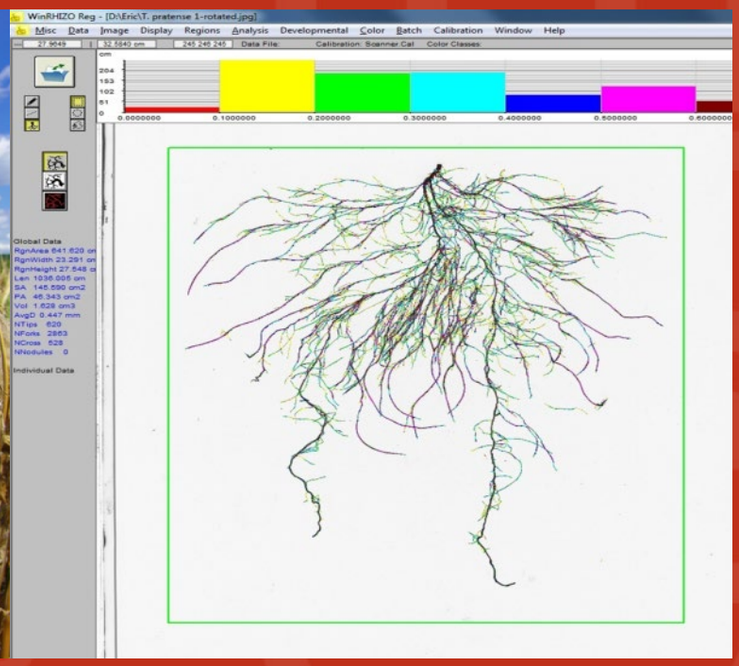
Underground plant traits: many mysteries to be solved



Eric Visser

Associate professor Experimental Plant Ecology

Eric.Visser@science.ru.nl
https://www.ru.nl/science/plant/people/group/eric-visser/

Radboud University Nijmegen

Profile:

- Ecophysiologist
- How plants adapt to their environment
- Intrigued by the hidden half of the plant

What we'll see today?

- roots in wild and crop species
- using traits of wild species to combat environmental stress
- plasticity in root formation
- how to use this in farming
- what's needed?

deVolkskrant

Columns & Opinie Uitgelicht Wetenschap Mensen De Gids Cultuur & Media

NIEUWS NEERSLAGTEKORT

Wetenschappers slaan alarm: ‘Droogte is een sluipmoordenaar’

Klagen over het weer is typisch Nederlands, maar nu is er reden: het is te droog, voor het derde jaar opeen. Met het actuele neerslagtekort van 40 millimeter doemt het spookbeeld op van 1976, het droogste jaar uit afgelopen decennia. Wetenschappers buigen zich over de vraag wat te doen.

Jean-Pierre Geelen 16 april 2020, 20:00

In een droog stuk bouwgrond wordt mest geïnjecteerd. Beeld Harry Cock / de Volkskrant

http://www.hartwoodfarm.com/

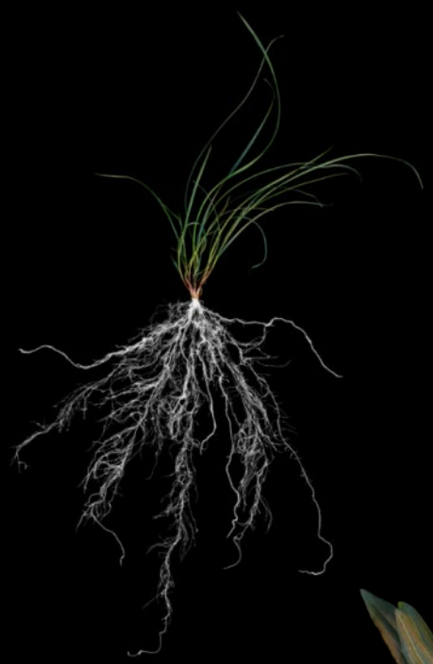
It becomes increasingly urgent to have crops adapted to a changing world, and roots are key in this!

Root development of wild plant species evolved to respond to their environment

Radboud University Nijmegen

Species in the same field may vary strongly in their root development

Anthoxanthum odoratum

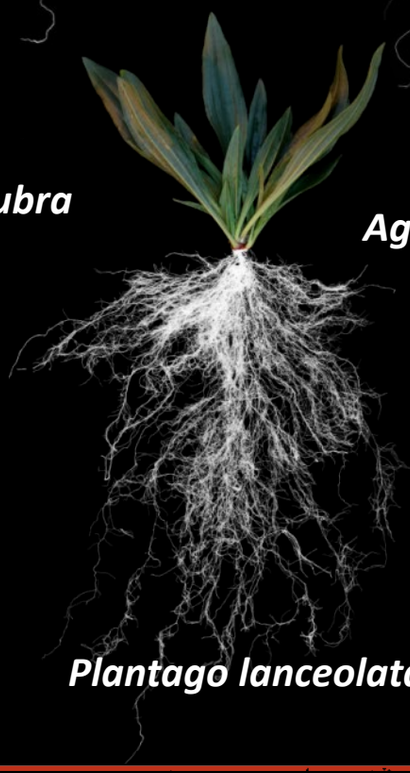


Festuca rubra

Agrostis capillaris

Nardus stricta

Leontodon hispidus



Plantago lanceolata

Achillea millefolium

Veronica chamaedrys

The natural environment is often strongly heterogeneous

- in space

- in time

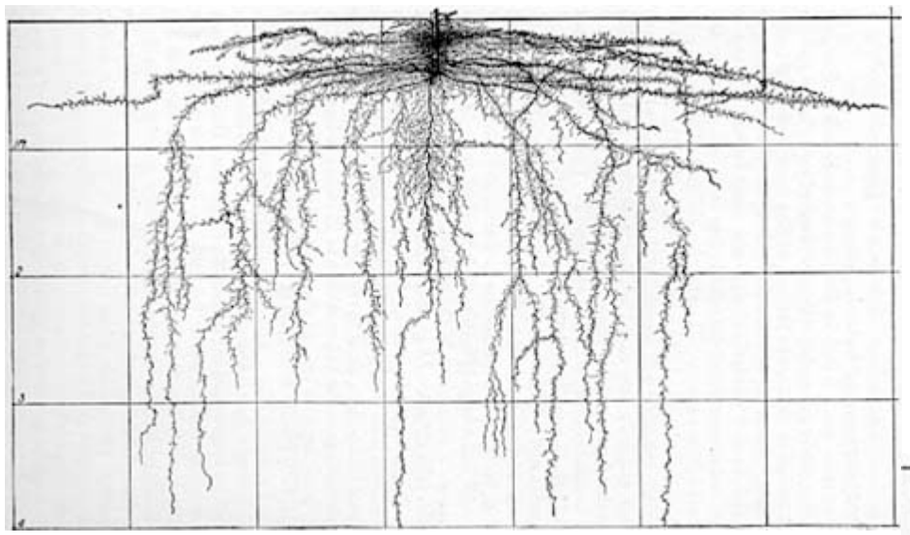
soil strength
nutrients
water
neighbouring plants

Root development of
vegetable crops
Weaver and Bruner 1927

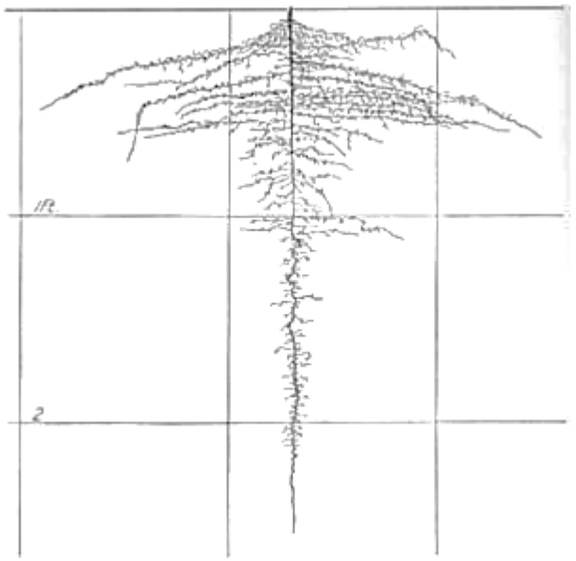
Crops typically grow in more predictable conditions

still a wide variation in how roots develop

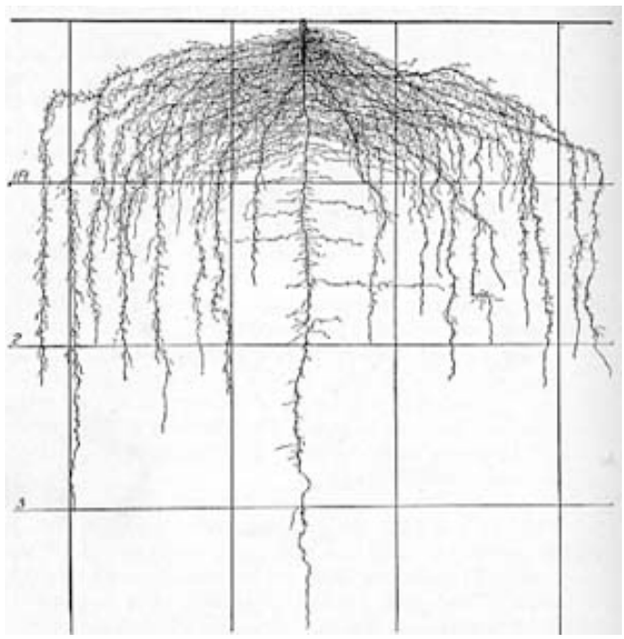
tomato 8 weeks



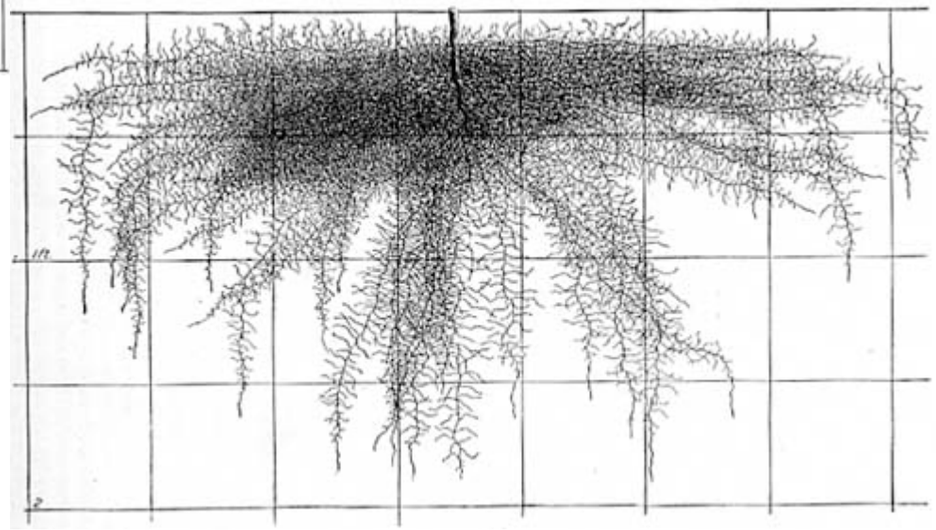
spinach
6 weeks



lettuce 8 weeks



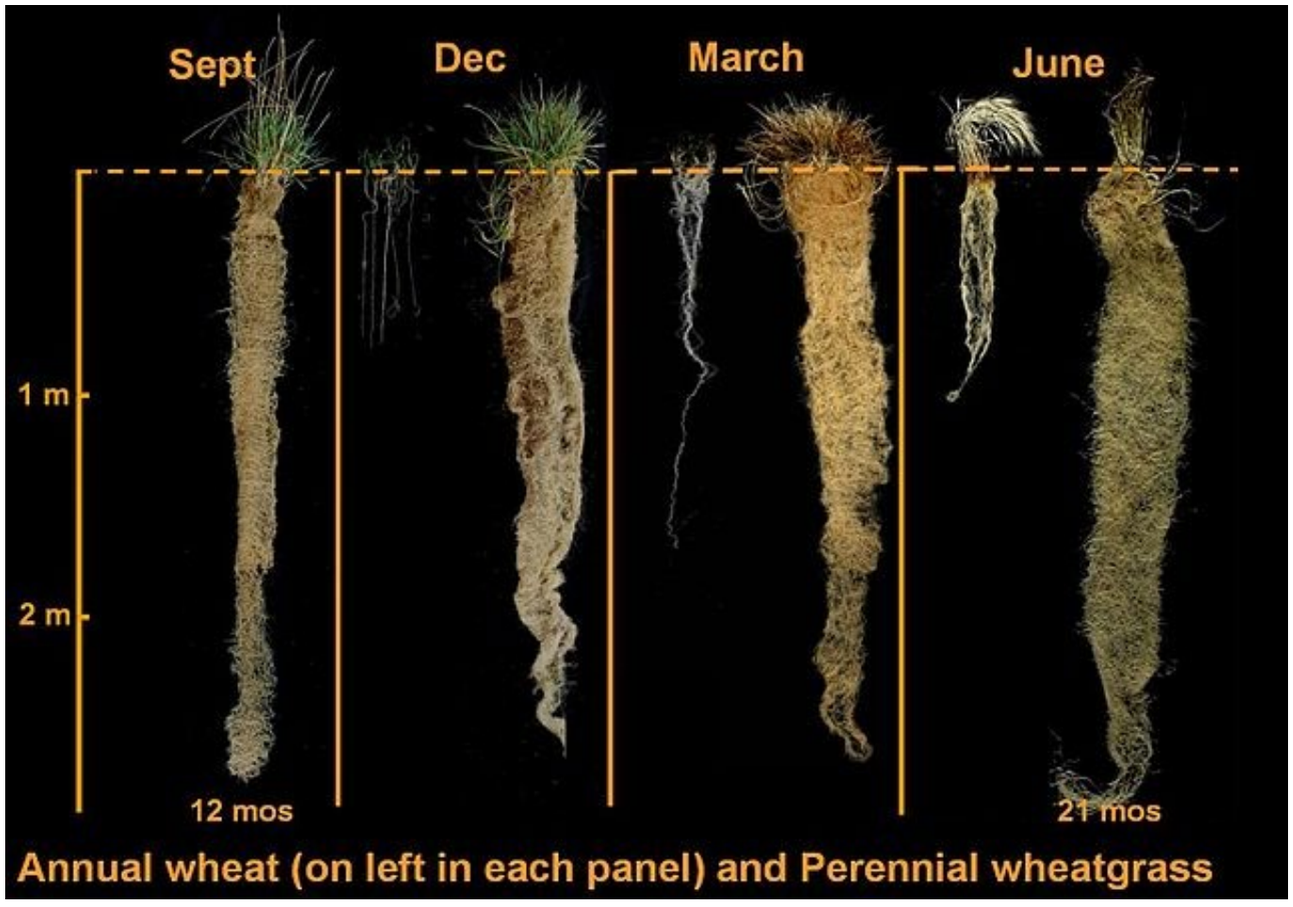
pepper 6 weeks



Selection for aboveground yield in crops typically leads to

- decreased root:shoot ratio
- lower lateral root density

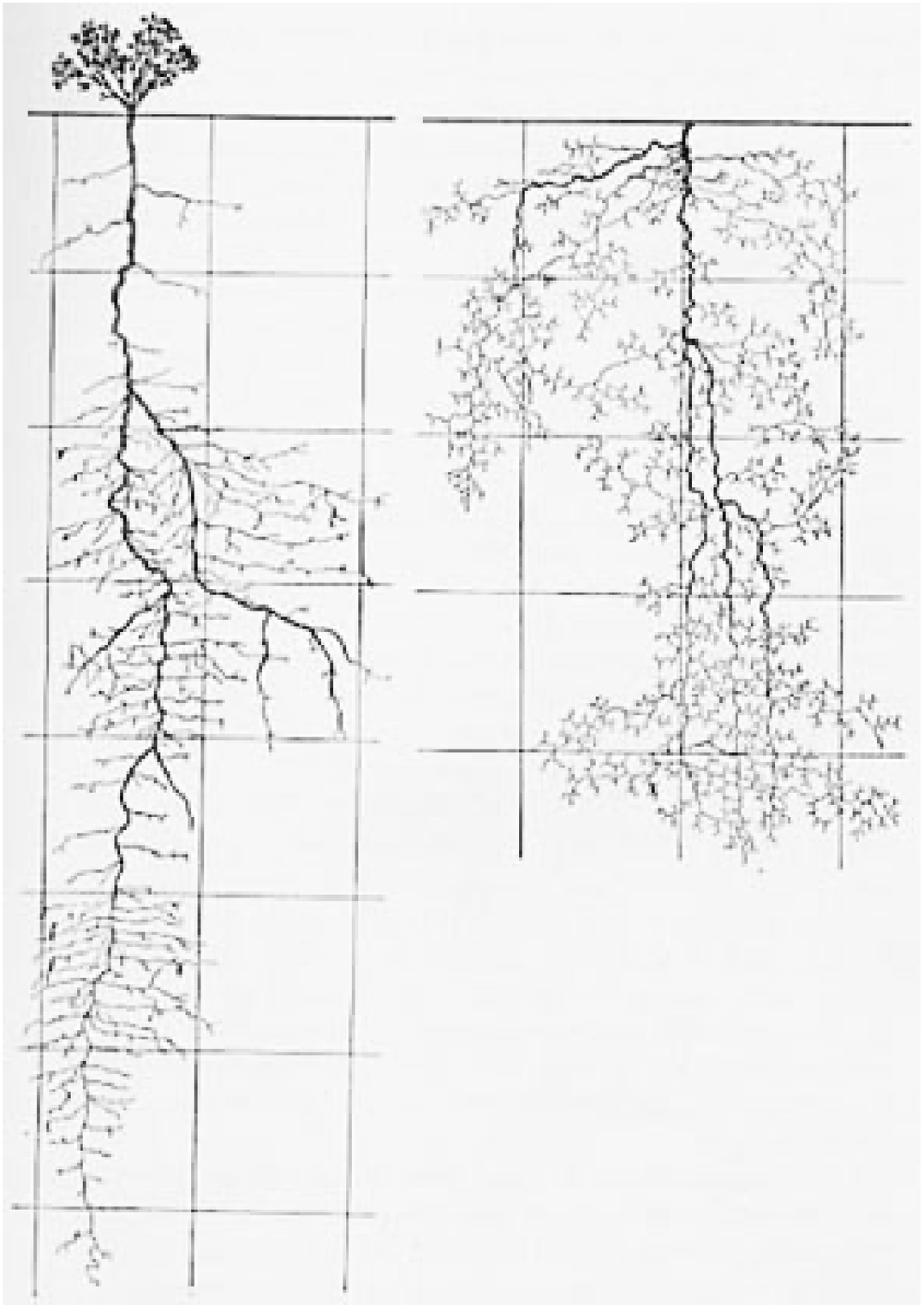
Schmidt et al. FrontPlantSci 2016
doi: 10.3389/fpls.2016.00373



By Dehaan - Jerry Glover, CC

some selection criteria may lead to improved root development:

stay-green QTLs coincide with enhanced root growth and changes in root angles



Root development of
vegetable crops
Weaver and Bruner 1927

Euphorbia brachycera (syn. montana)

in a prairie soil and in a gravel slide

root development can show great plasticity

We give priority in our research to how root systems may help crops to cope with:

- increasingly frequent but unpredictable extreme weather events
- precision agriculture including smart fertilisation

Greenhouse and root lab in Nijmegen

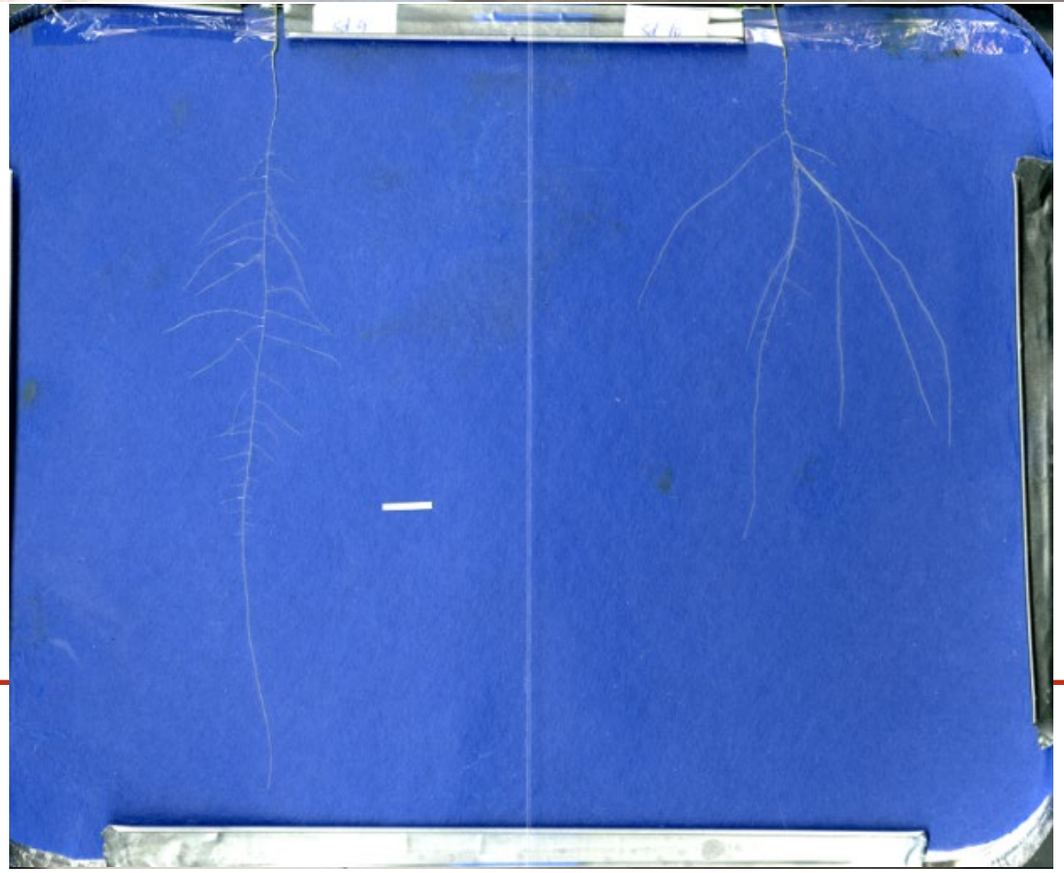
Radboud University Nijmegen

A very straightforward way to adapt the root system of a crop is simply *grafting* it on a suitable rootstock

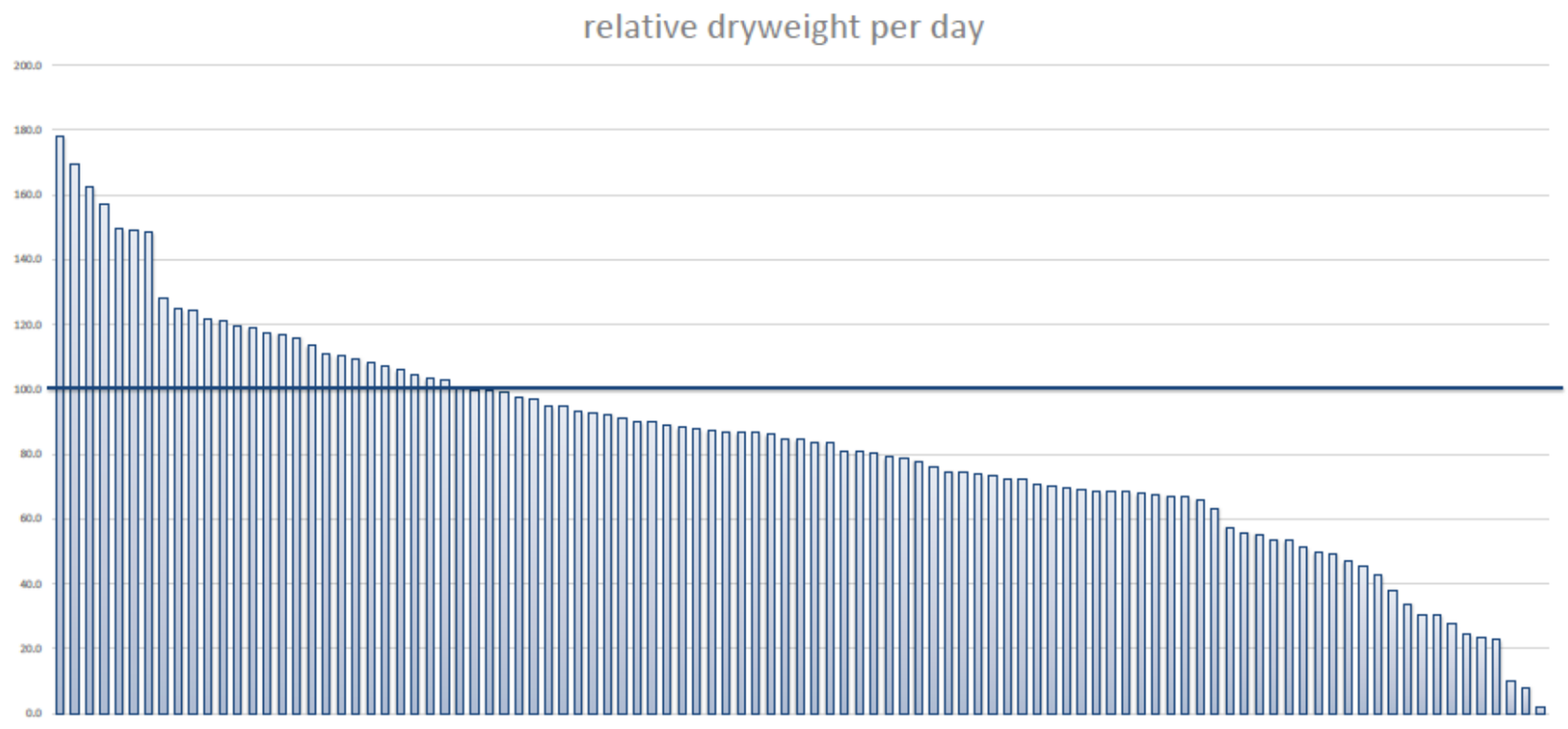
using the potential of ***wild relatives***

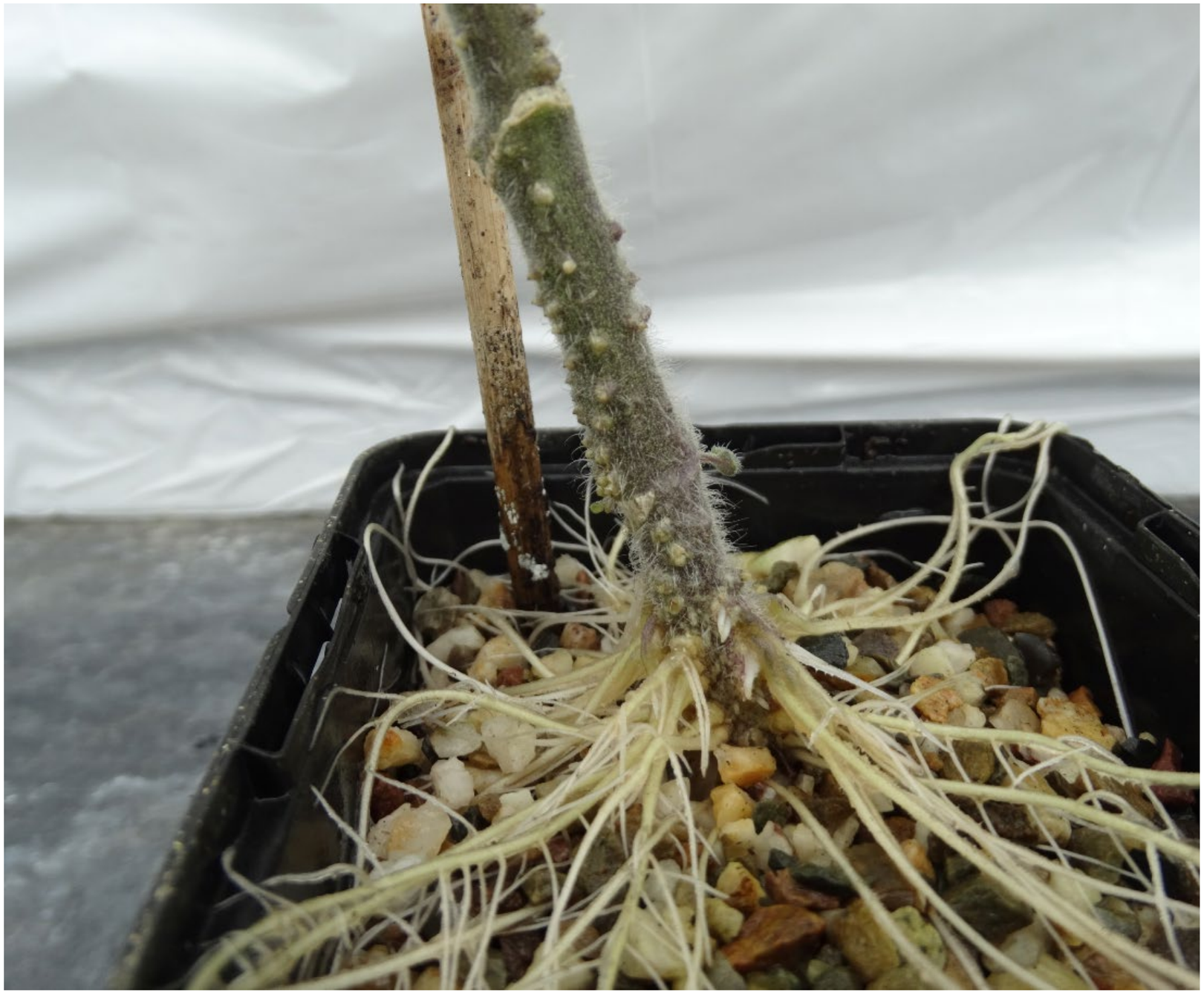
tomato graft on wild Solanum species

Extensive screening for abiotic stress resistance needed to find suitable species and accessions



Several combinations of tomato grafted on new *Solanum* rootstocks were successful, even in the absence of stress

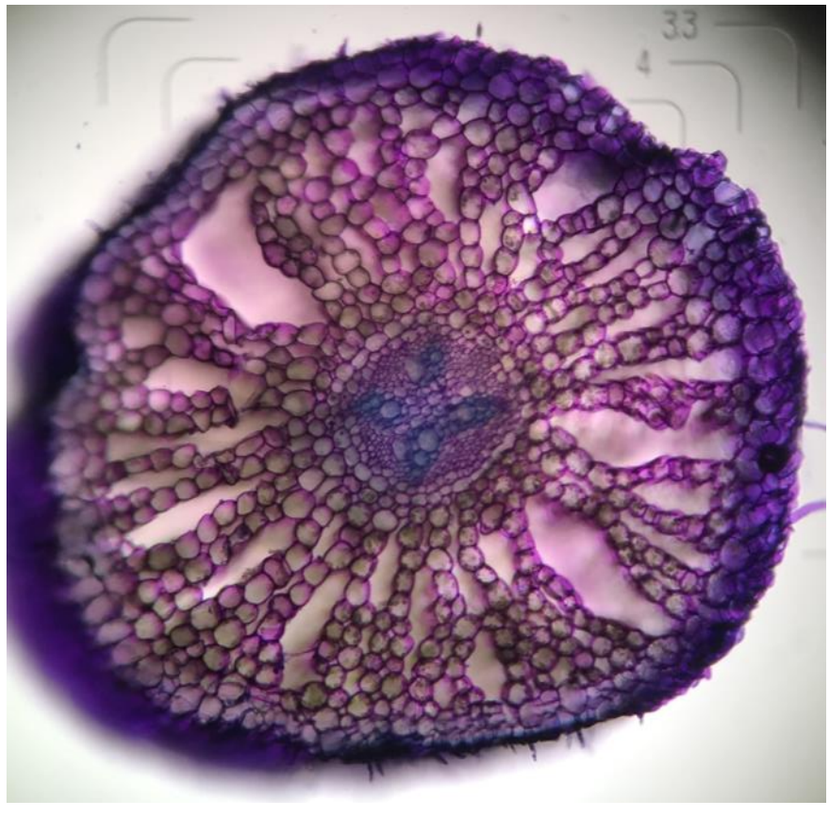


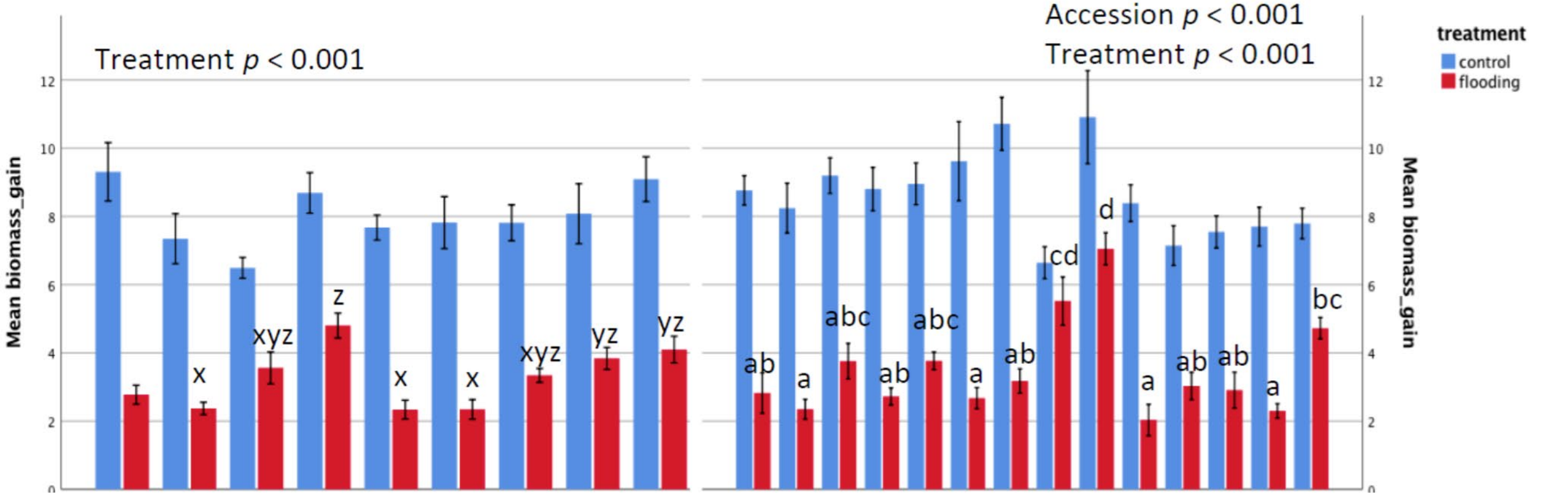


flood tolerant rootstock responding to waterlogging

Testing for tolerance to:

waterlogging
salinity
drought




Treatment $p < 0.001$
Accession $p < 0.001$
Treatment $p < 0.001$
treatment
control
flooding
Mean biomass_gain
Mean biomass_gain
0
2
4
6
8
10
12
x
xyz
z
x
x
xyz
yz
yz
ab
a
abc
ab
abc
a
ab
cd
d
a
ab
ab
a
bc

https://melkveebedrijf.be/

maize

https://www.standaard.be/

cauliflower

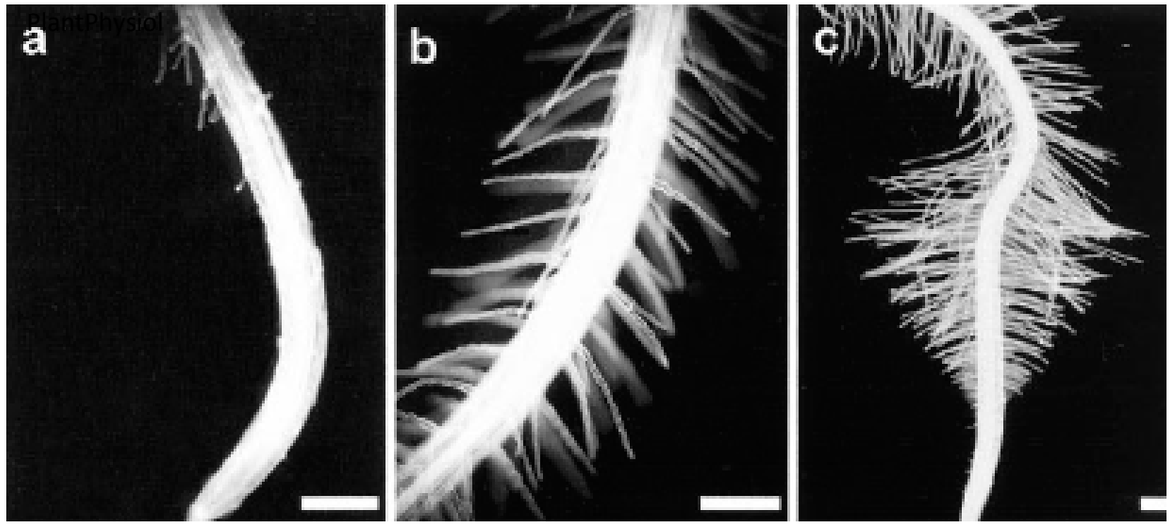
More frequent but still unpredictable drought in the Netherlands and Belgium

Constitutive root traits may help, but root systems that respond to their environment might be even better

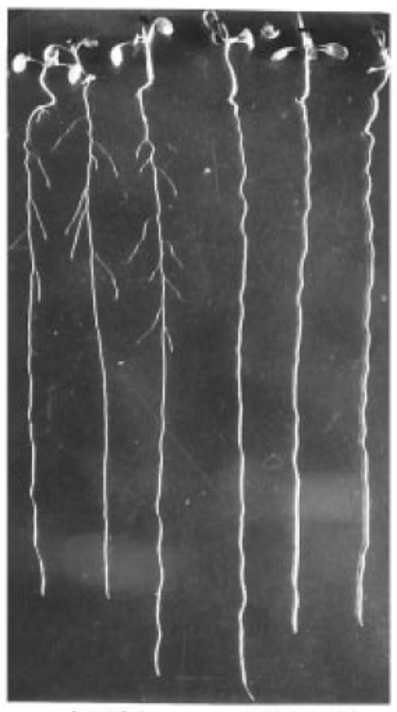
Root phenotypic plasticity **adds to the resilience of the plant**

Nutrients control the architecture of the root system (RSA)

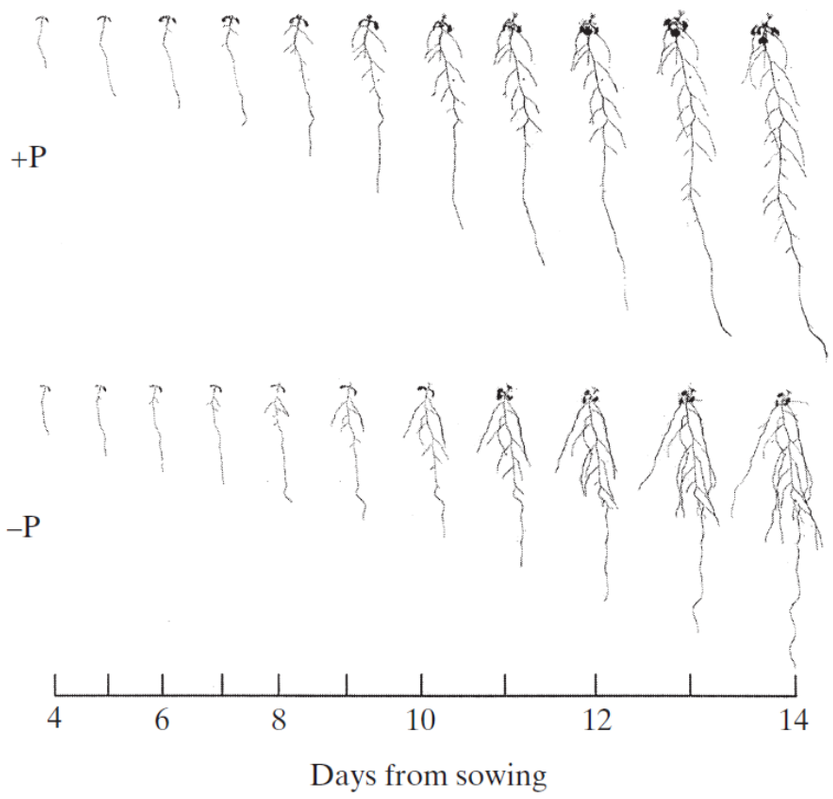
Schmidt and Schikora 2001
PlantPhysiol



control **-Fe** **-P**

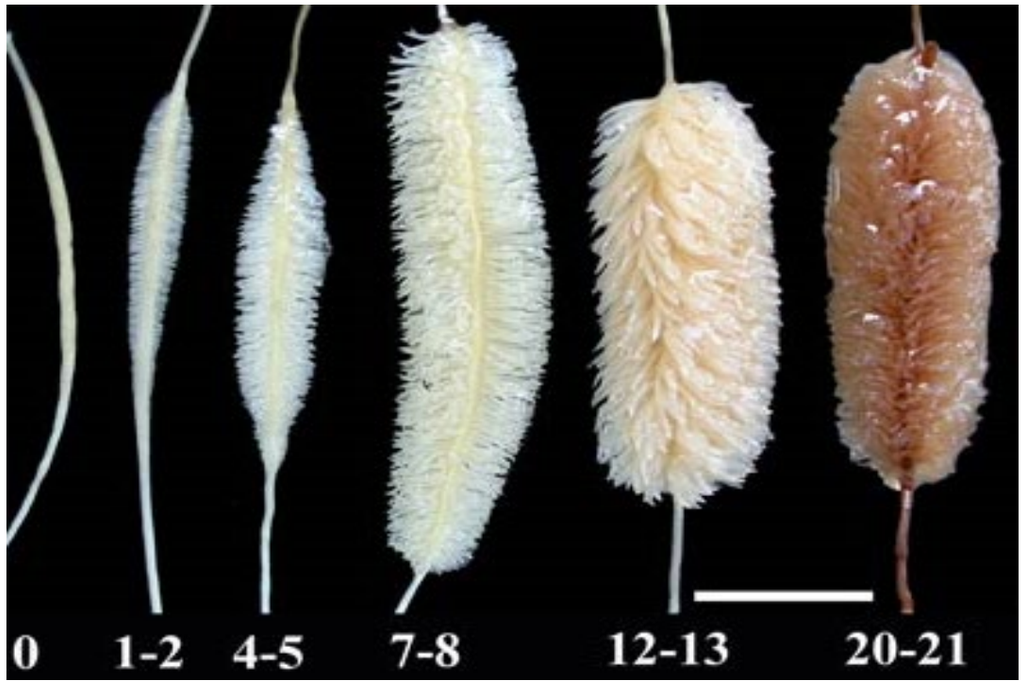


Zhang et al. 1999 PNAS

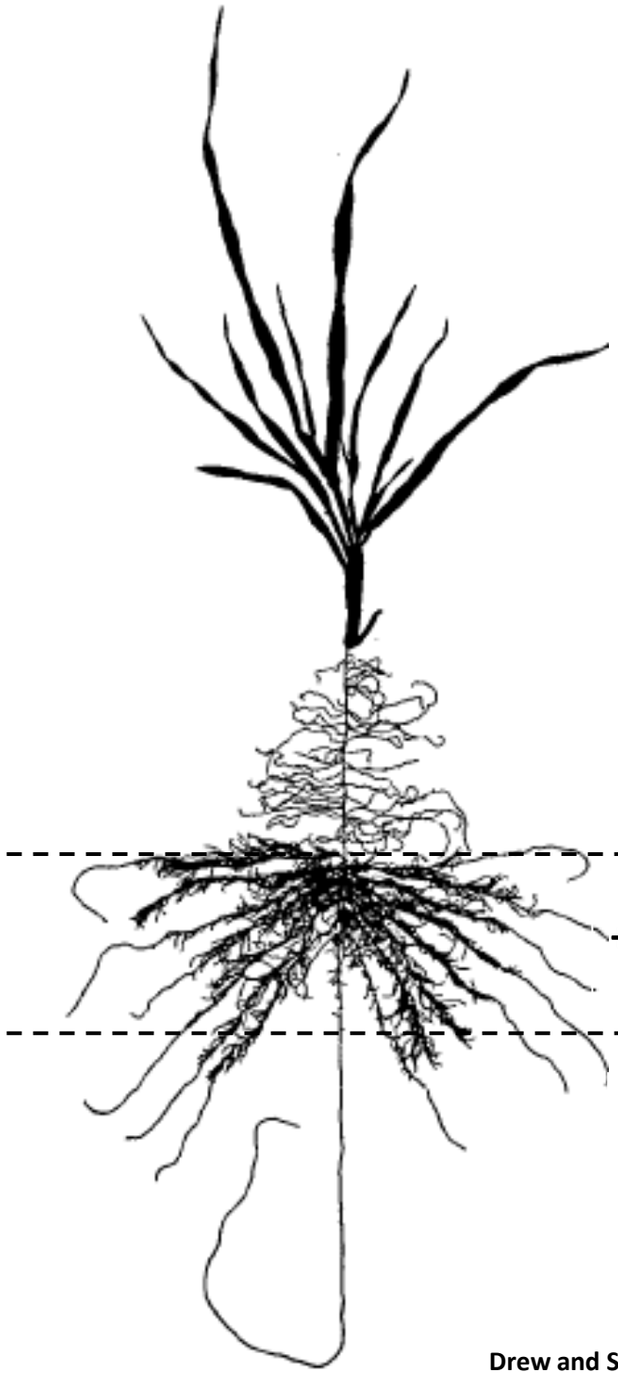


Al-Ghazi et al. 2003 PlantCellEnviron

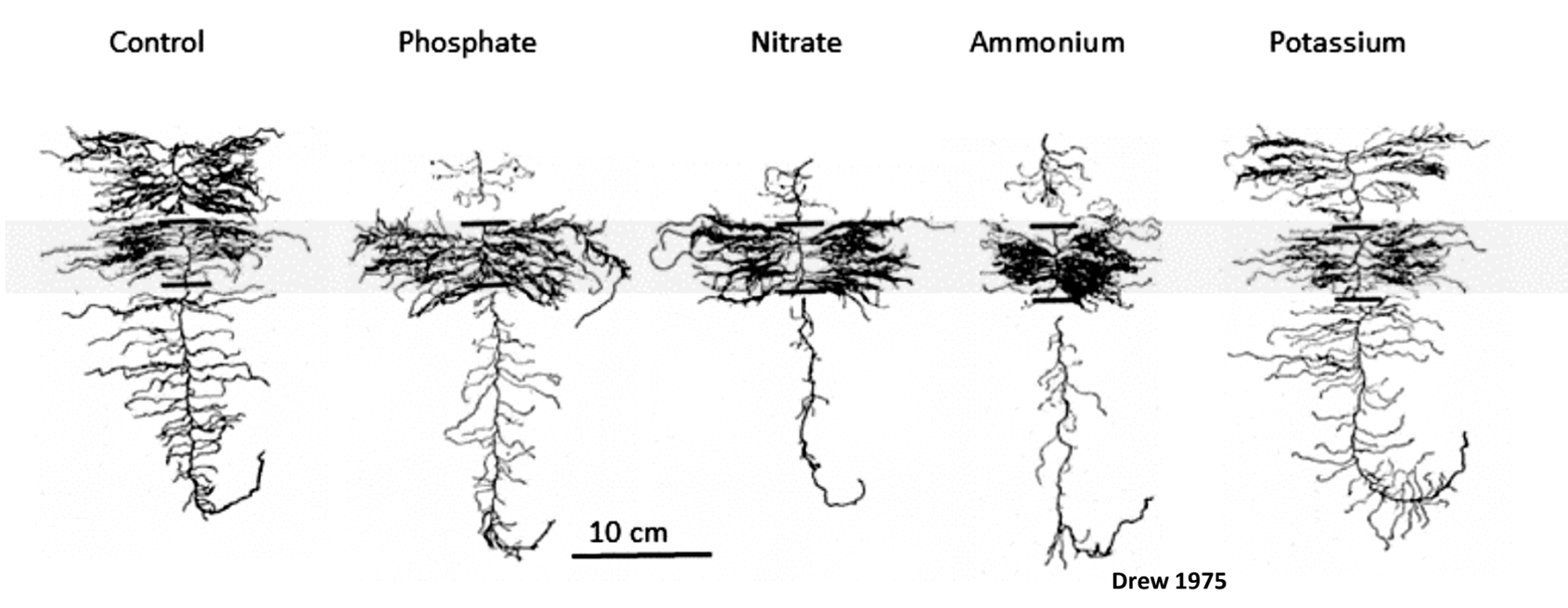
Photographs by Mike Shane, UWA (Plant and Soil, 2005)



Pioneer work of Malcolm Drew et al. on barley in nutrient patches



Drew and Saker 1978



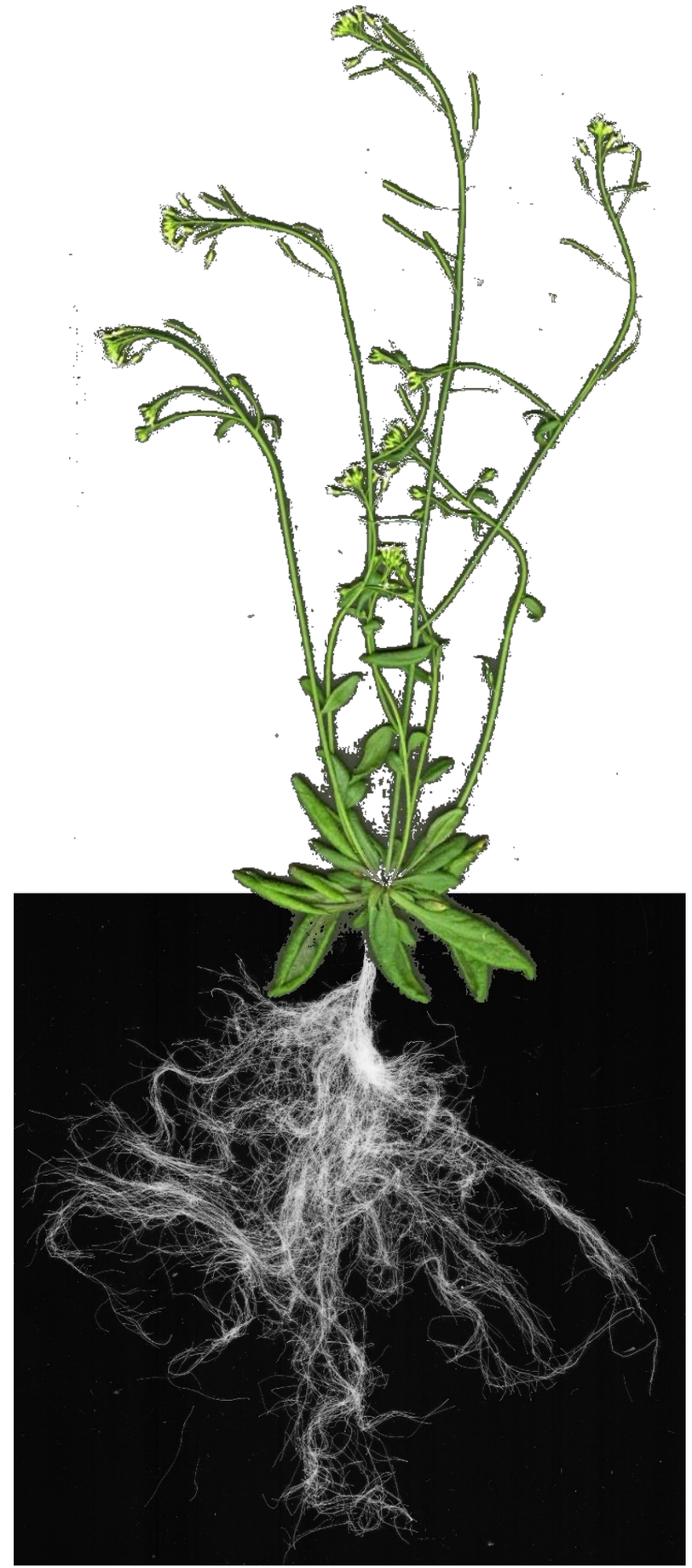
Drew 1975

selective root placement

Arabidopsis thaliana

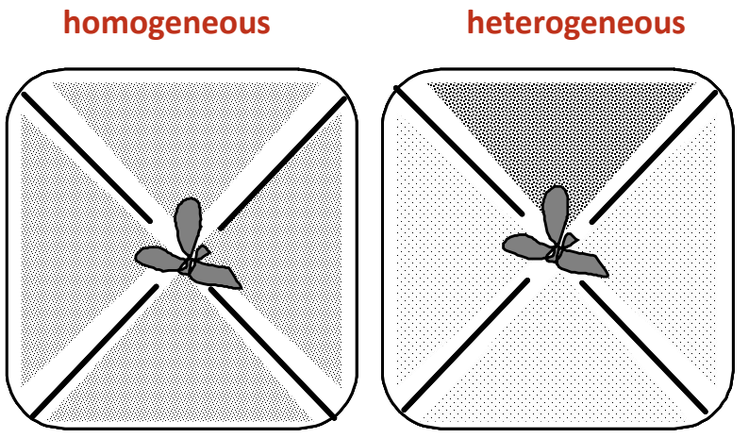
shoot DW 384 mg
root DW 24.1 mg
root length 41.0 m
root diameter 0.157 mm
root length 0-0.1 mm 22.9 m
0.1-0.2 mm 13.1 m
> 0.2 mm 5.0 m

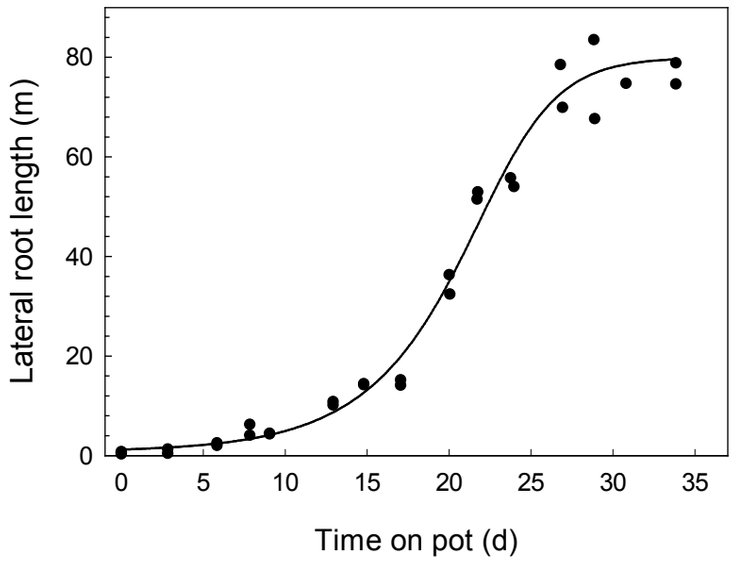
specific root length
1703 m per g DW

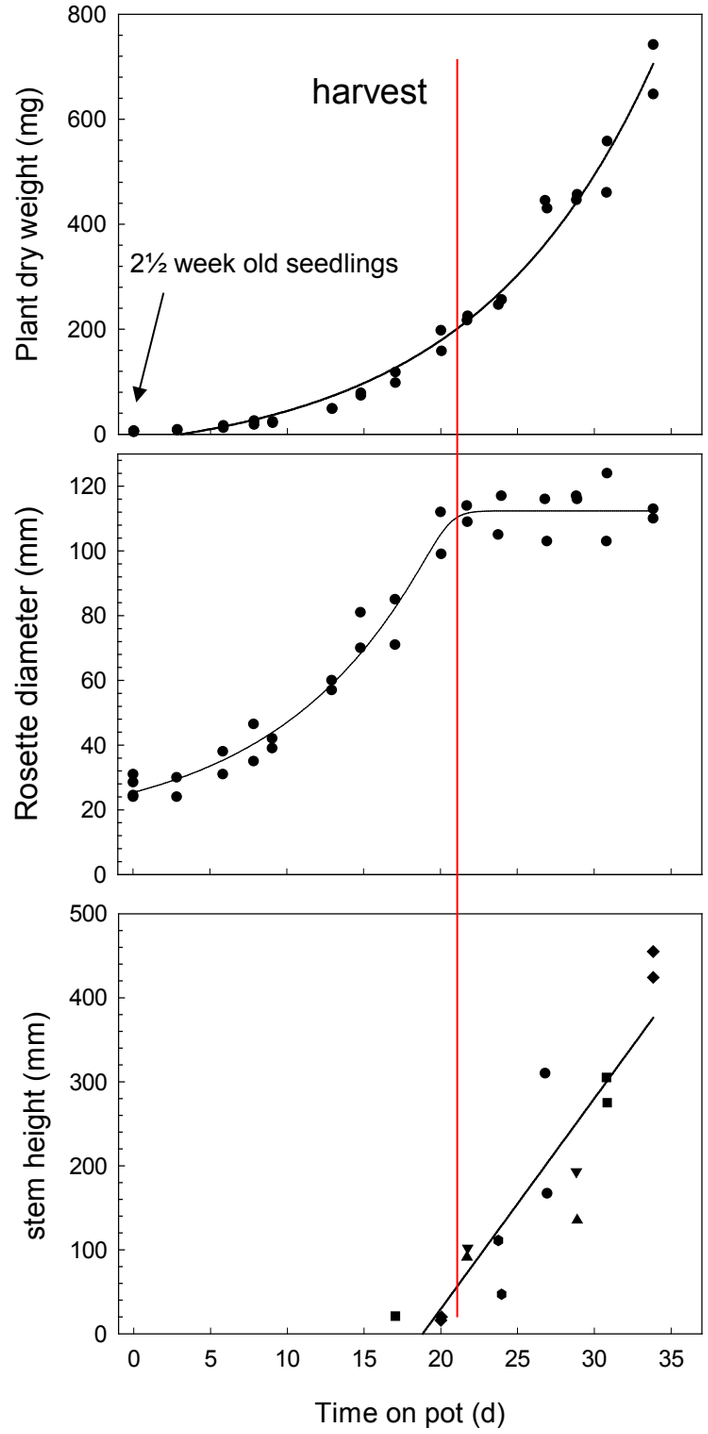


Arabidopsis sand culture with nutrient patches

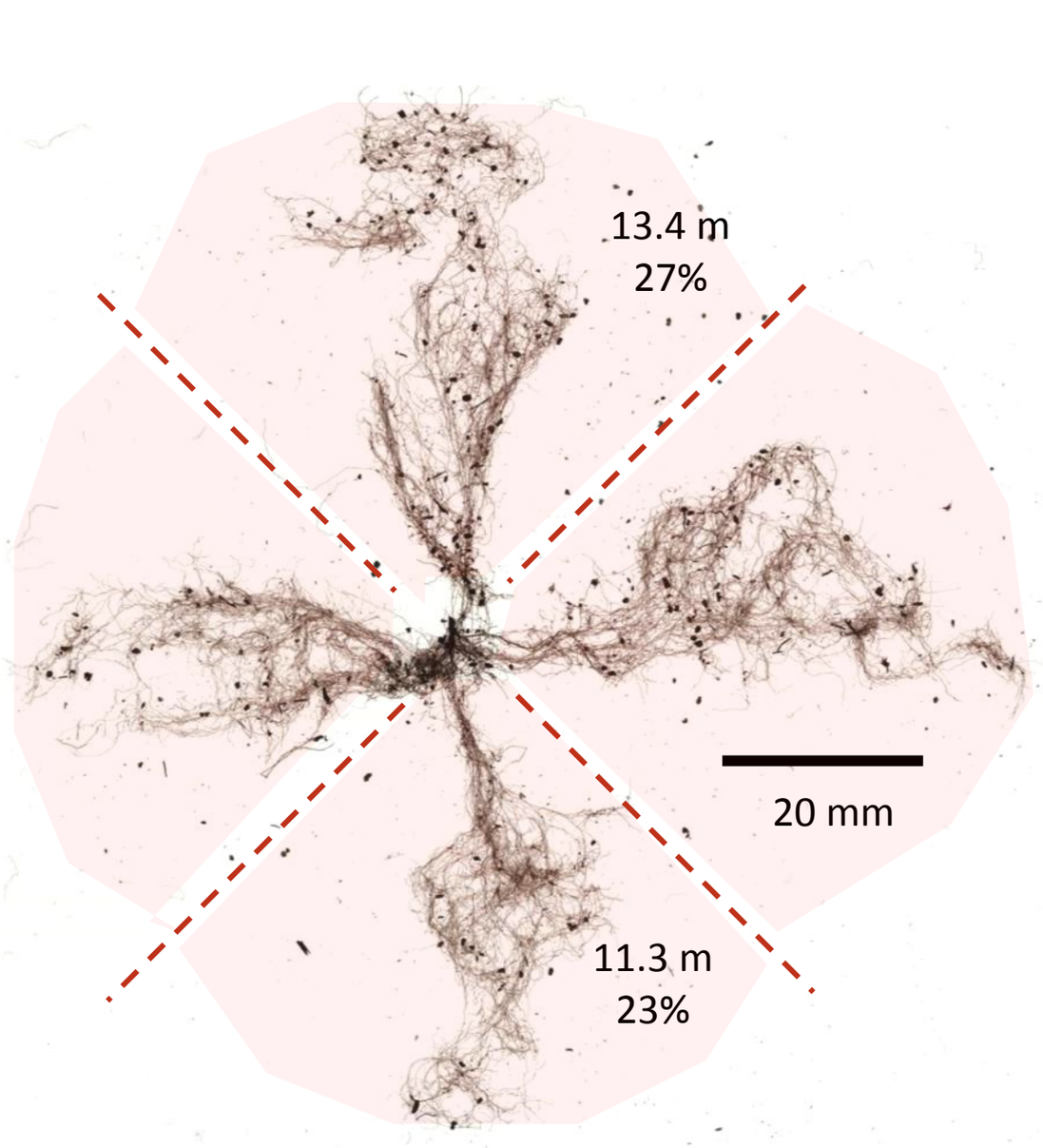
Ecotype Columbia-0

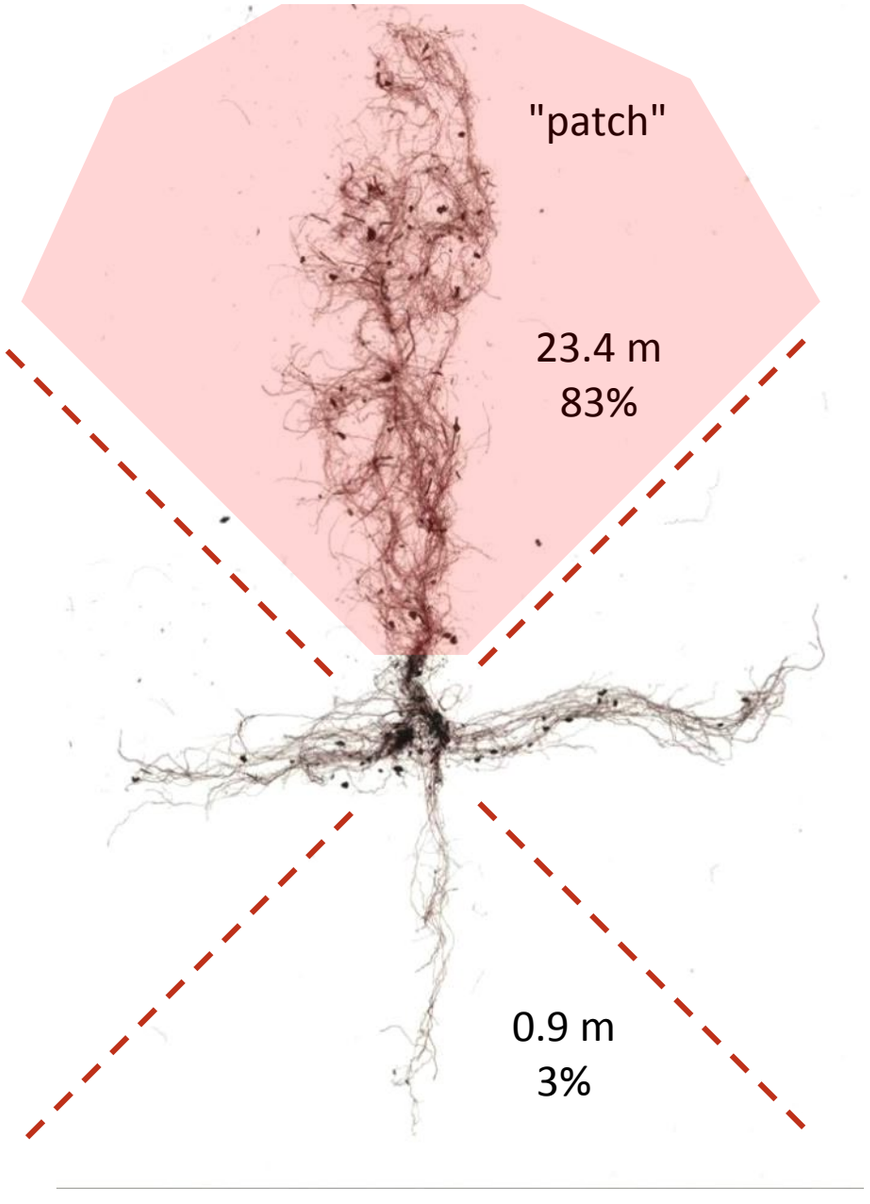






belowground responses to nutrient patches are strong





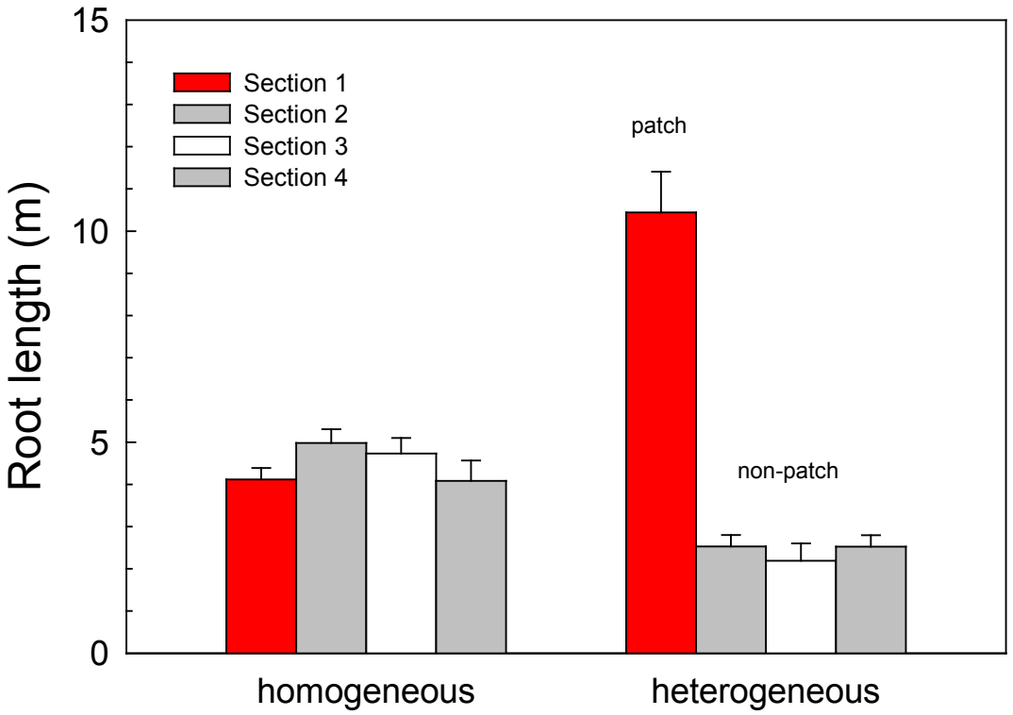
homogeneous

heterogeneous

nutrient supply

Selective root placement towards nitrate and phosphate (Pi) appears an additive response

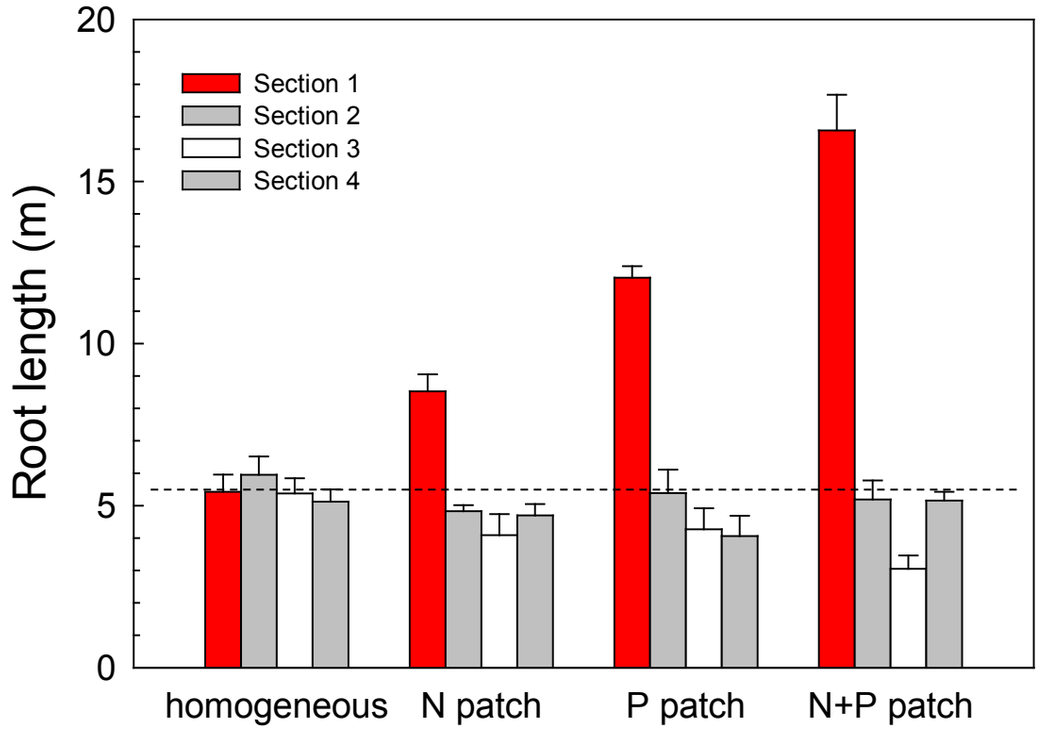
Patch with nutrient solution



Patch:

$[NO_3^-]$ = 9 mM

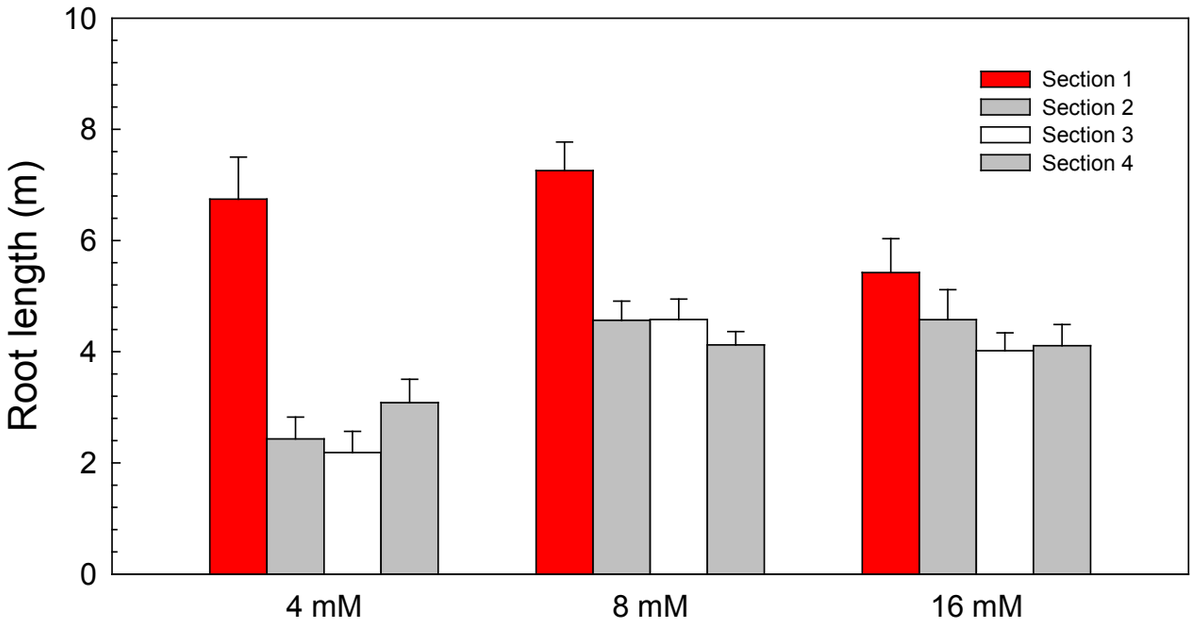
$[P_i]$ = 0.5 mM



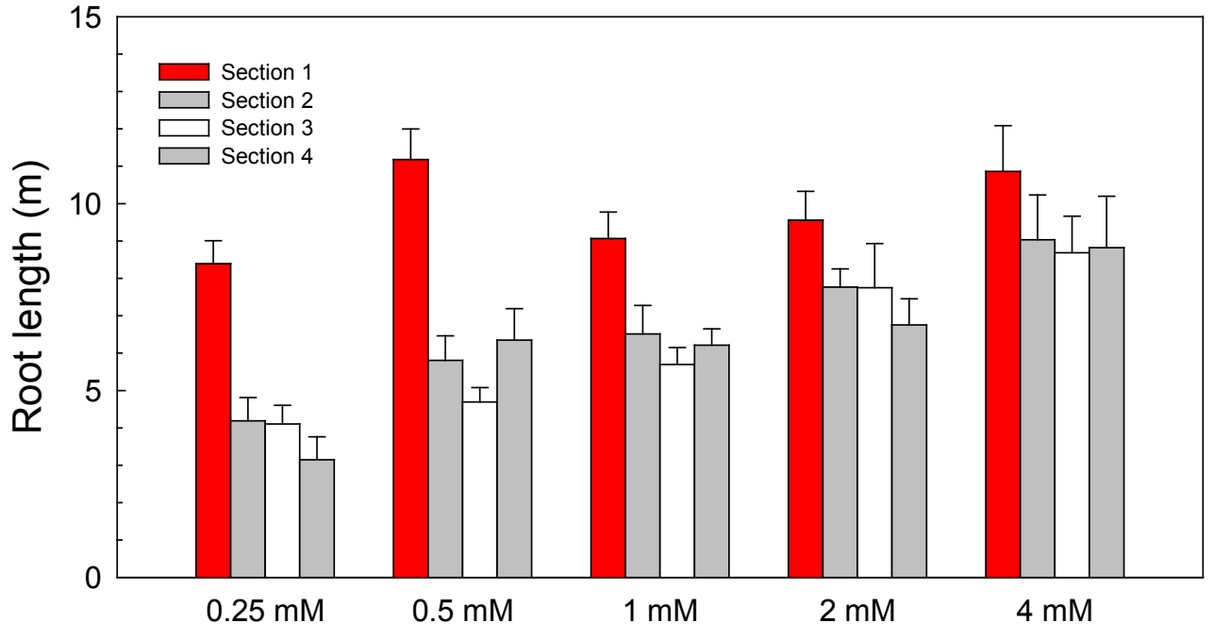
But:

root growth in patch and non-patch depends on concentration in the patch

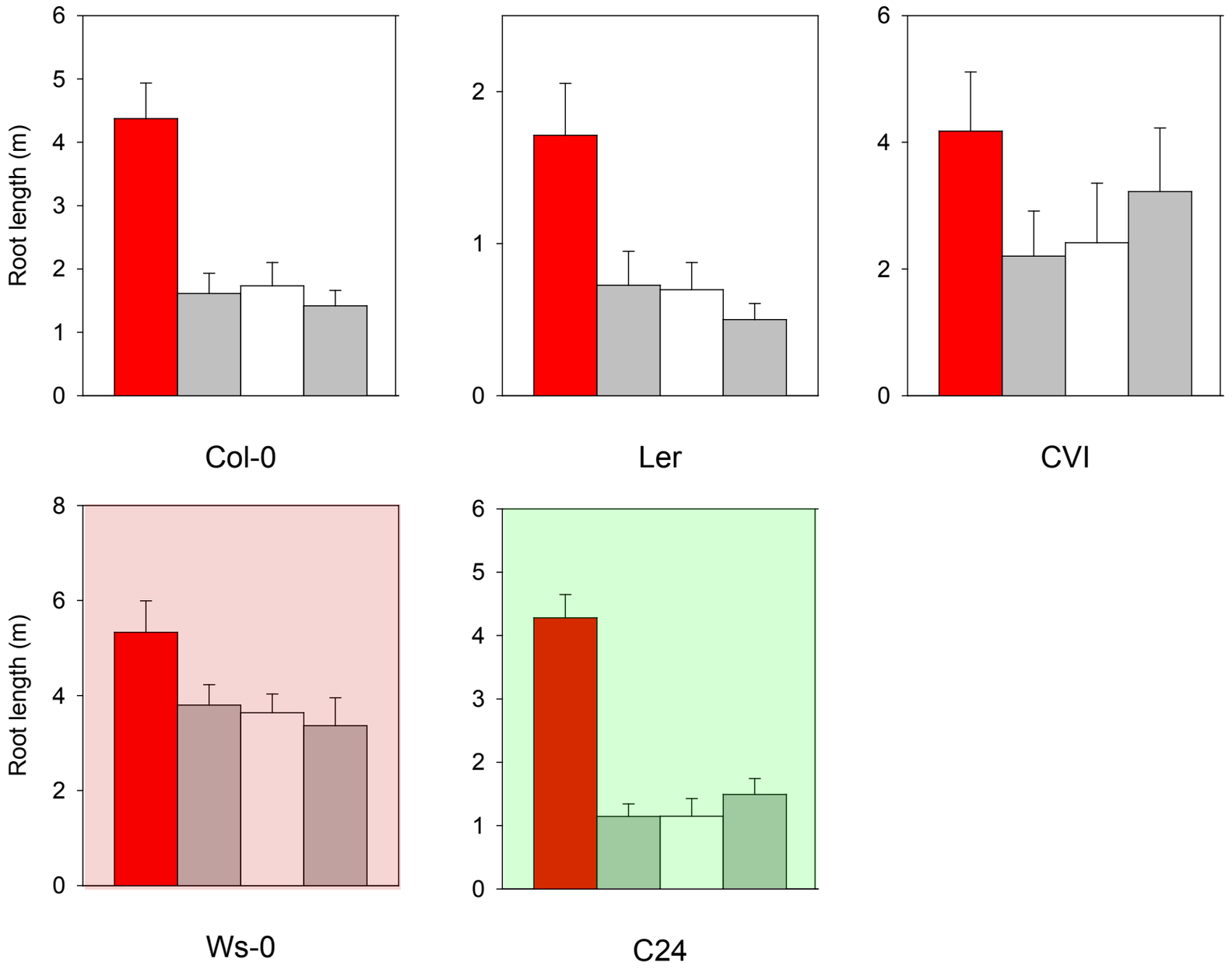
Background $[NO_3^-]$ = 0 mM
Patch $[NO_3^-]$ 4 – 16 mM



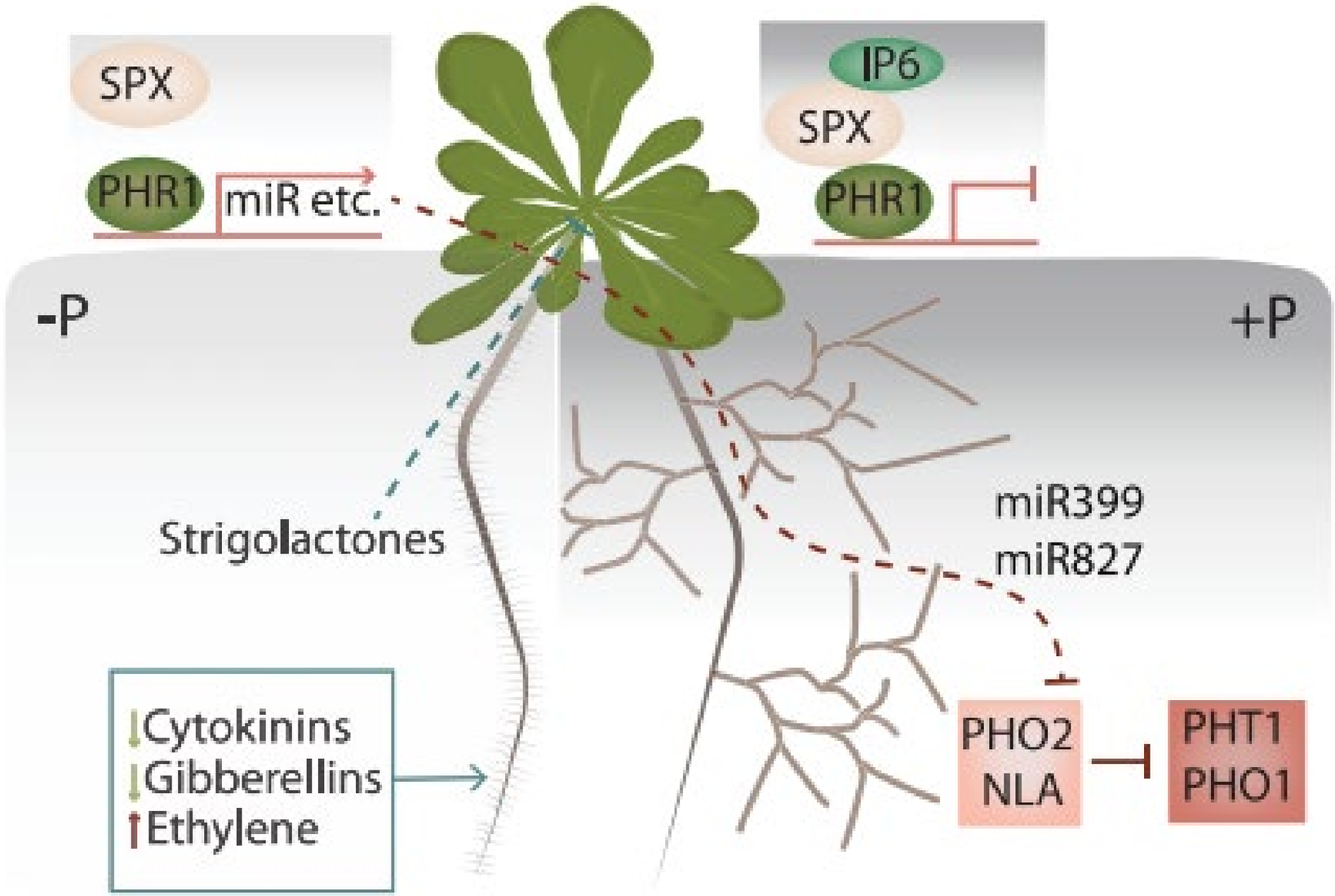
Background $[P_i]$ = 0 mM
Patch $[P_i]$ 0.25 – 4 mM



Variation in selective root placement to phosphate patches exists among genotypes



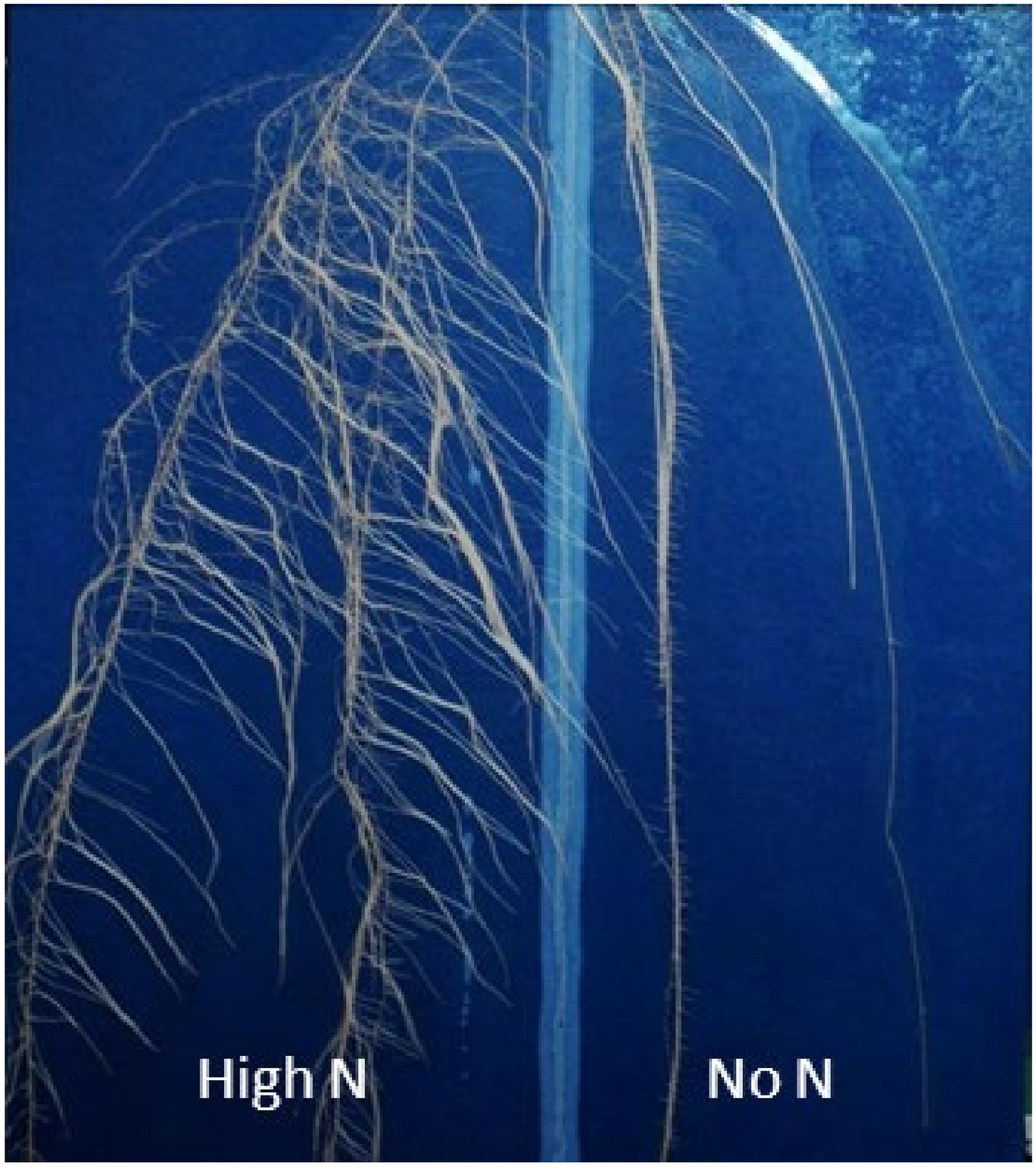
Regulation of selective root placement is now better understood, providing tools for selection



Oldroyd et al., Science 368, eaba0196 (2020)

How to apply such responses in agriculture?

Can deeper soil nutrients partially prevent drought stress by triggering deeper roots?



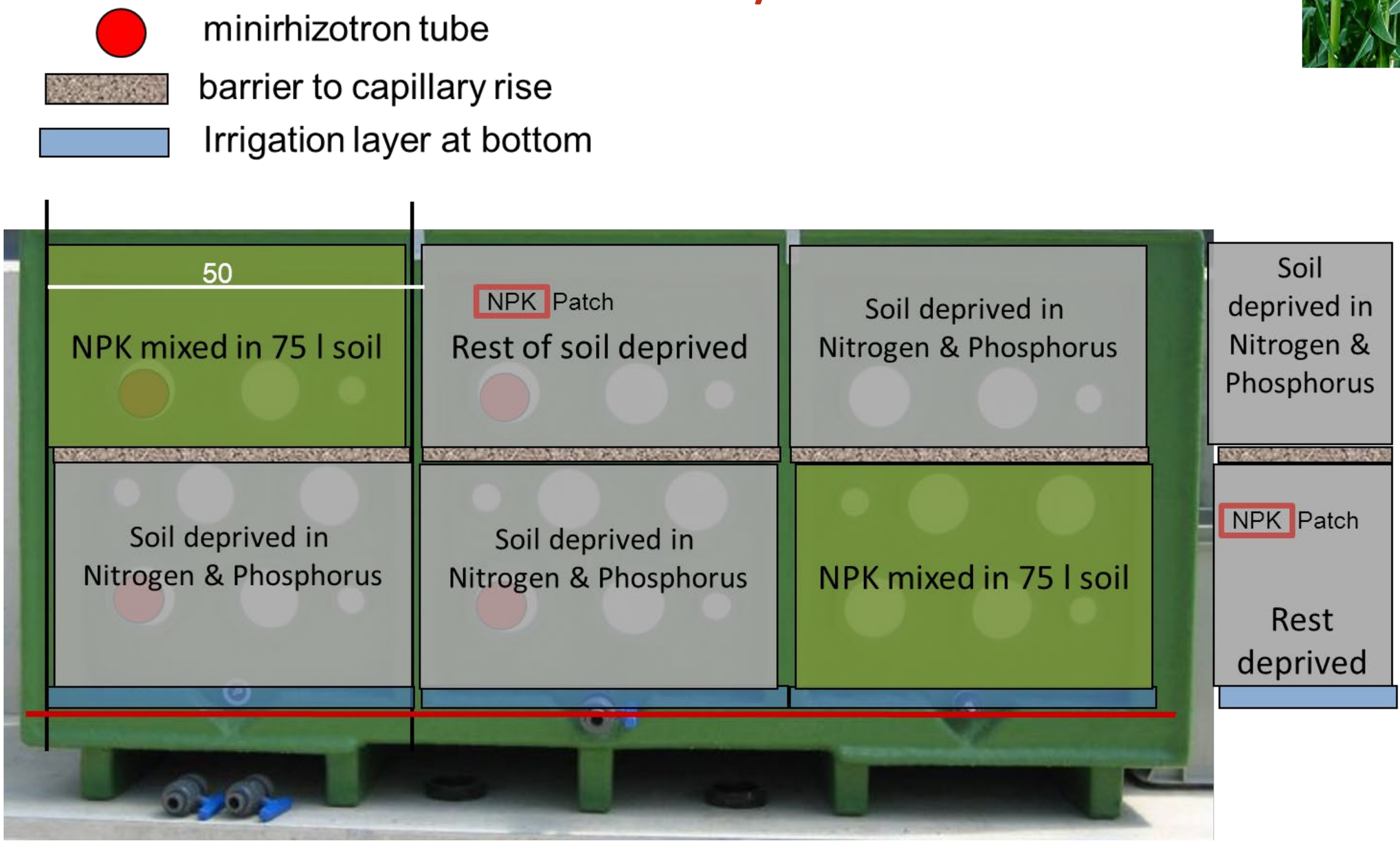
Maize shows selective root placement

Dina in ‘t Zandt et al.
JExpBot 2015

Nijmegen Root lab

enables studying roots in crops during the entire growing season, in compartments of 175 litres, in ambient conditions

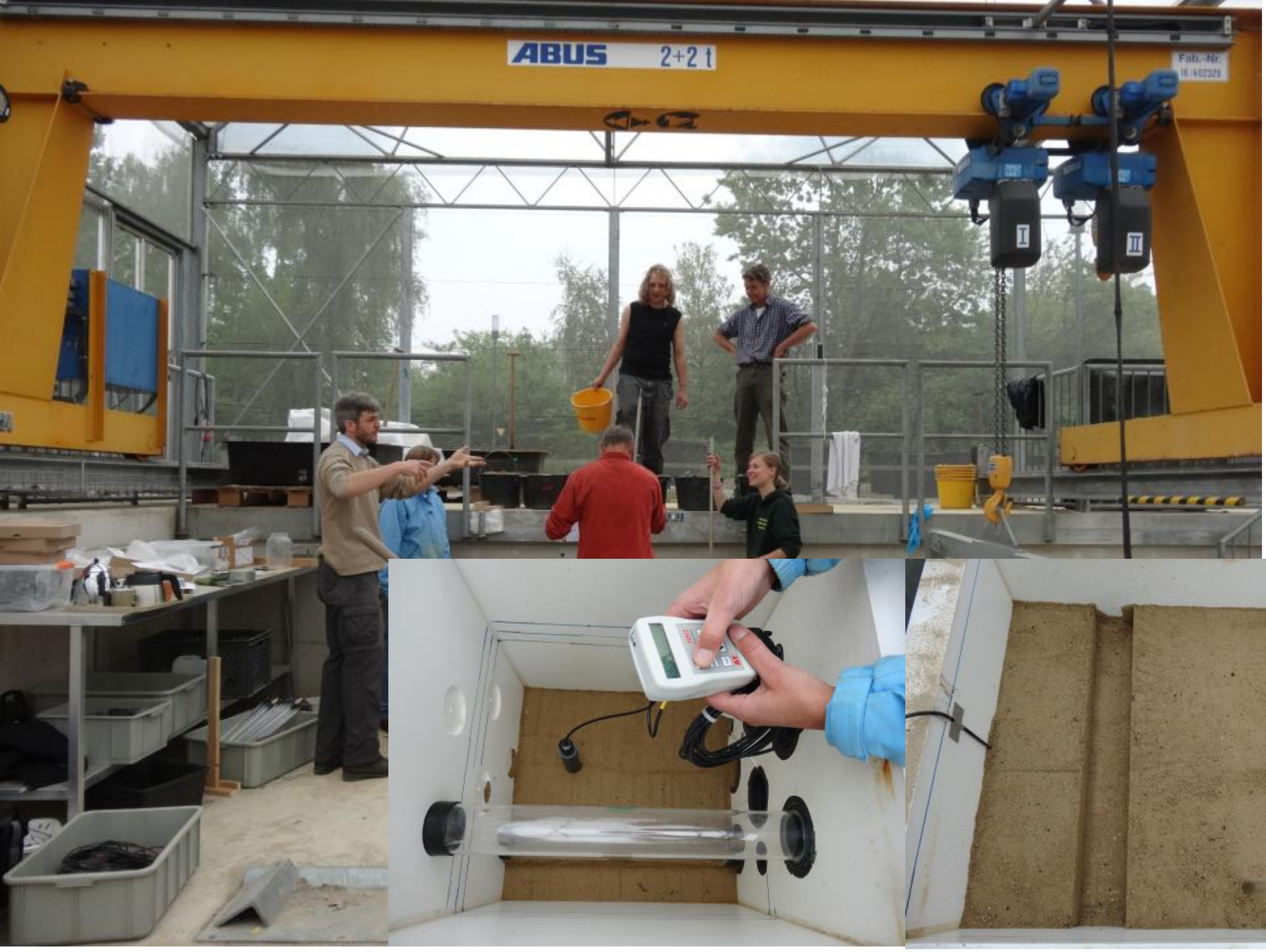
Maize B73xUH007 in nutrient-poor loam/sand



by Christian Fritz

Project EURoot
FP7 programme with Emmanuel Guiderdoni, Philippe Hinsinger, Bertrand Muller, Roberto Tuberosa, and many others

Radboud University Nijmegen


ABUS 2+2 t
Fab.-Nr.
I
II

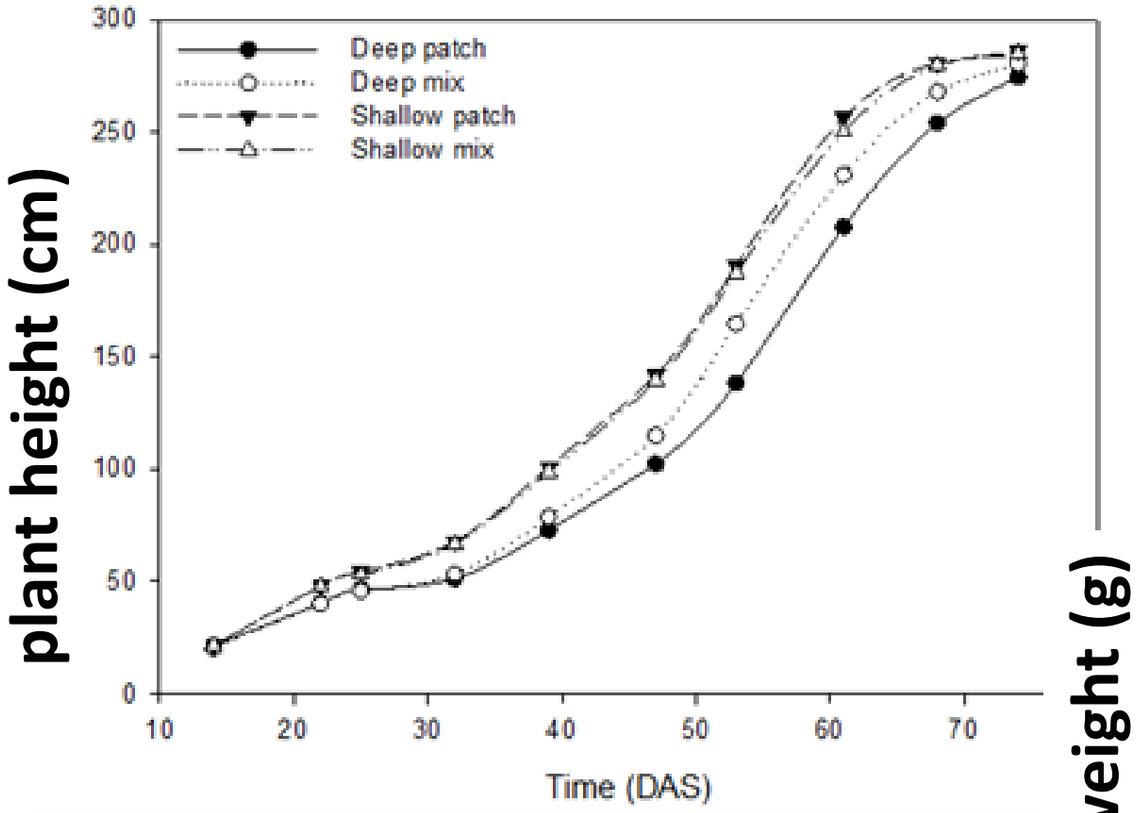

2 weeks

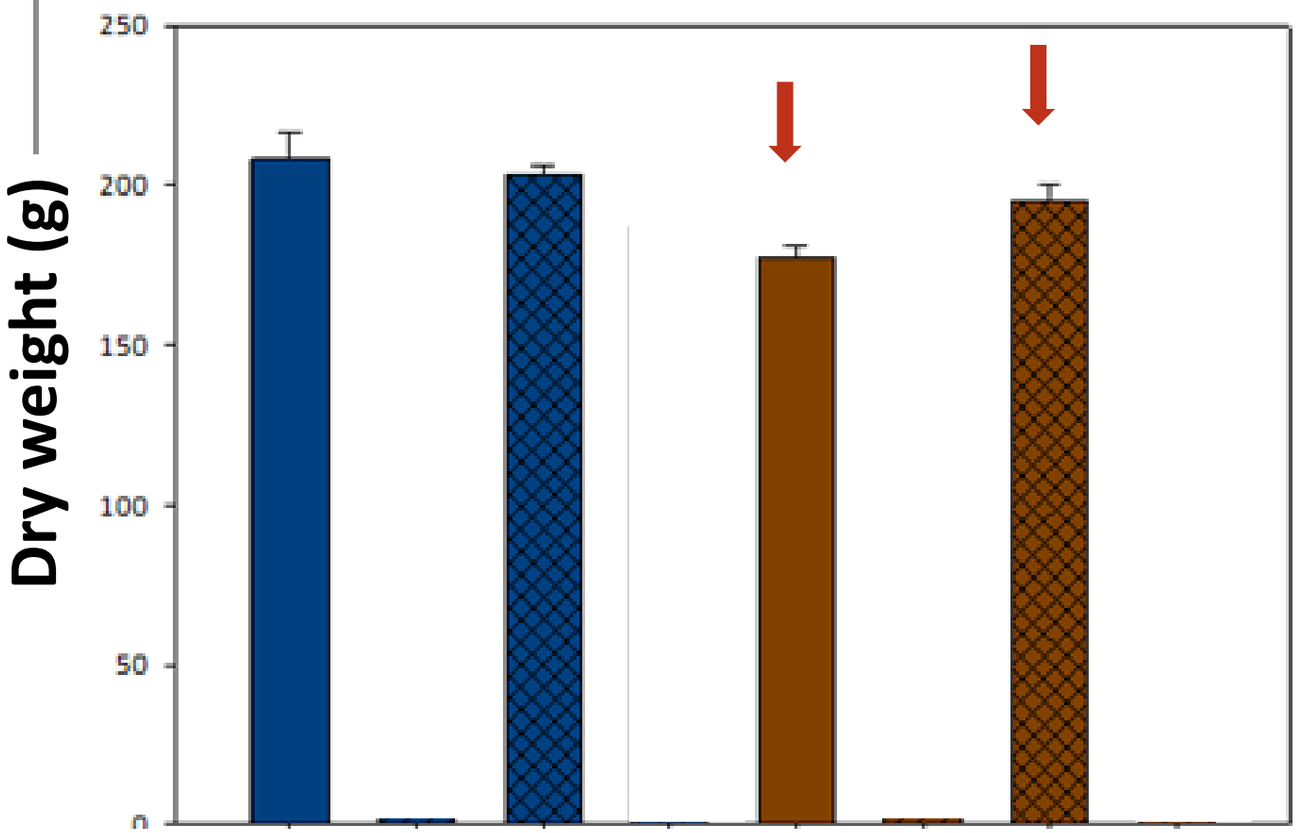
4 weeks

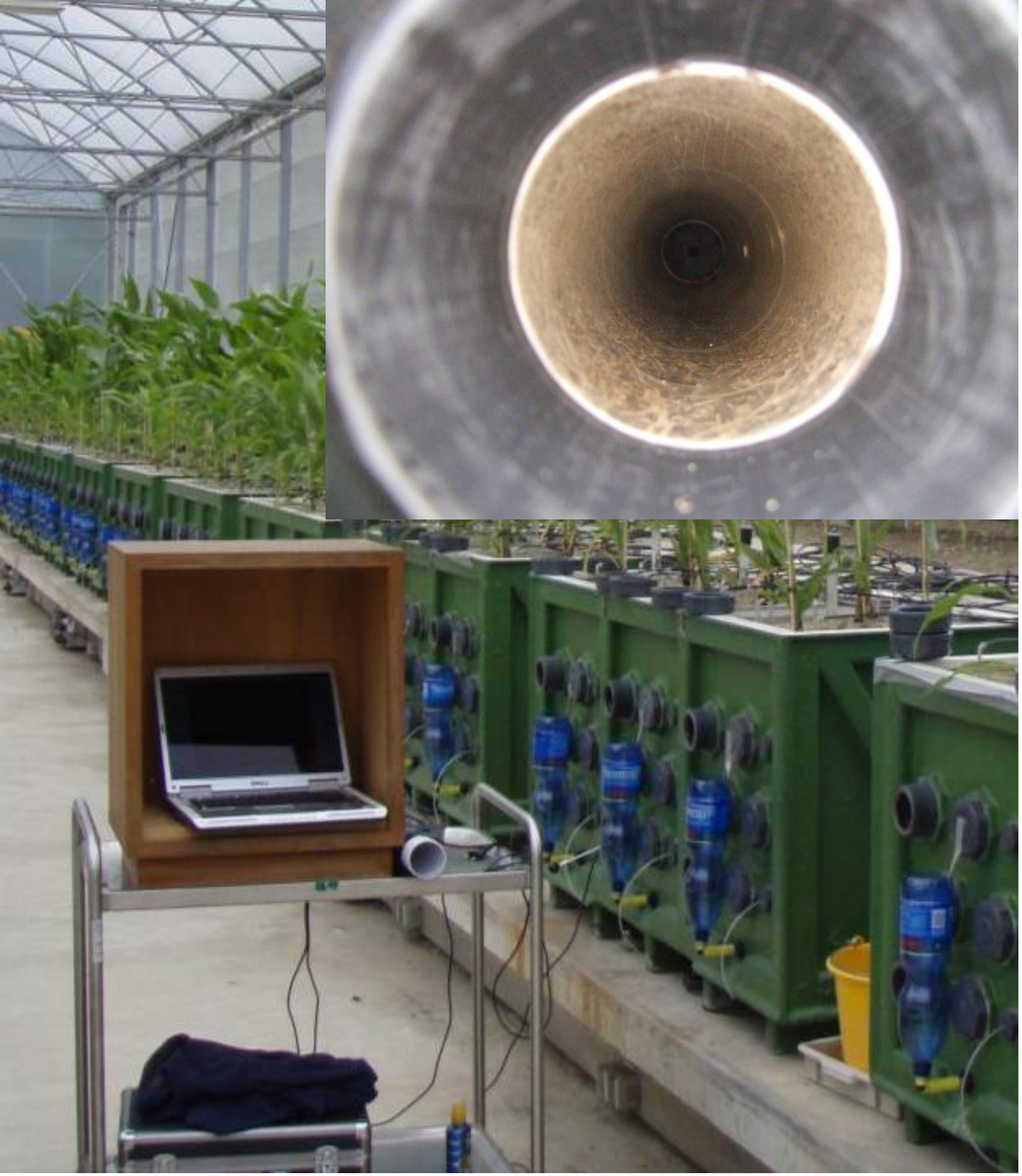
6 weeks

8 weeks

deep nutrients caused delayed growth, but resulted in somewhat better performance with progressing drought



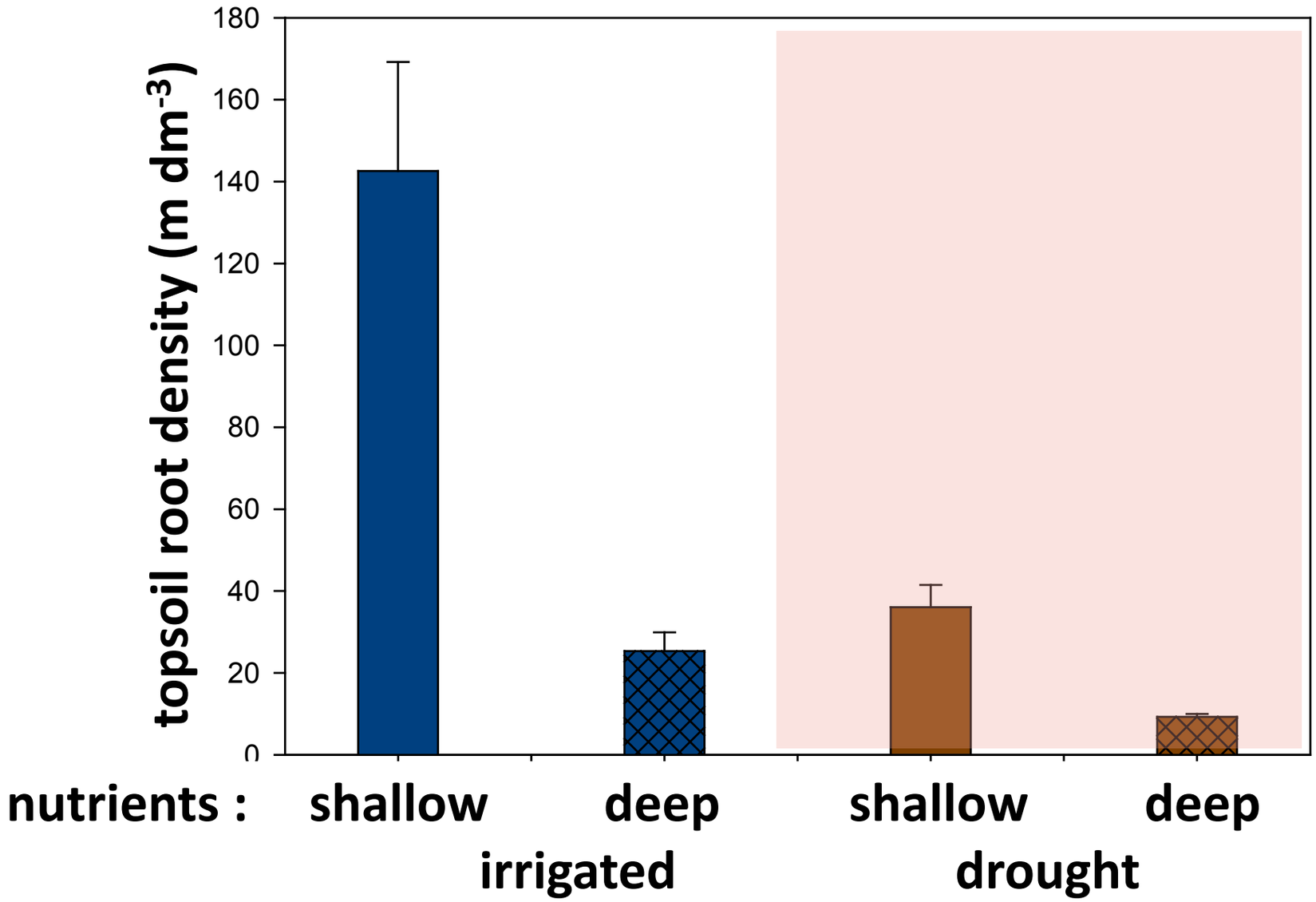




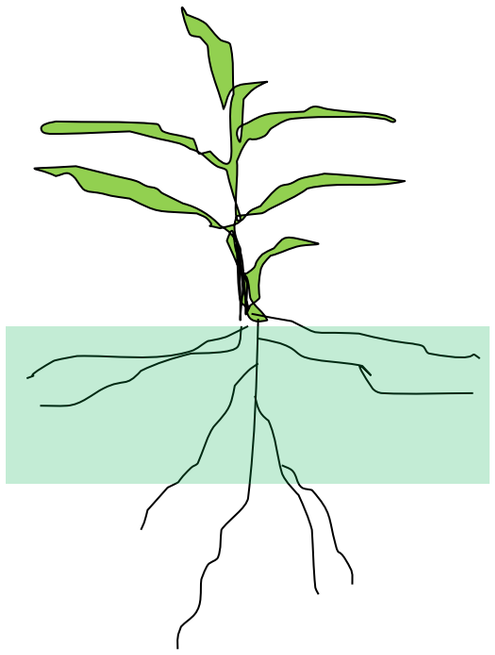
time

Many roots at the end of the season, but where are they positioned?

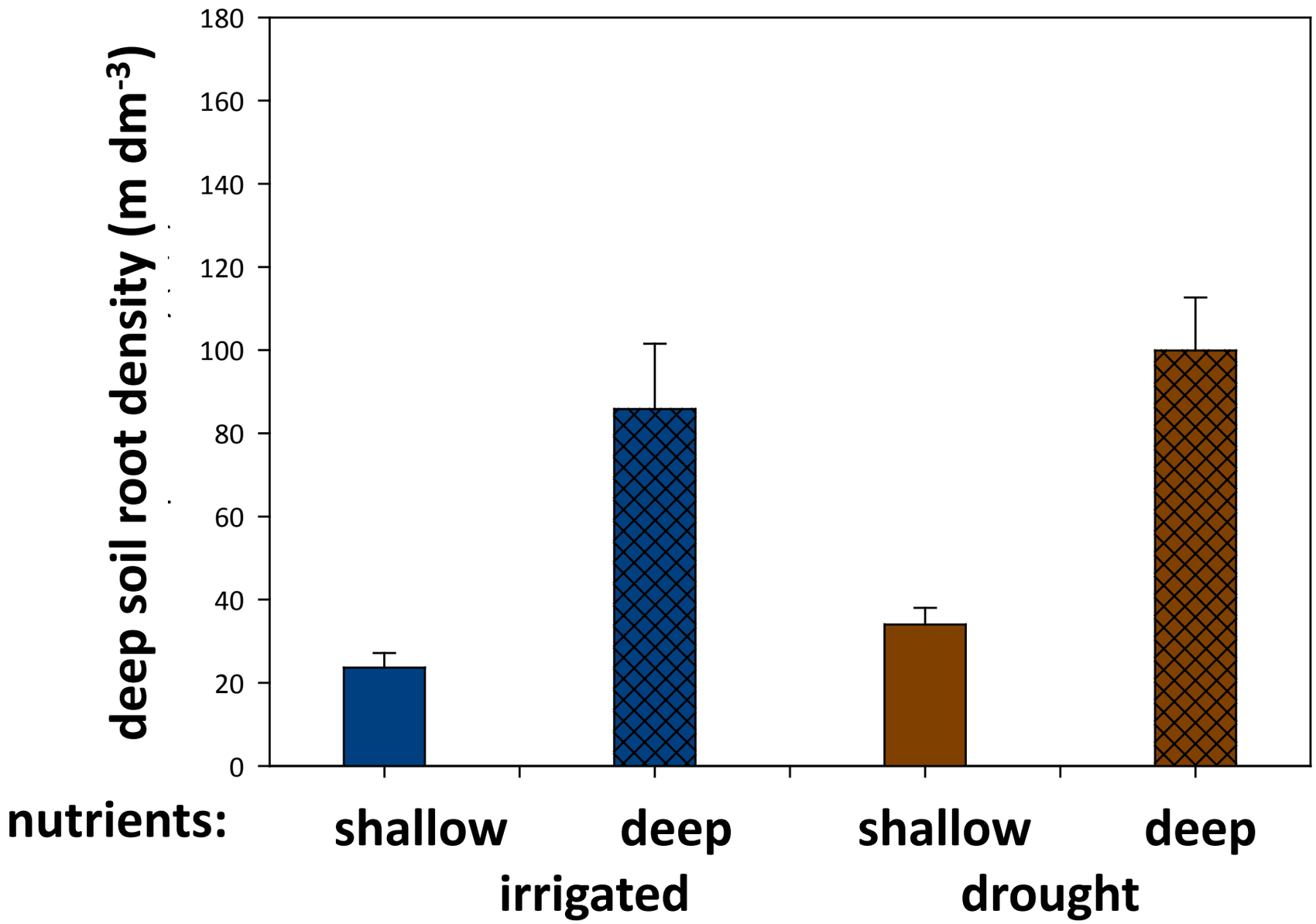
Roots developed in soil layers with high nutrient concentration, but avoided dry soil



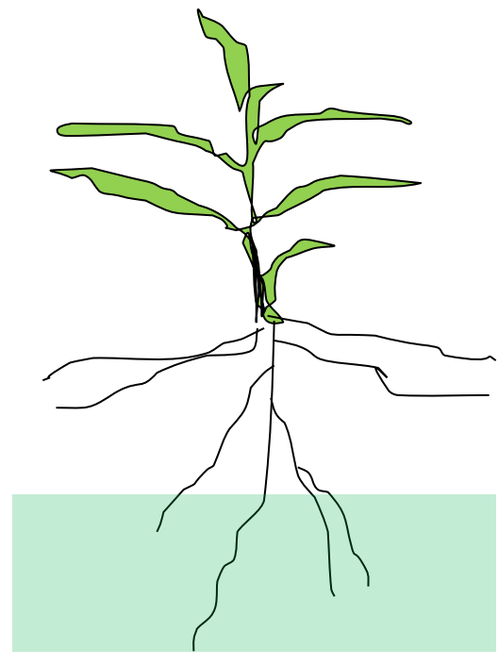
upper half of the soil column

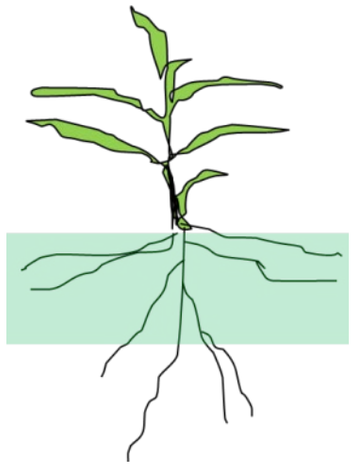


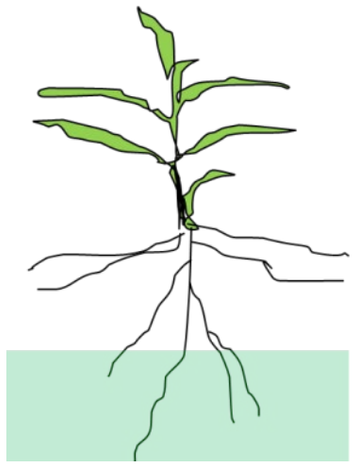
Deep nutrients resulted in deep roots, and drought forced roots to grow deeper too

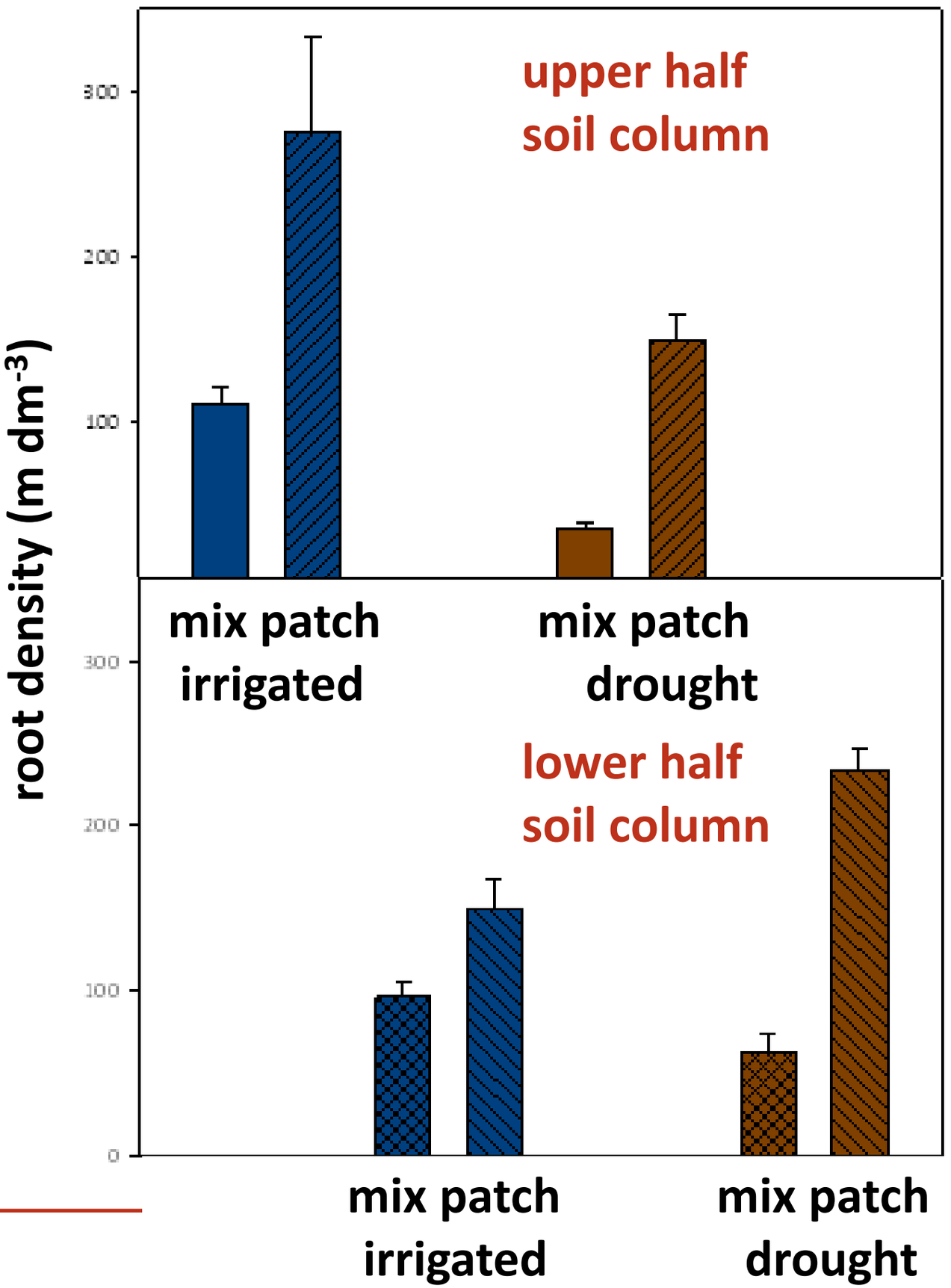


lower half of the soil column

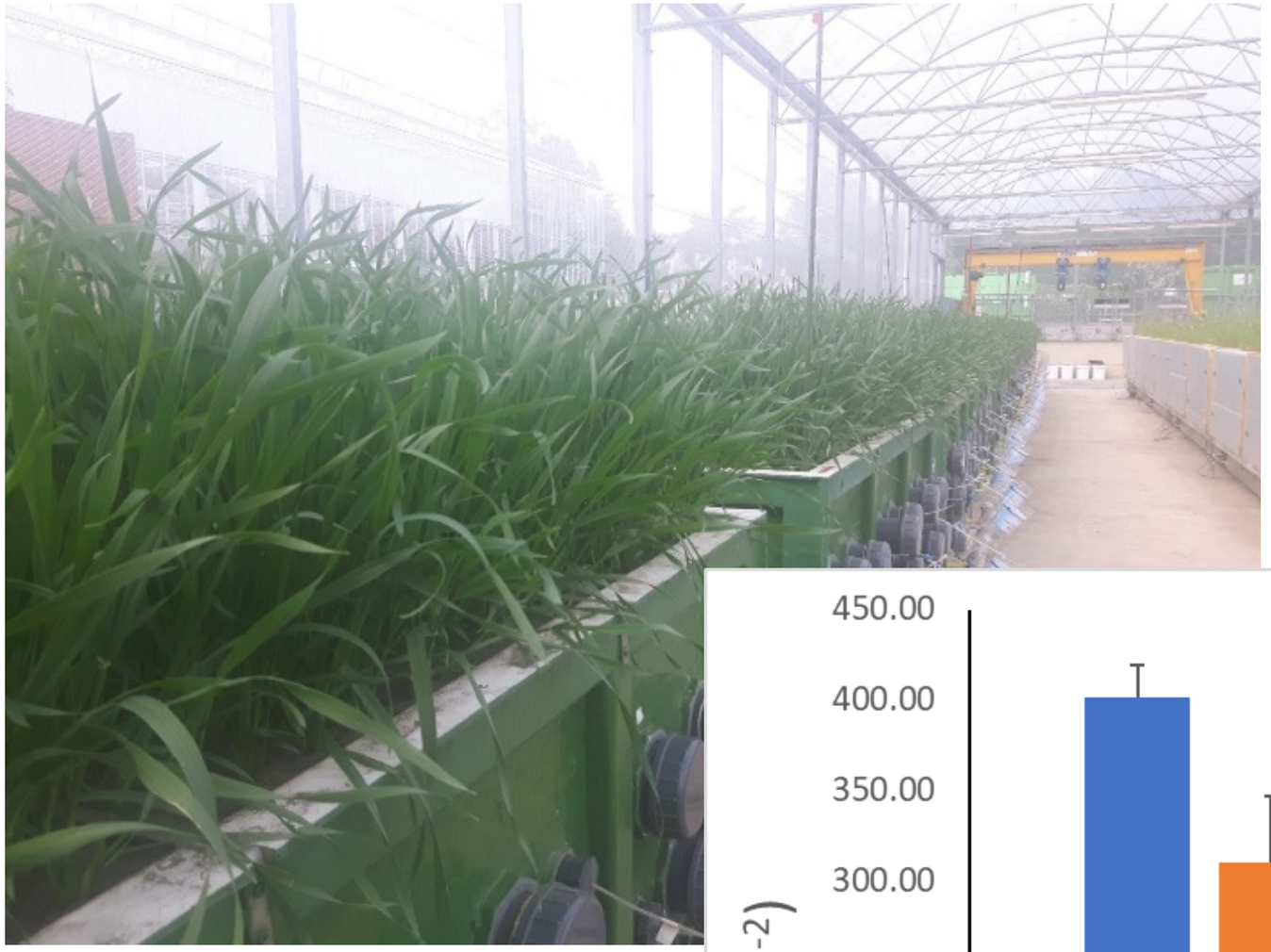




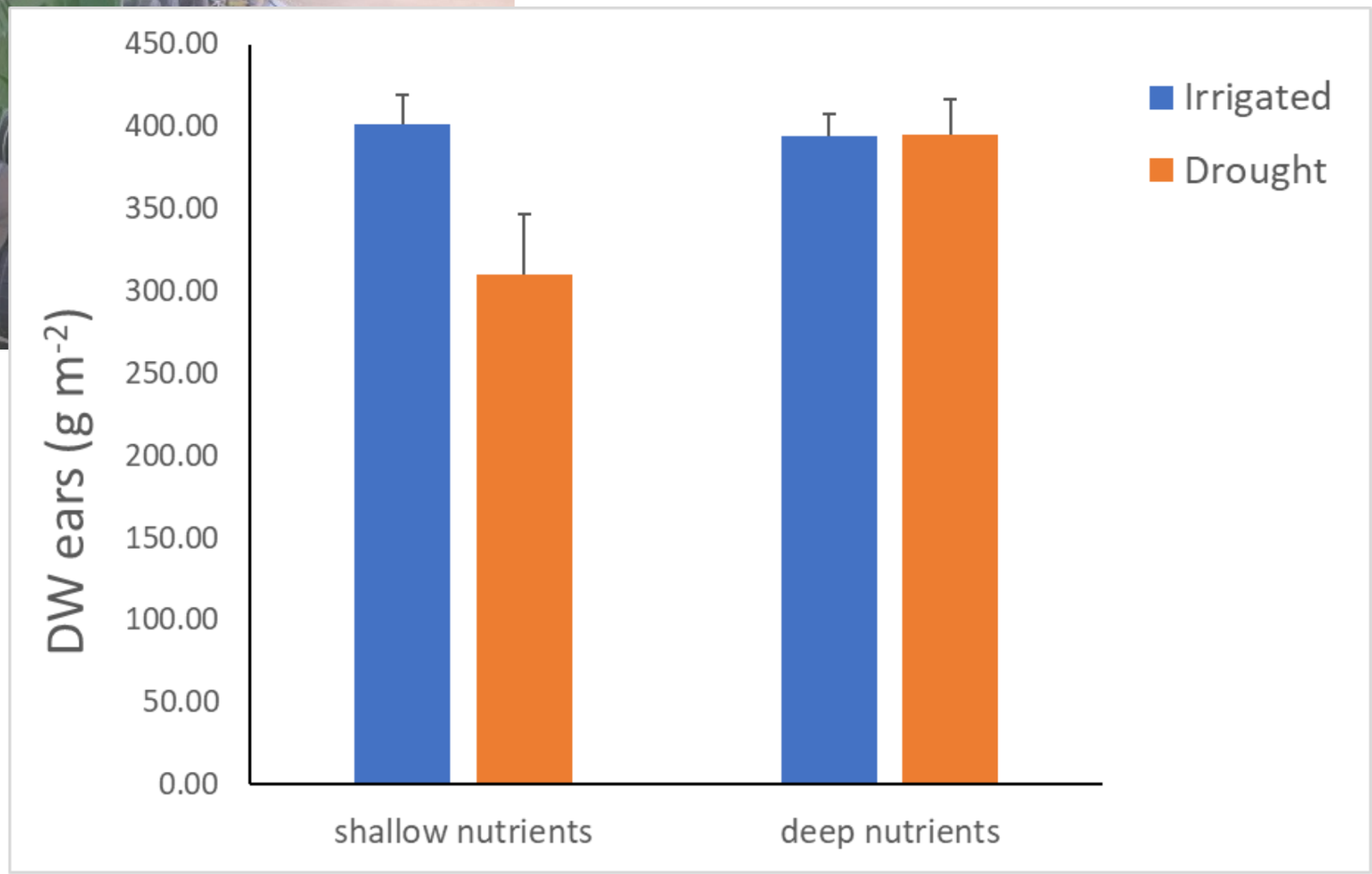




Very high root density in patches, also in the deep soil



Wheat plants performed much better on deep nutrients combined with drought



How many TKI initiated projects on roots in the last years?

Just a handful...

The challenge will be to bring together stakeholders and science and
invest more in understanding how root growth is controlled and how plasticity is improved

Thank you for joining me!