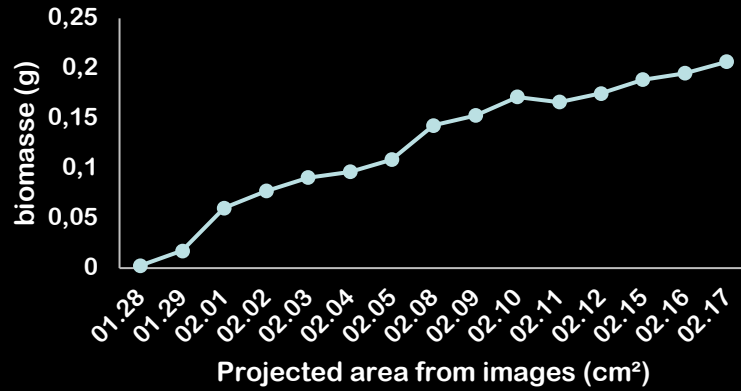


Nodules detected

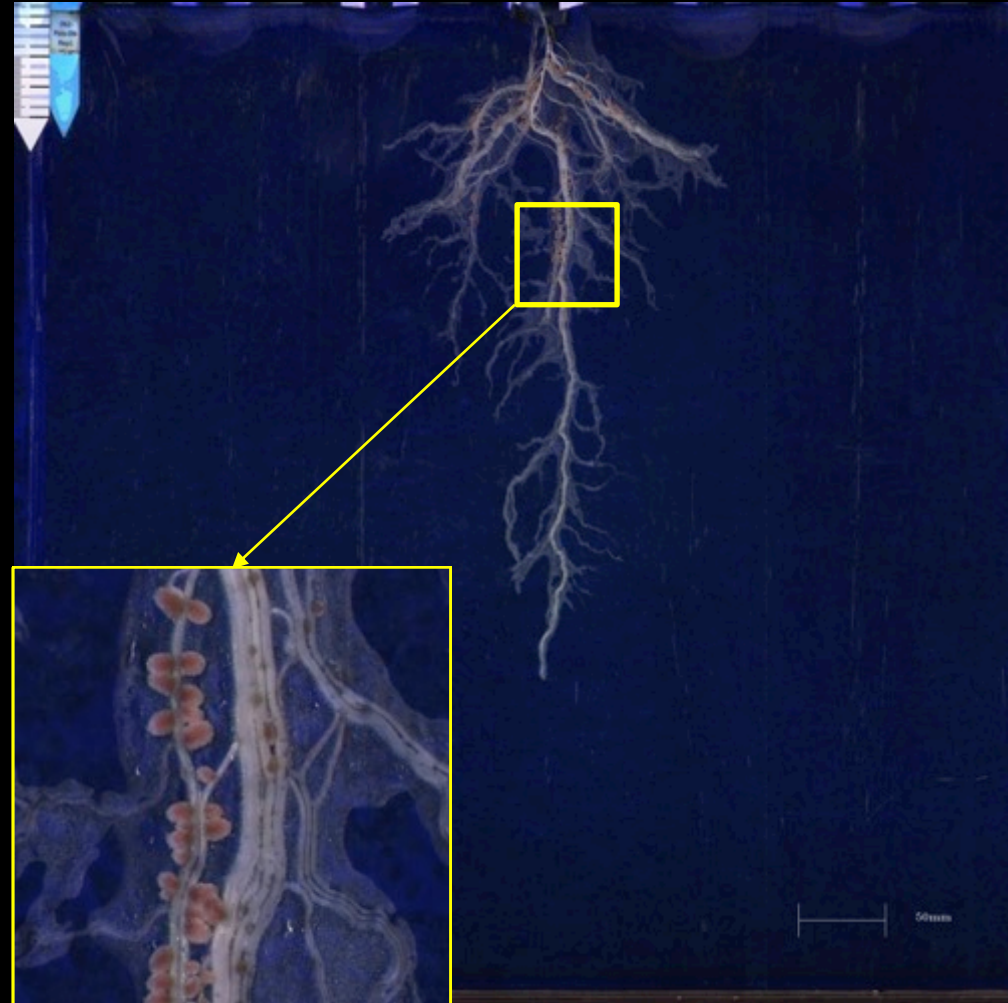
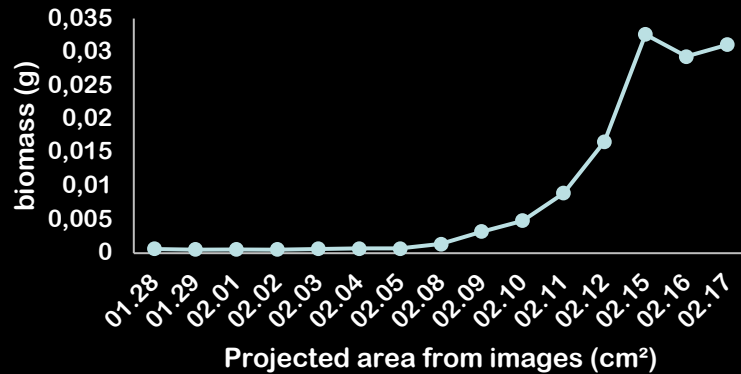


A simple example: root and nodule dynamics

Root biomass



Nodule biomass



Which species?



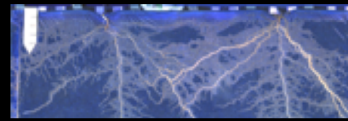
Pea



Vesce Commune



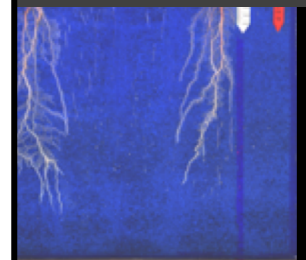
Tomato



Wheat



Soybean



Maize

Alone...

... or in association

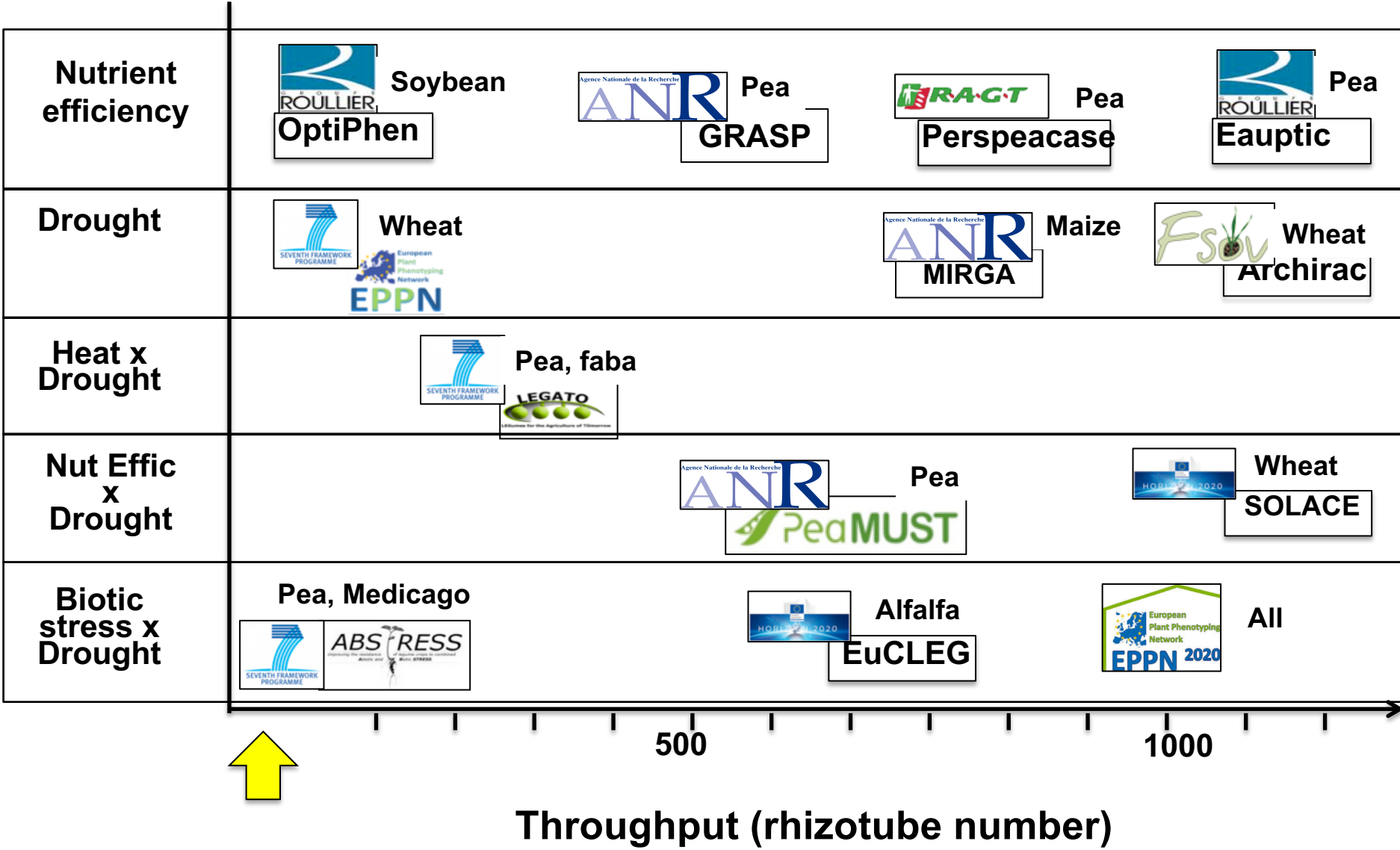


... or in association

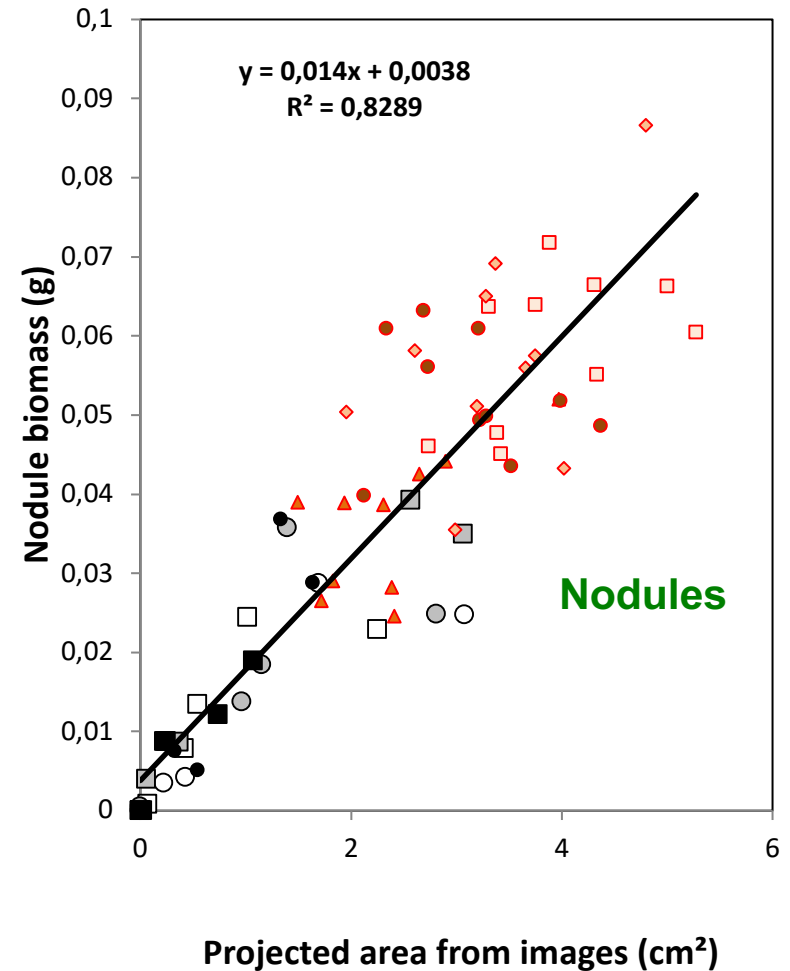
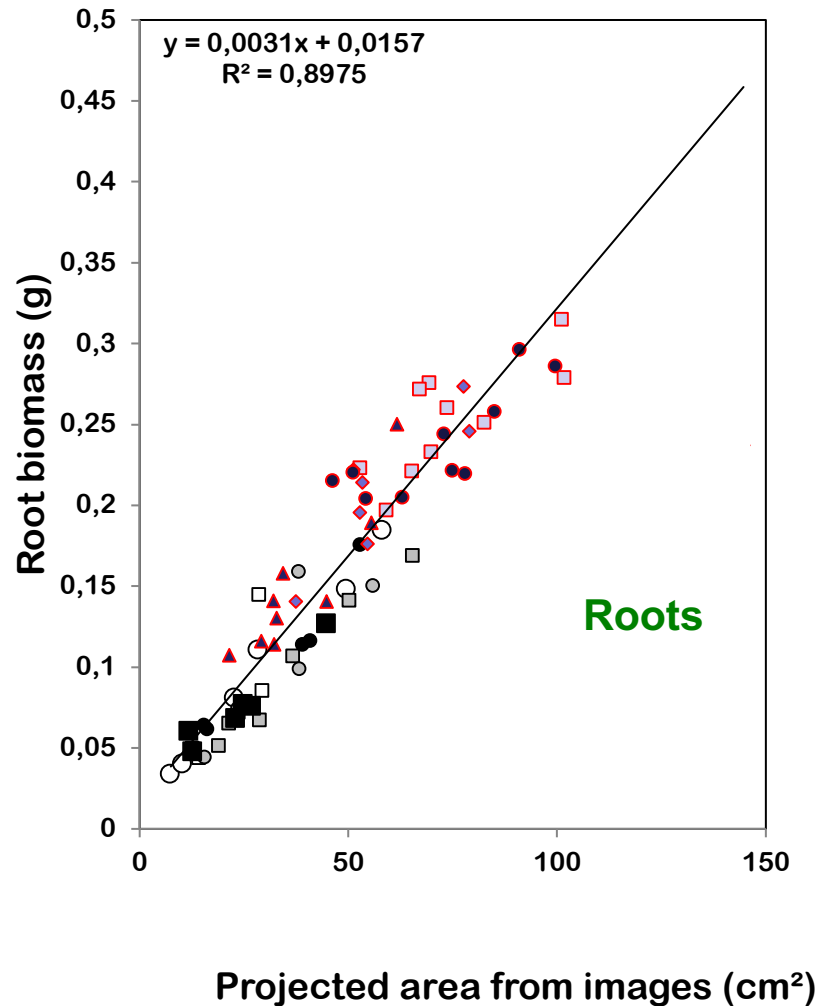
Medicago

Brachypodium

Grape



Genotypes with contrasted architectures: pea



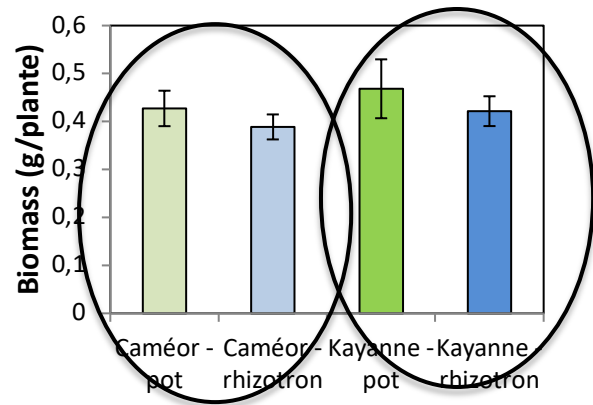
RhizoTubes vs Pots ?

Similar traits in pots and RhizoTubes: pea

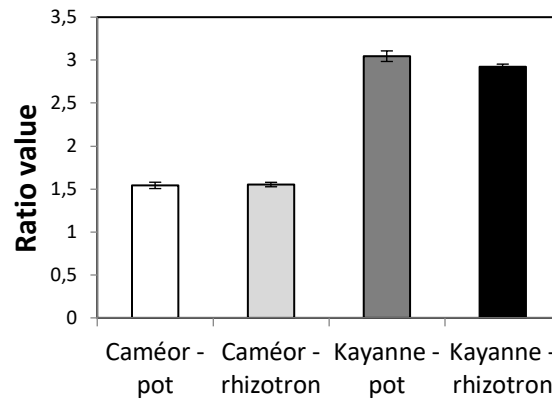


C. Jeudy

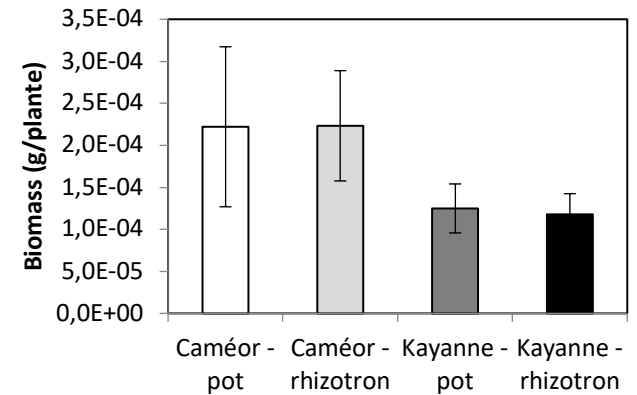
Plant biomass



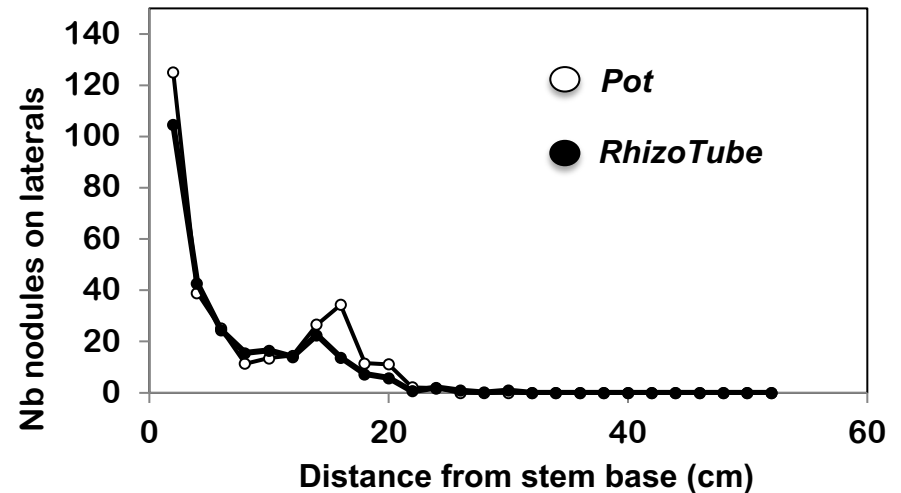
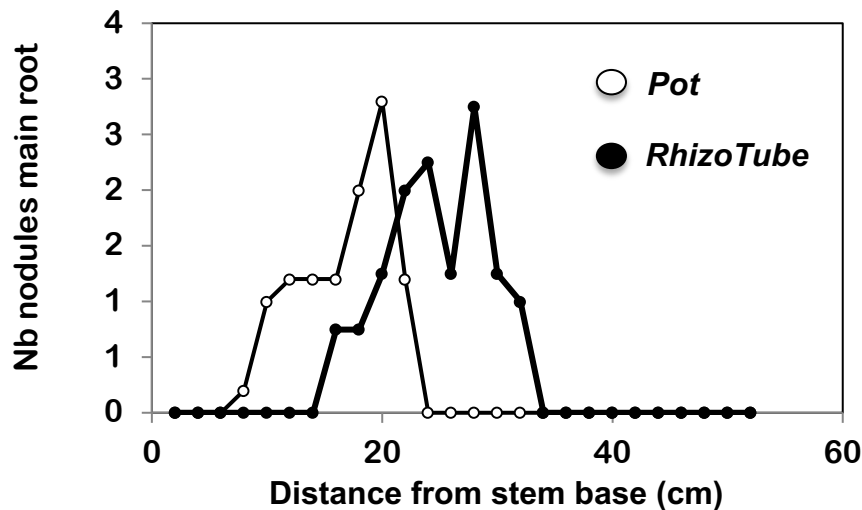
Shoot/root biomass



Mean nodule biomass



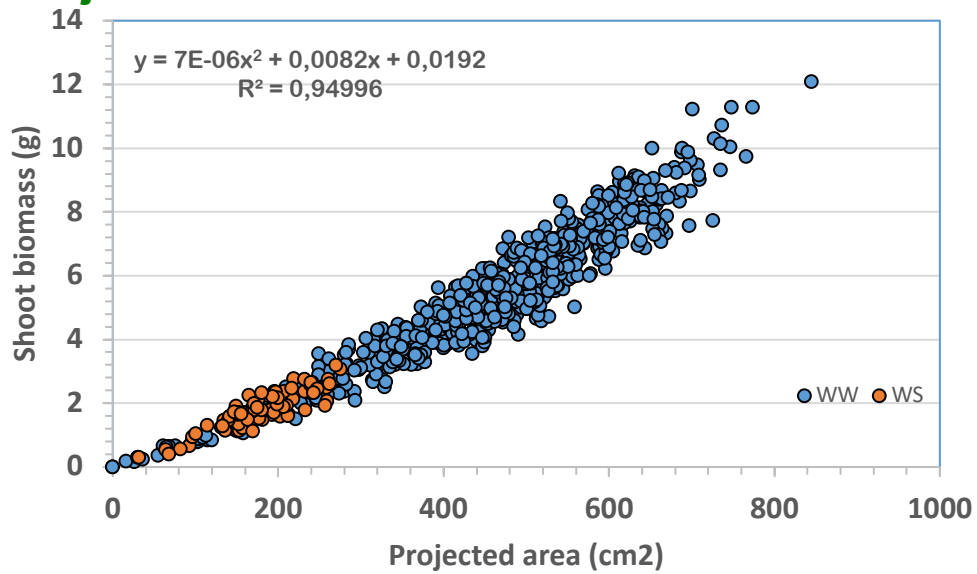
Same distribution profile!



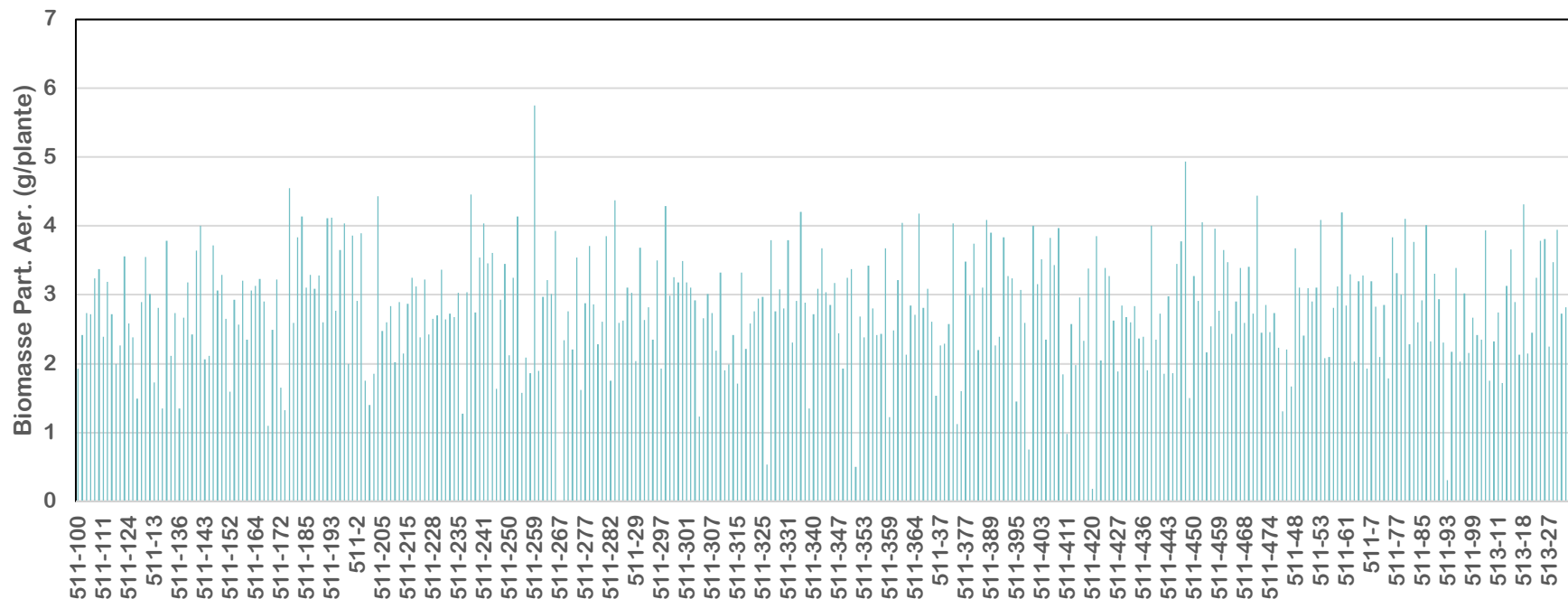
Some results: Maize (MIRGA)



Projected area vs shoot biomass



Large panels (e.g 400, up to 1200) of genotypes



Pro

14

13

12

11

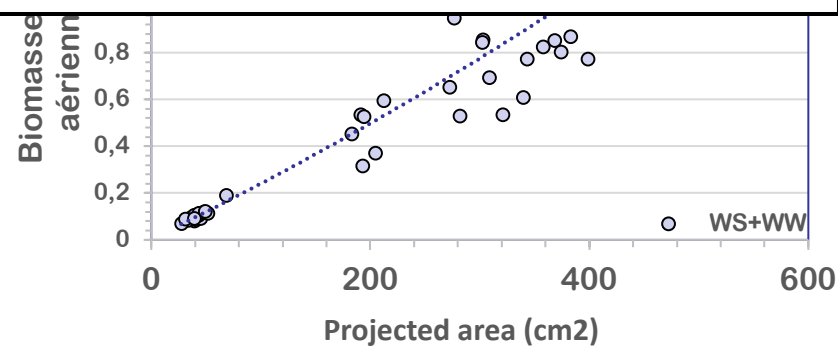
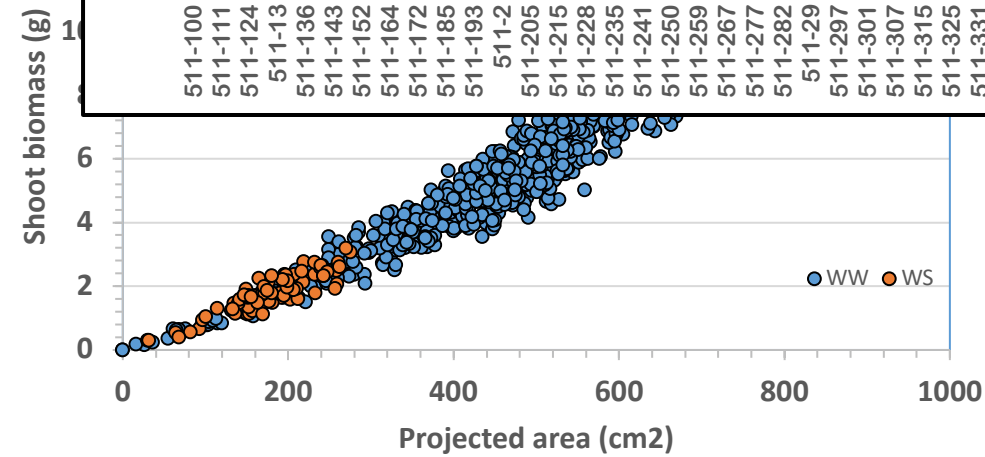
10

9

8

7

6





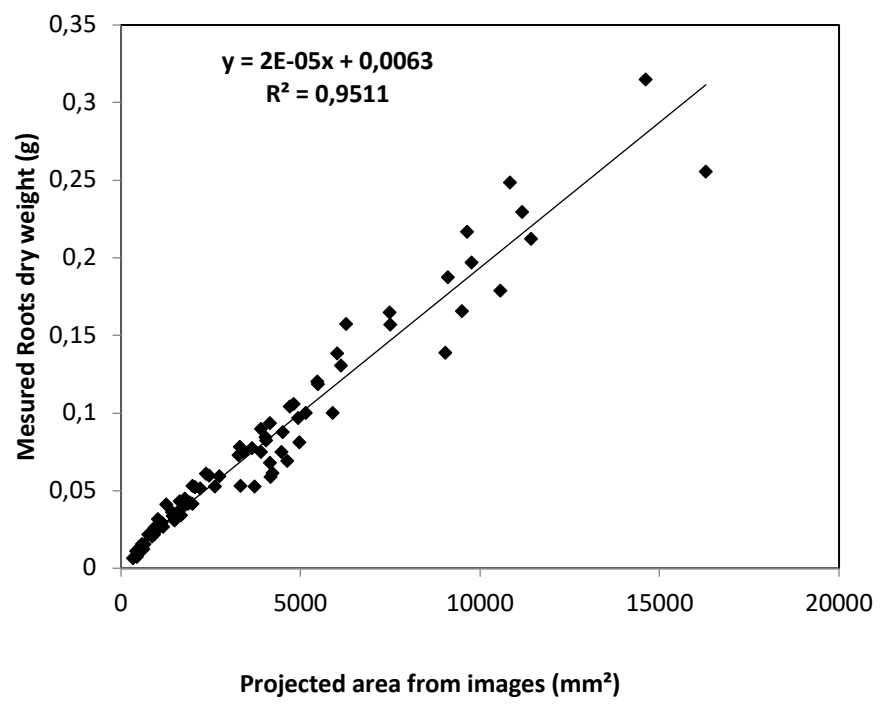
Projected area vs root biomass and length: wheat

EPPN Project, Josh Klein AARO Volcani Israel

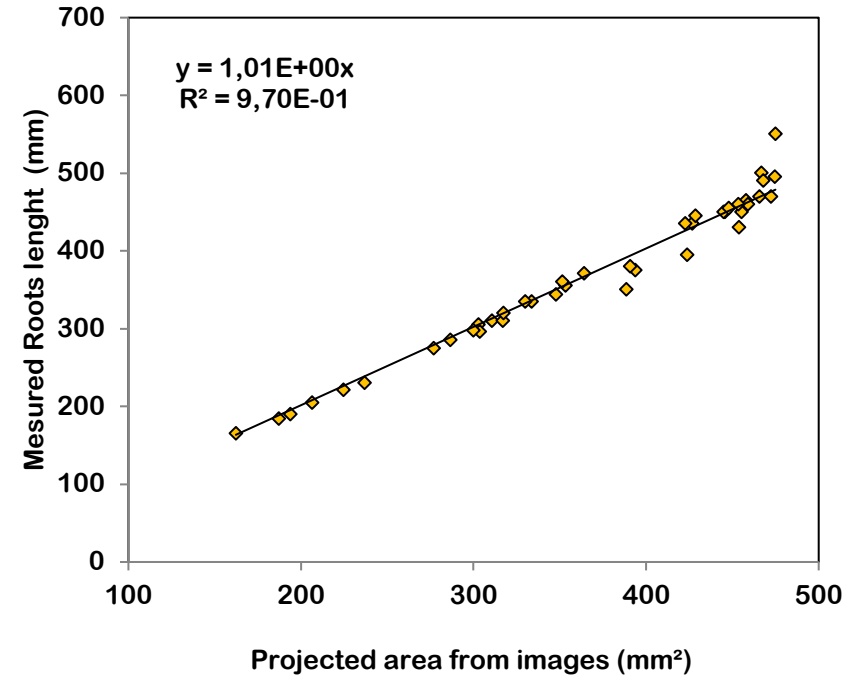


Josh Klein

Root dry matter



Root length



Christmas wishes...and what you'll get under the tree

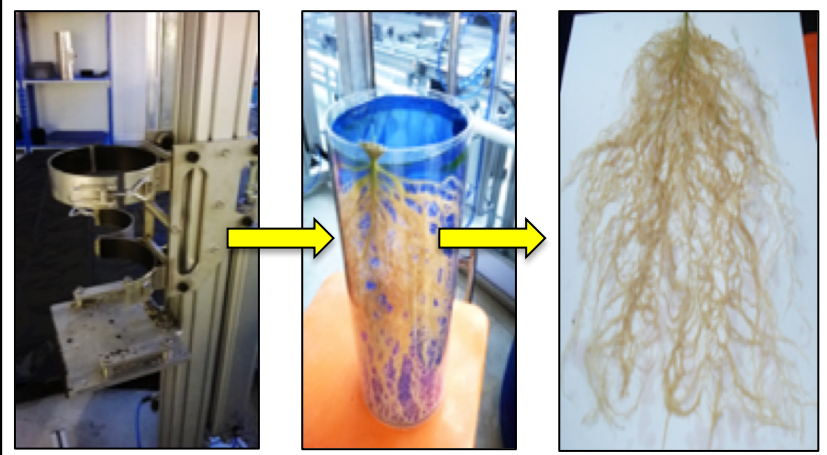
Automatic trait quantification	Done	Nearly done	... soon
Root projected area	X		
Total root length	X		
Root convex hull	X		
Root exploration dynamics (H and V)	X		
Root density		X	
Root number (incl. typology)		X	
Root angle		X	
Root diameter		X	
Nodule projected area	X		
Nodule number (inc.typology)	X		
Nodule biovolume (inc. classes)		X	
Nodule number, position on each root			X
Nodule efficiency			X
Mycorrhizes, hyphae		X	
Germination checkup	X		



Mounting



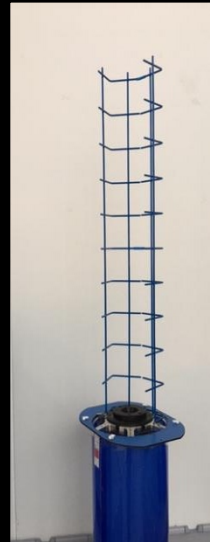
Empoting



**Fast root recuperation
(allows 'omics)**

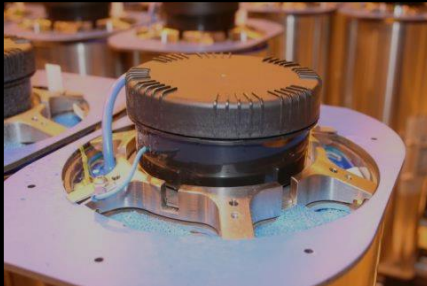


Germination chamber



Tutors

Tram Hydroponic RhizoTubes



Bubbling pump



Energy base



Food for thoughts...



Combine approaches

Phenotyping
Approach

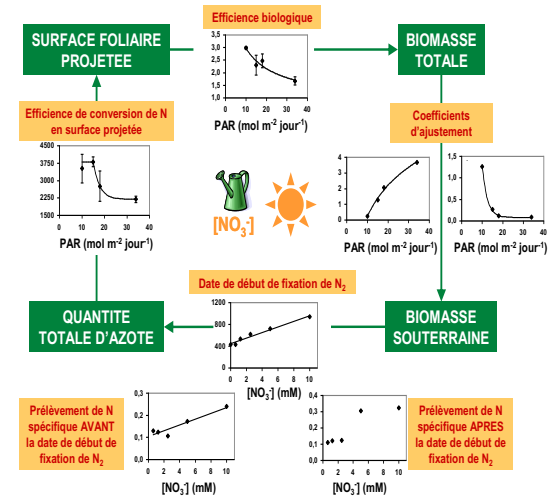
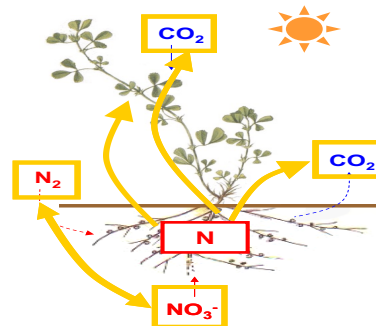
+

Analytical
approach

+

Models

(e.g.
fluxomics)



Identifying differences
among genotypes

Interpreting the
detected difference



C Bernard



C Jeudy



J Martinet



K Palavioux



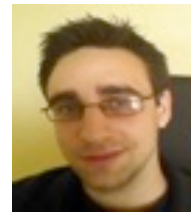
S Han



JC Simon



F Cointault



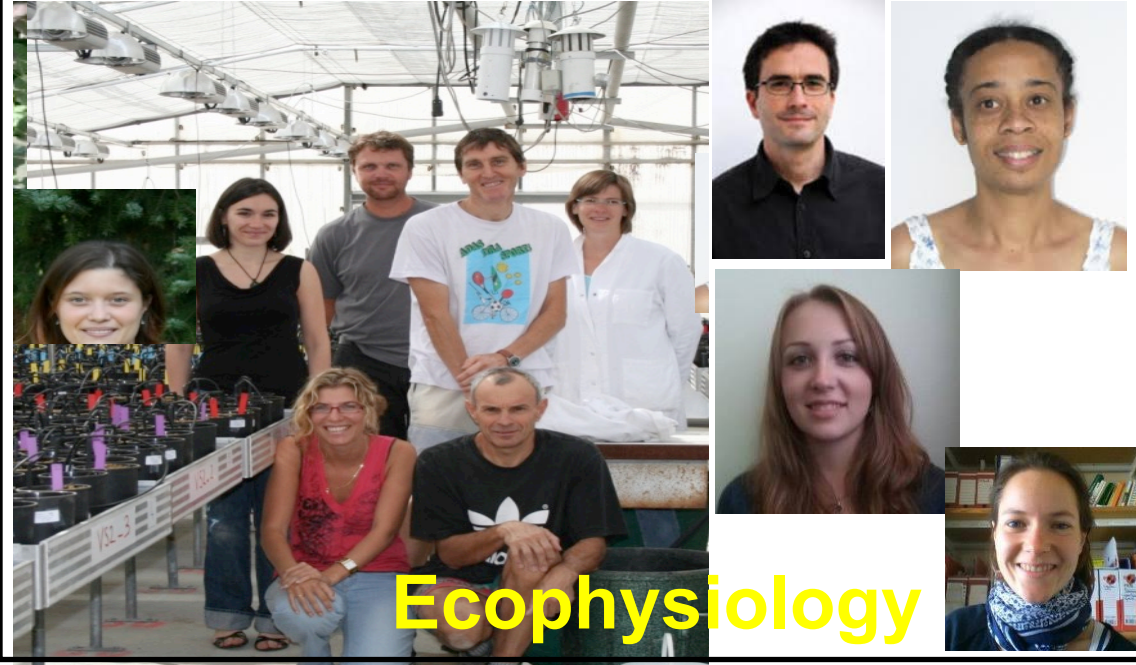
M Lamboeuf



C Baussard



The GEAPSI Group...



FILEAS



Proteaginous target crop

