JÜLICH
FORSCHUNGSZENTRUM

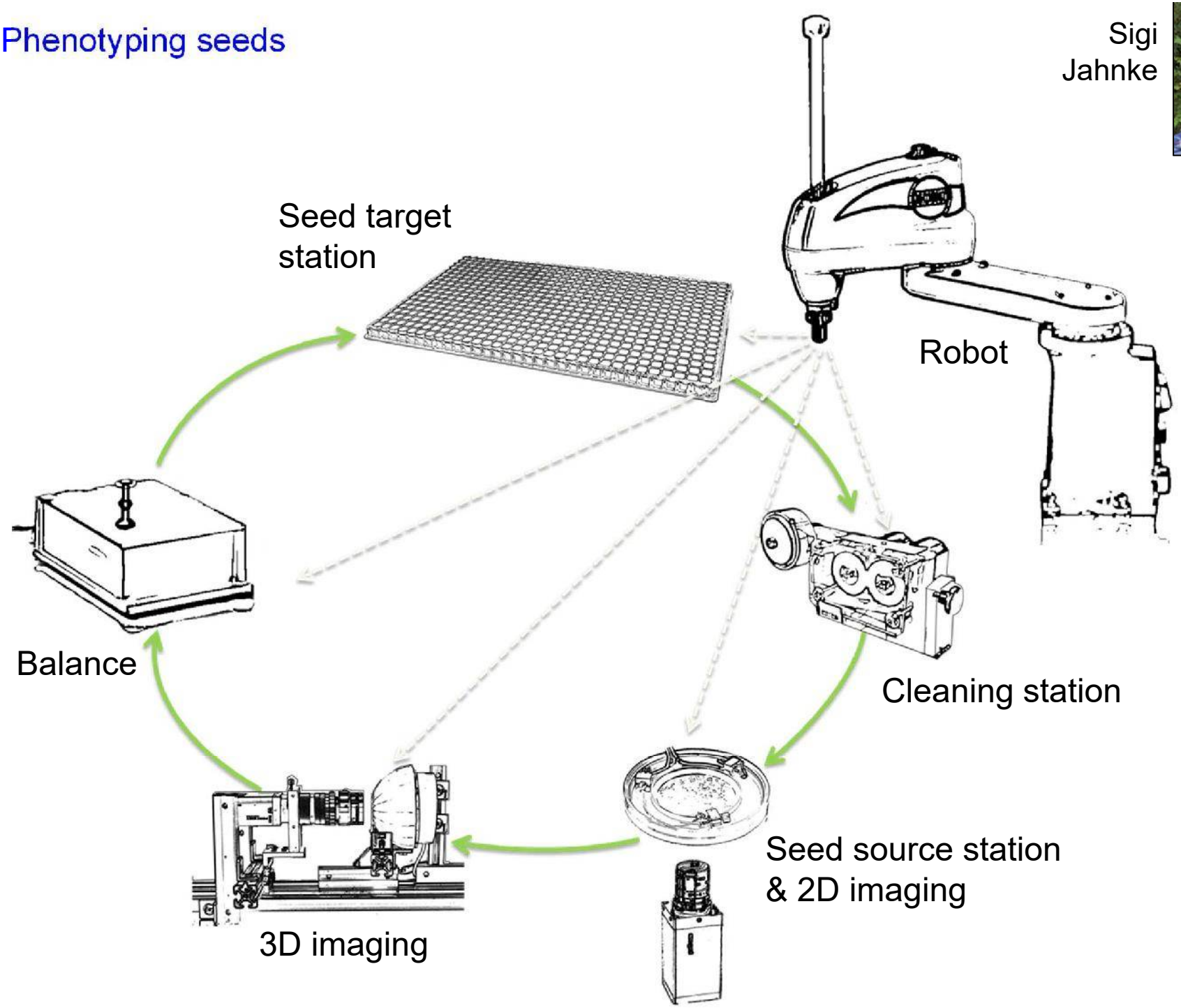
1. Genes, phenes and machines @ FZJ
2. Bridging the gap between lab and field

Poorter et al. (2016)
Pampered inside, pestered outside?
Differences and similarities
between plants growing in
controlled conditions and in the field.
New Phytol. 212: 838-855

Uli Schurr
Hendrik Poorter

1. Phenotyping seeds

Sigi Jahnke



1. Phenotyping seeds

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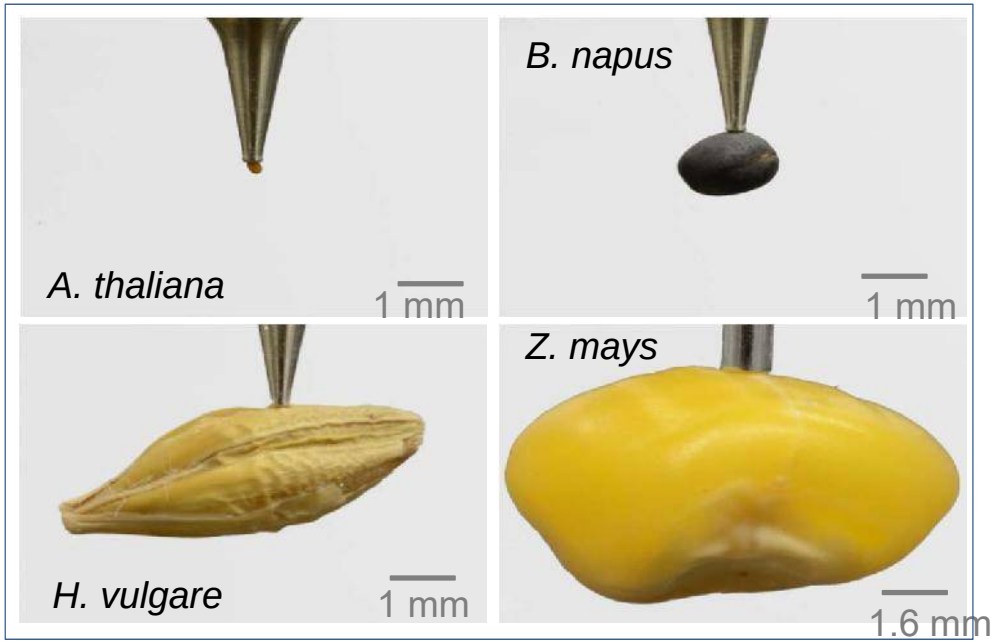
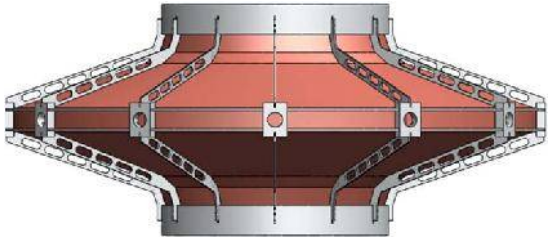
Jahnke et al. (2016)
Plant Phys., in press



	WT	*etr1*	P
Plant mass (mg)	35	14	***
RGR (mg g^{-1} day^{-1})	260	268	ns
Ind. seed mass (µg)	20	13	

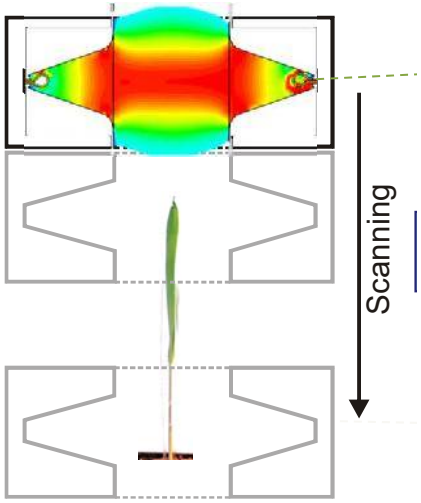
Plant Physiol. 134: 1803

2. Measuring water



Microwave cavity resonator

Viktor Sydoruk



- Homogeneous field in x,y plane
- High sensitivity in x,y plane
- Narrow range of sensitivity in z direction

2. Measuring water

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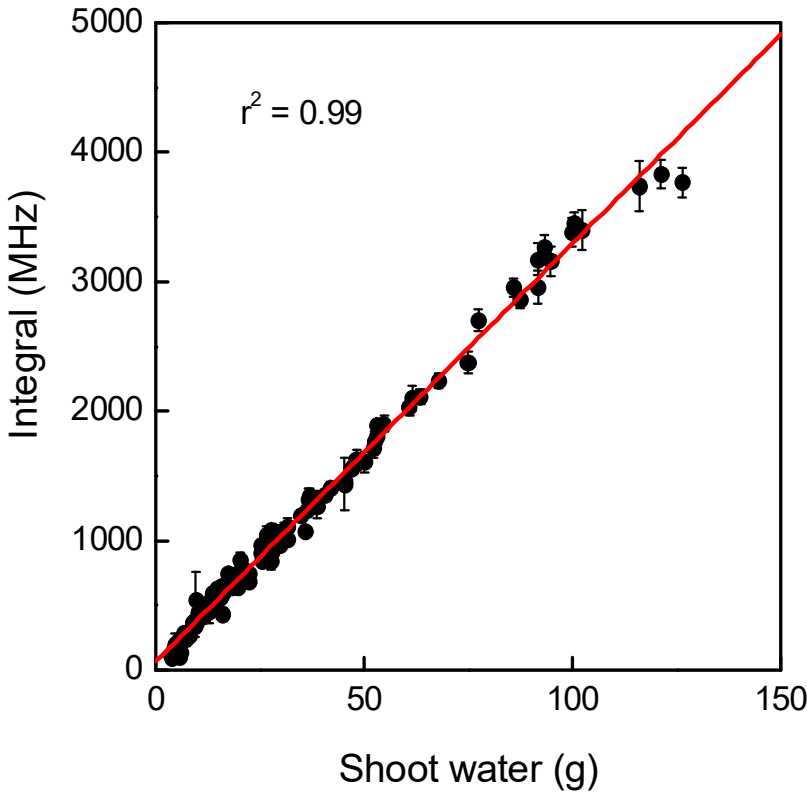
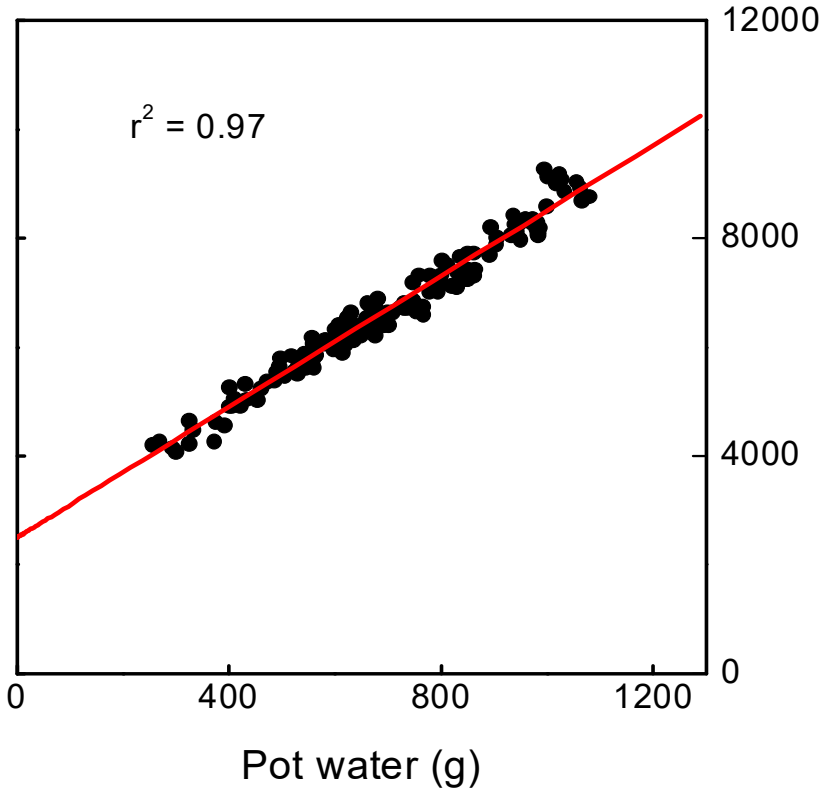
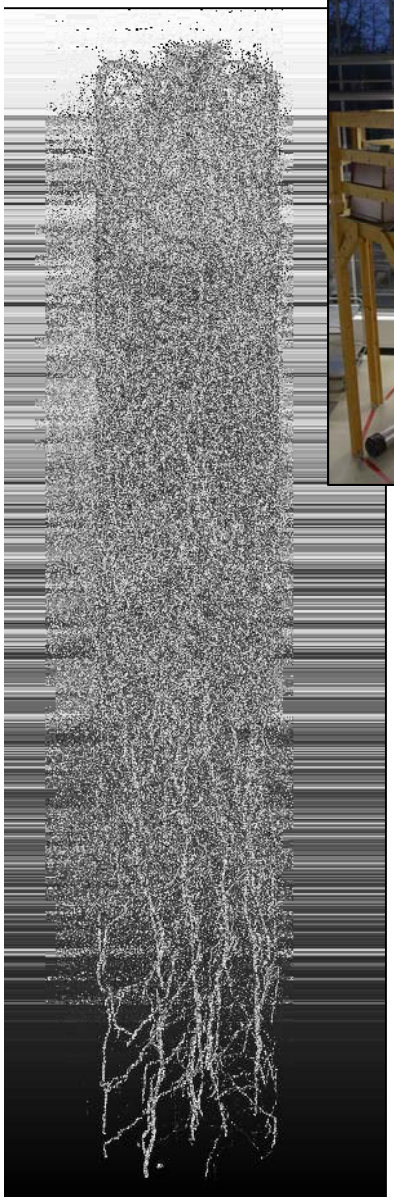
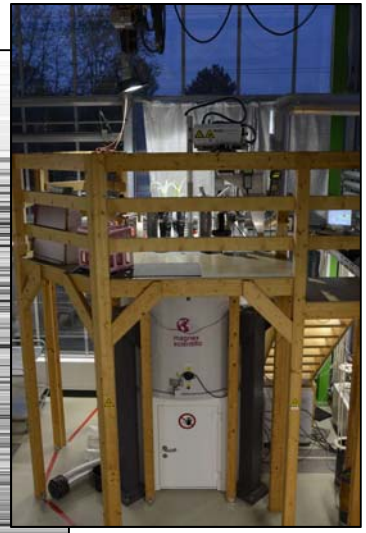
Sydoruk et al. (2016)
IEEE Transact. 64: 2894

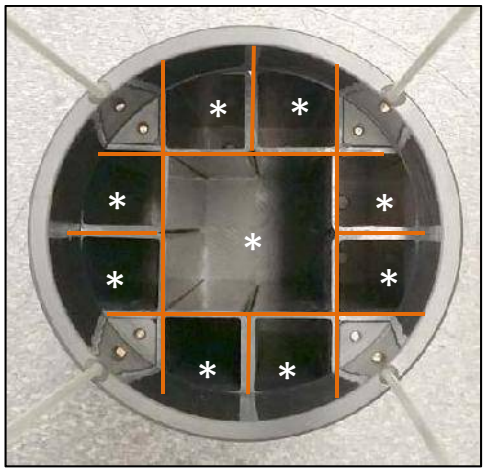




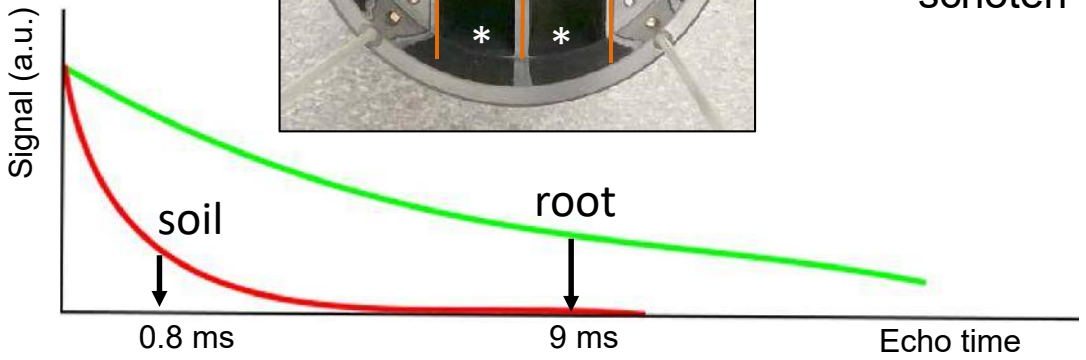
3. Measuring spatial root distribution and activity:





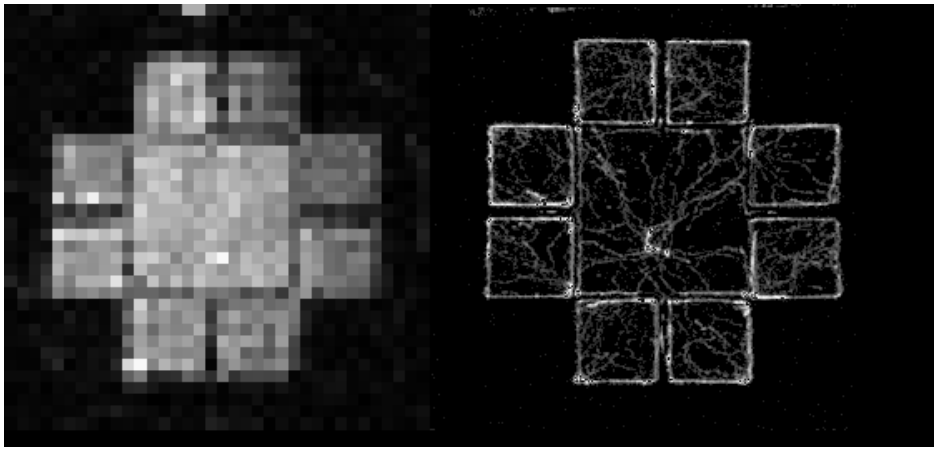


Dagmar van Dus-schoten

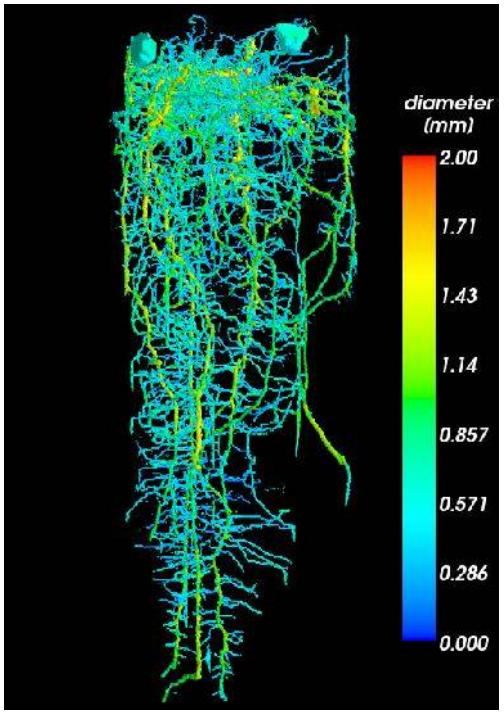


Soil water

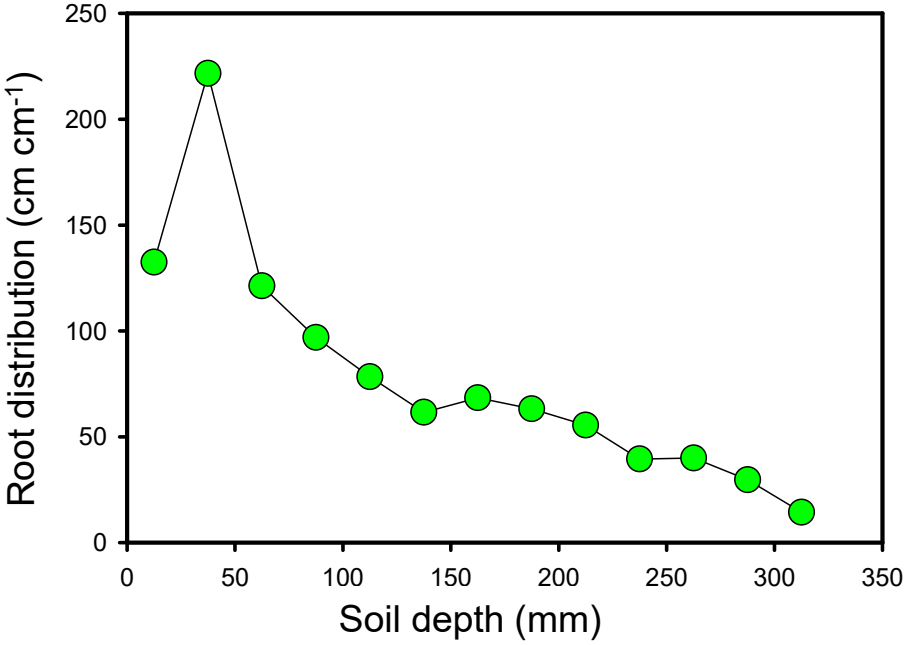
Root signal

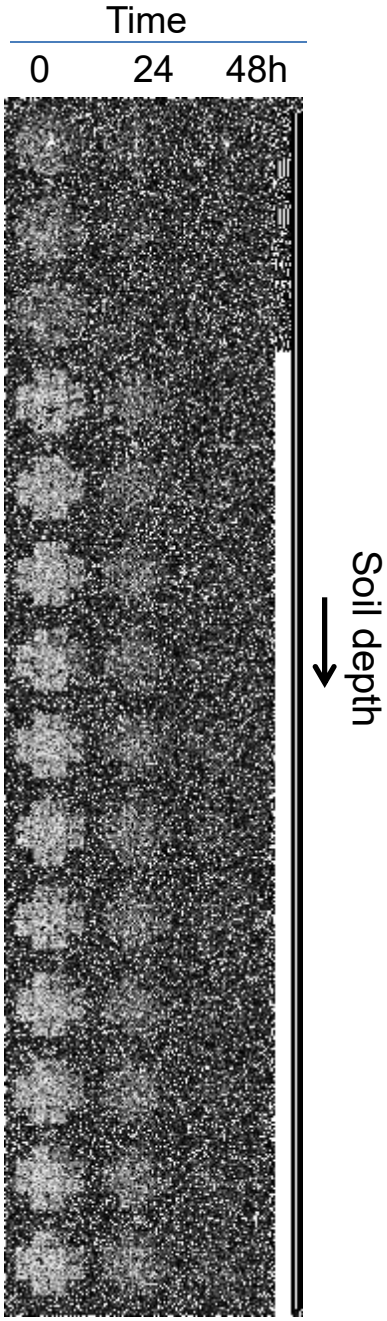


3. Measuring spatial root distribution and activity:



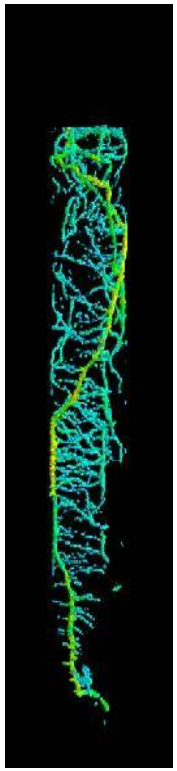
Total length: 26.7 m
Root tips: 1460
Avg. branch angle: 70-75°
Fresh mass: 6.1 gram

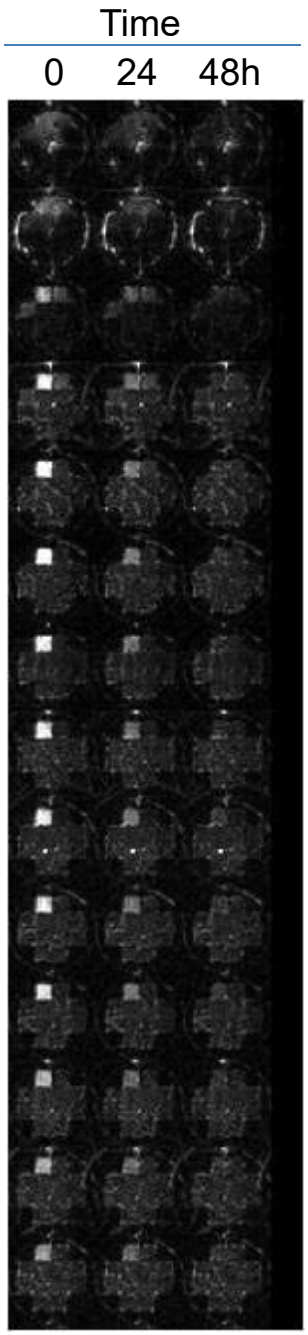


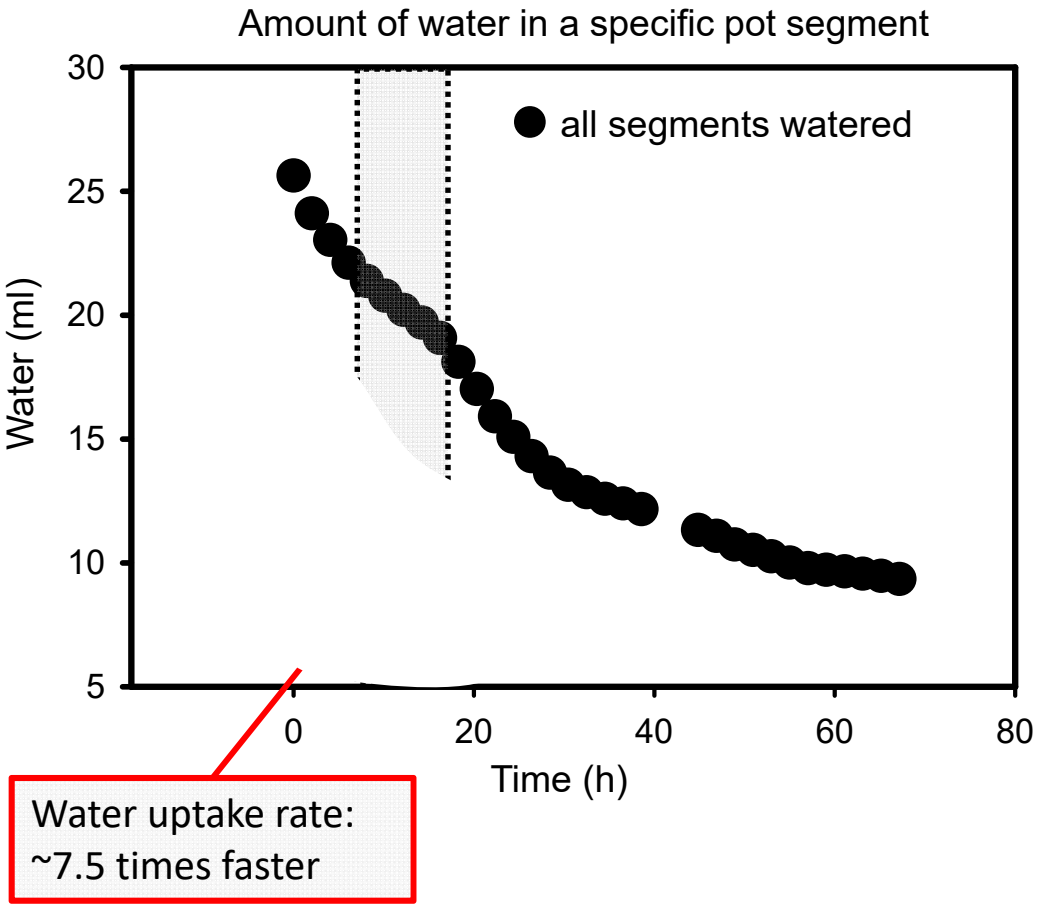


3. Measuring spatial root distribution and activity:

Van Dusschoten et al.
Plant Physiol. 170: 1176

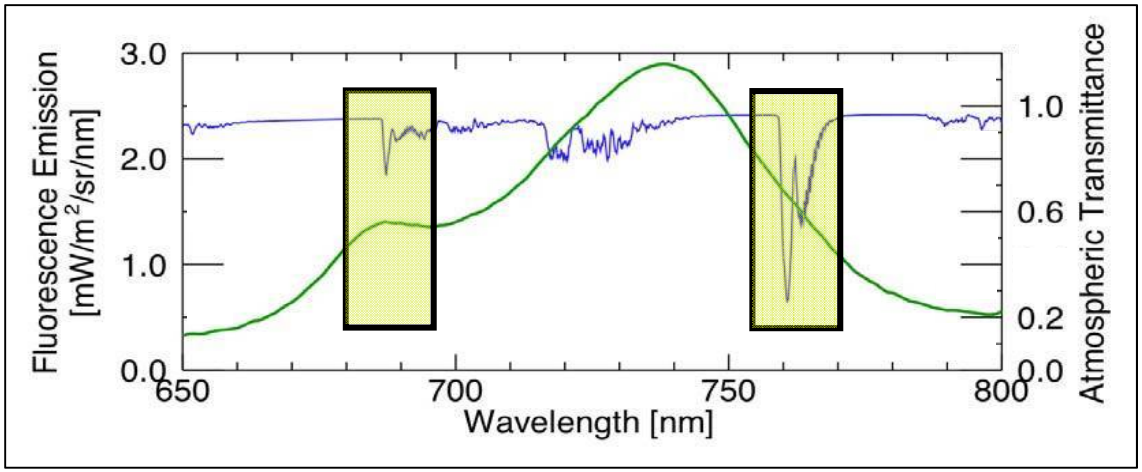






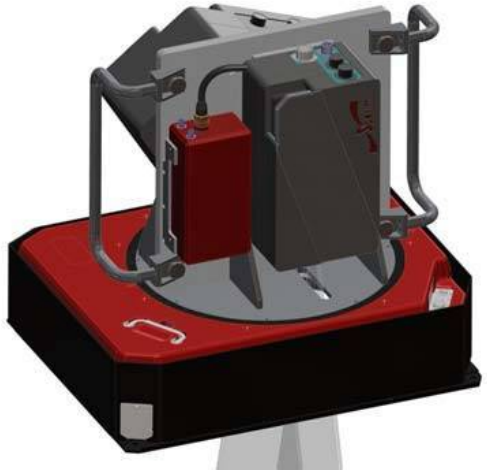
4. Sun-induced fluorescence:

Uwe Rascher



HyPLant:

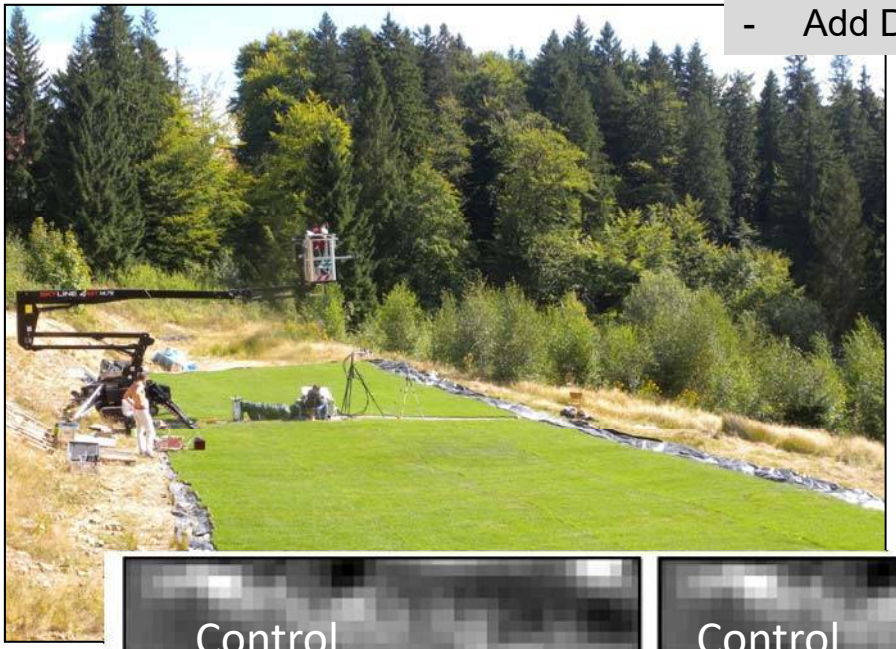
- Module 1:
  Broad spectrometer (380 - 2500 nm)
- Module 2:
  High-resolution fluorescence module (670 - 780 nm)

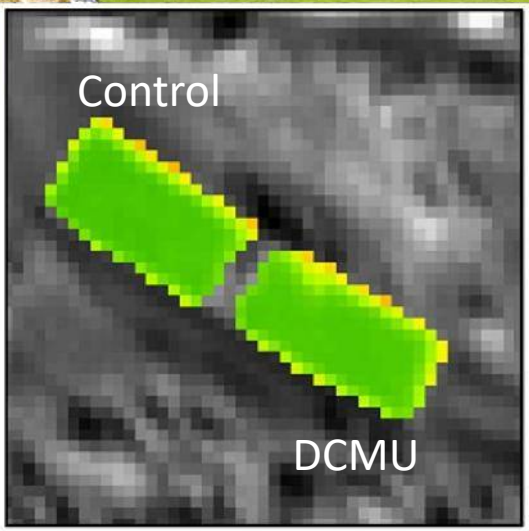


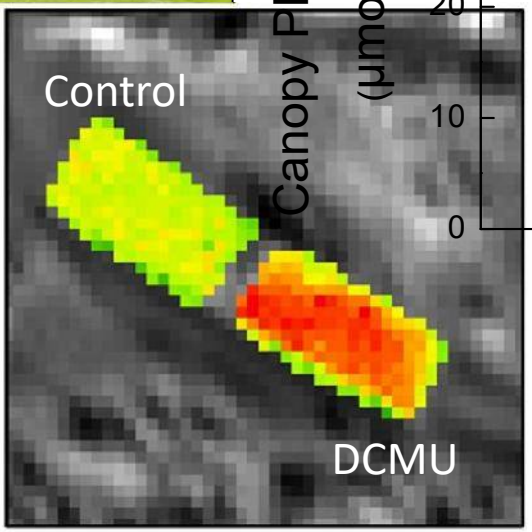
4. Sun-induced fluorescence:

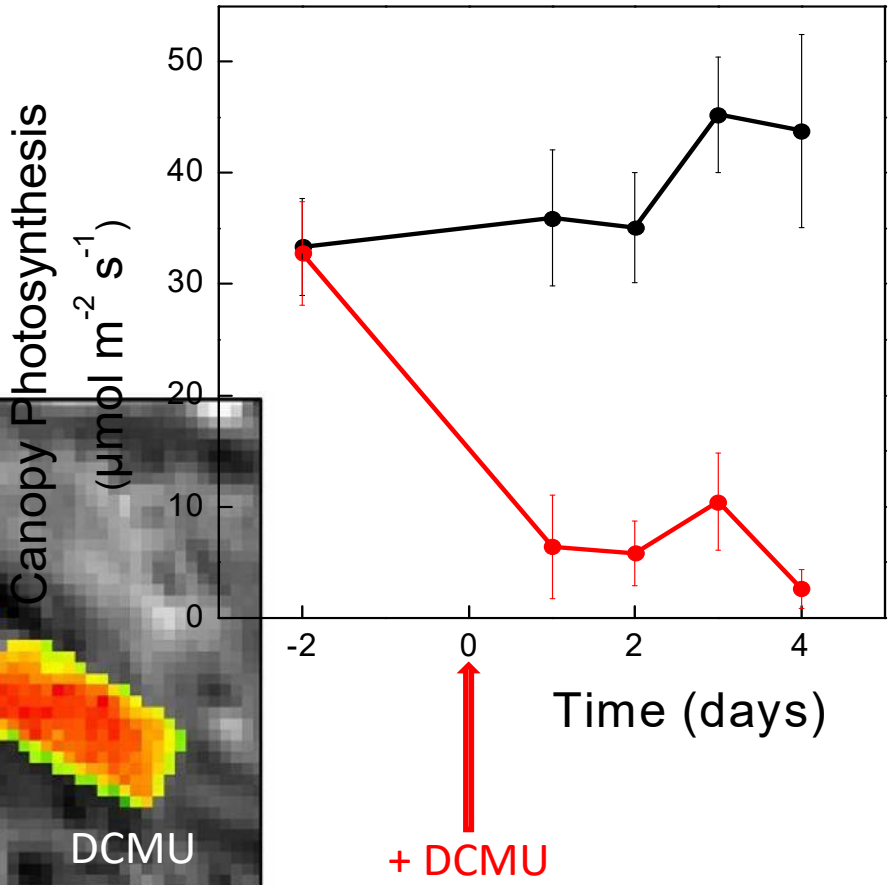
Rossini et al. (2015)
Geophys Res. Lett. 42

- 2x 140 m^2 grass carpets
- Add DCMU to one









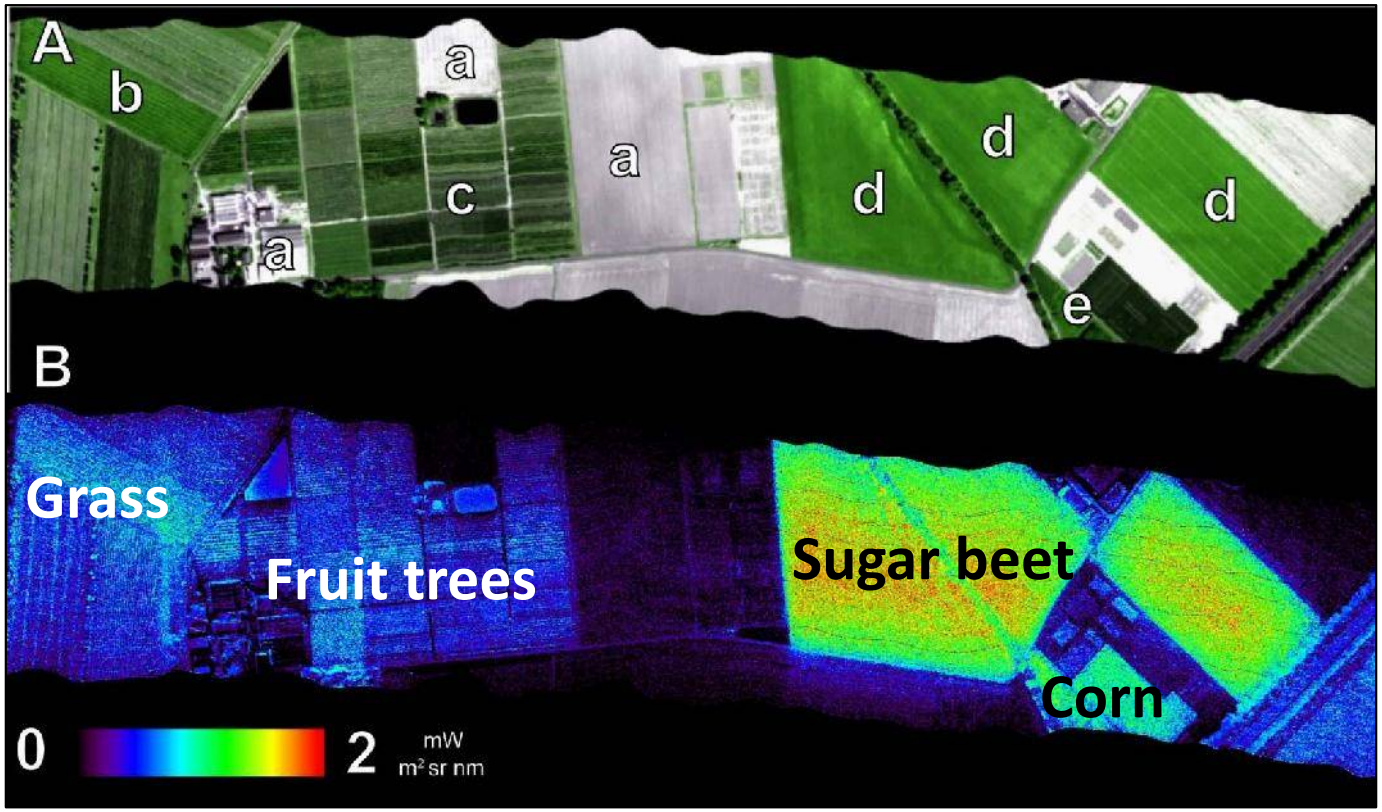
NDVI

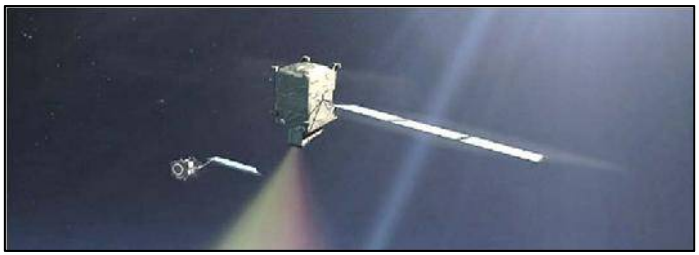
0 — 1

F_{FR} (mW m^{-2} sr^{-1} nm^{-1})

0 — 5.2

4. Sun-induced fluorescence:





Flex satellite mission 2022 (ESA):

- Direct measurements vegetation fluorescence
- Pixel size: 300 x 300 meter
- In tandem with vegetation temperature
- Covering each location on earth
  every 10-25 days

Creating a sustainable Plant Phenotyping Community in Europe:

Deutsches Pflanzen Phänotypisierungs-Netzwerk DPPN

PHENOME Réseau Français Phénomique végétale FPPN

UK Plant Phenomics Network

National platforms

European Plant Phenotyping Network EPPN

cost

European projects/ networks

EMPHASIS

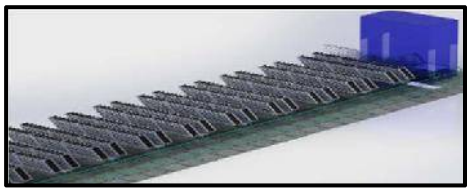
ESFRI

European Infrastructure

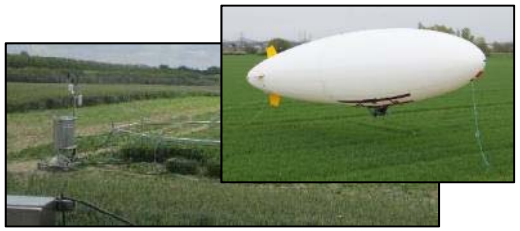
European infrastructure for Multi-site plant PHenotyping And SImulation for food Security in a changing climate

Emphasis infrastructure:

- Lab-based platforms for high resolution, high throughput phenomics



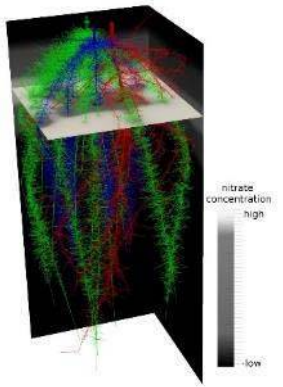
- Semi-controlled field systems for high throughput phenomics



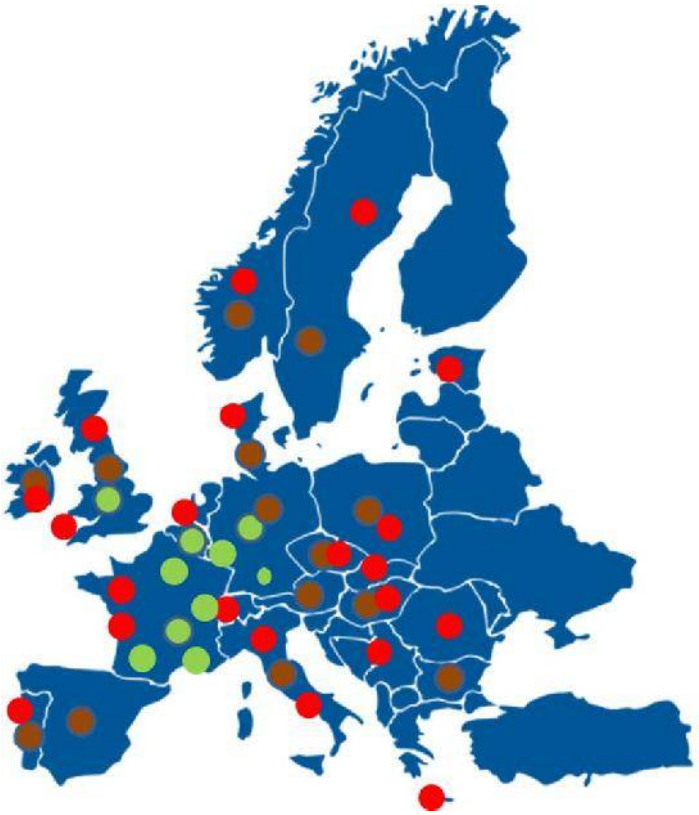
- Network of field sites for lean-phenotyping all over Europe

- Joint data management and e-infrastructure

- Modelling for improving phenotypic processes and for testing existing or virtual combinations of alleles in a variety of climatic scenarios and management practices



Emphasis: development



EMPHASIS project partners

Field sites

EMPHASIS associated partners

with support from

Australian Plant Phenomics Facility

International Plant Phenotyping Network IPPN

CGIAR

Field networks of seed companies

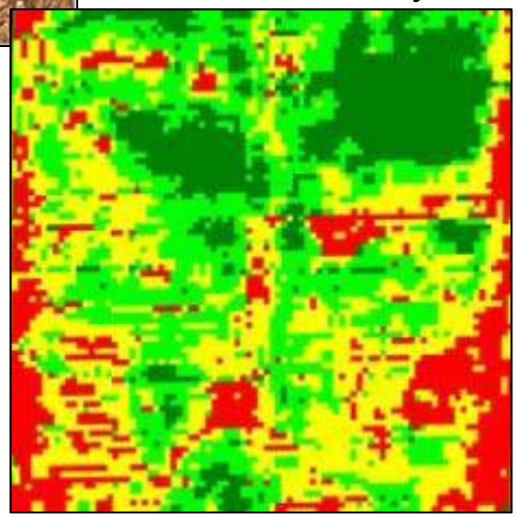
EMPHASIS - open for additional partners

The problems of growing plants outside:

srh.noaa.gov
archive.boston.com
plantstress.com

Large temporal variation

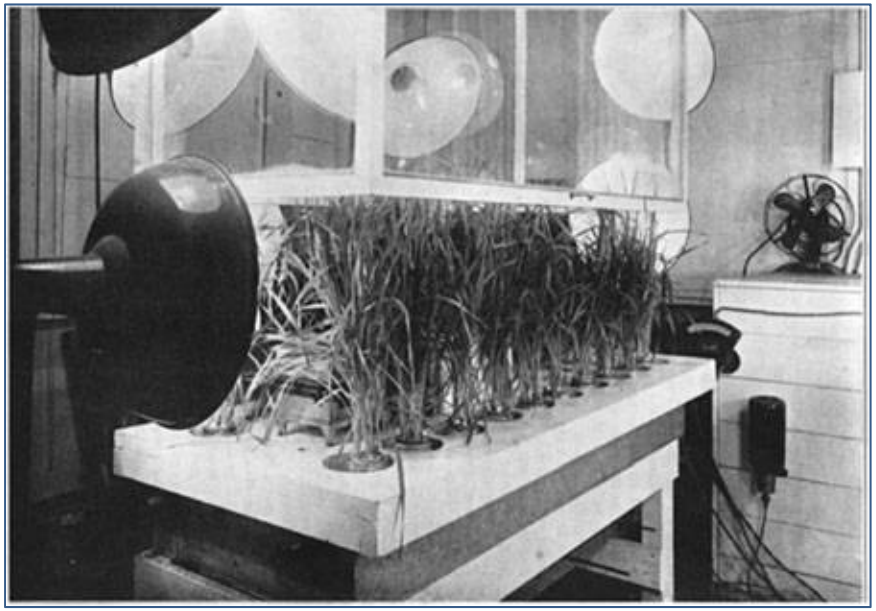
Normalised yield



Large spatial variation

Strong improvements in environmental control:

Davis & Hoagland (1928)



modernfarmer.com

Questions to us scientists:

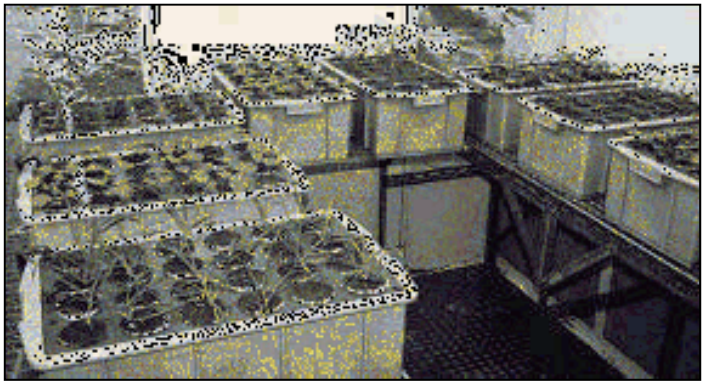
1. How different are plants growing

in controlled conditions and in the field?

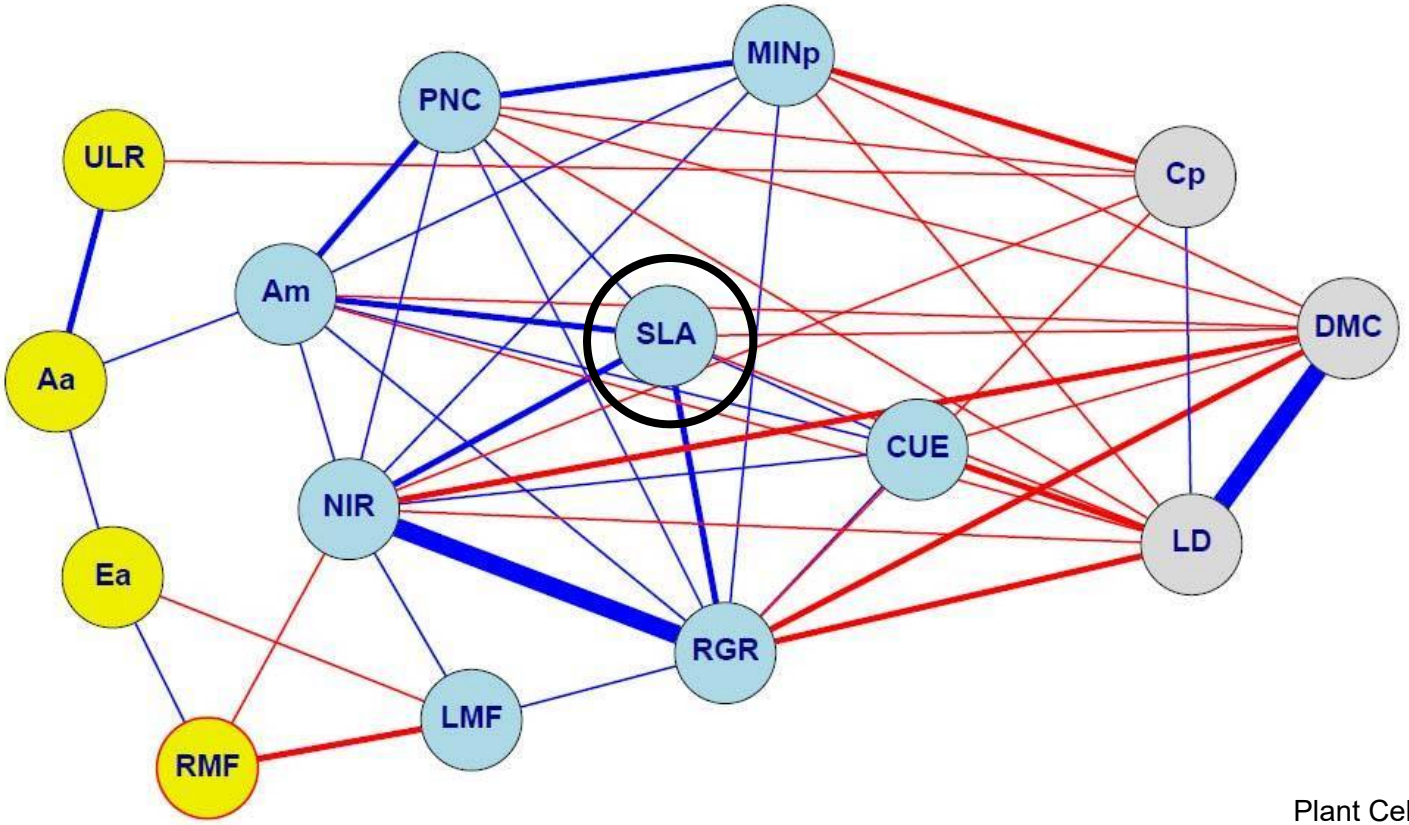
2. How can the differences be explained?

3. What can we do to improve the lab-field correlation?

Q1: Do lab and field plants have similar phenotypic values?

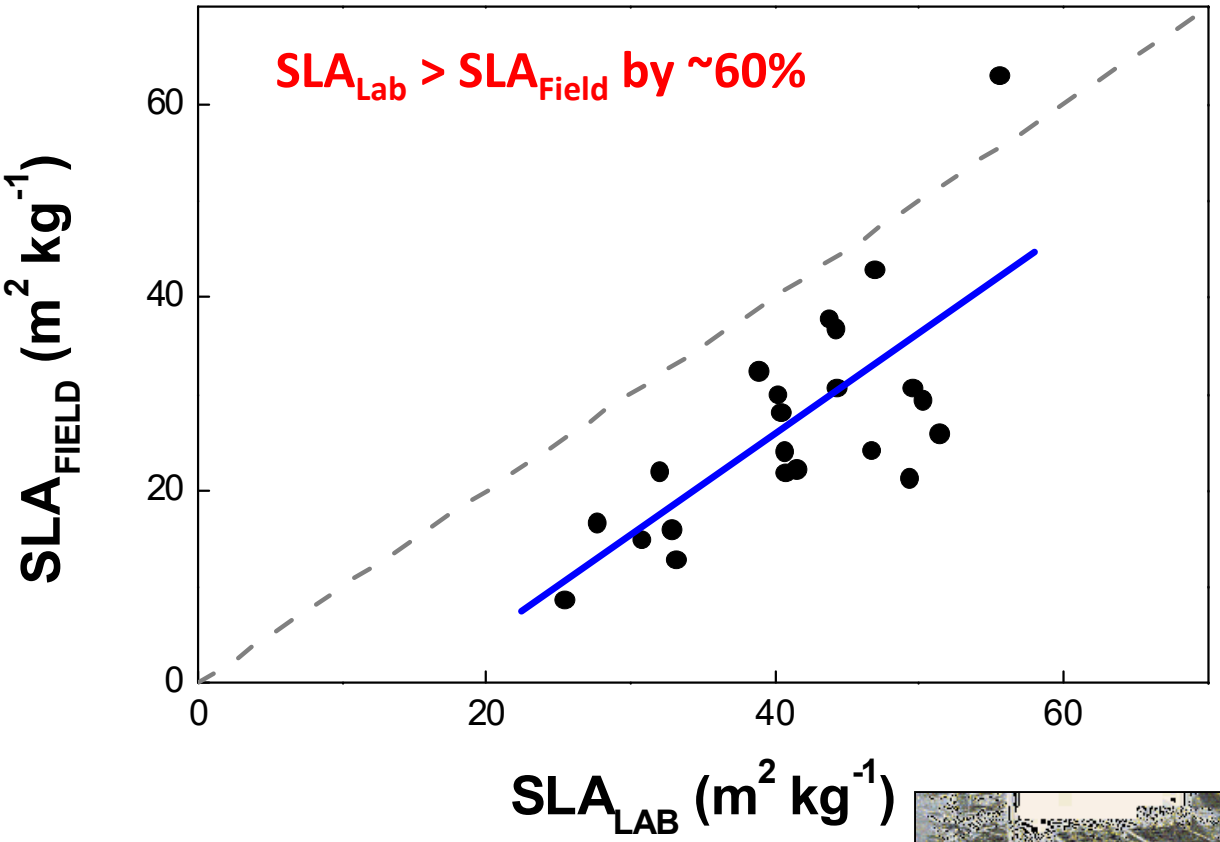


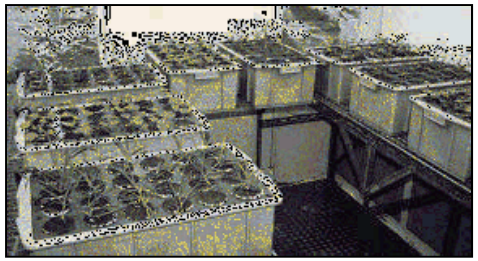
- $T_{Day} = T_{Night} = 20\ ^oC$
- Irradiance = 315 μmol m^{-2} s^{-1}
- Daylength = 14 h
- RH = 70%
- Nutrients = 2 mM NO_3^-
- 24 species



Plant Cell Env. 36: 1673

Q1: Do lab and field plants have similar phenotypic values?





New Phytol. 143: 163

Q1: A ‘brute force’ approach:

Meta-Phenomics database:

> 1000 controlled experiments
> 1100 species
~ 10 traits
- 12 environmental factors

LEDA database:

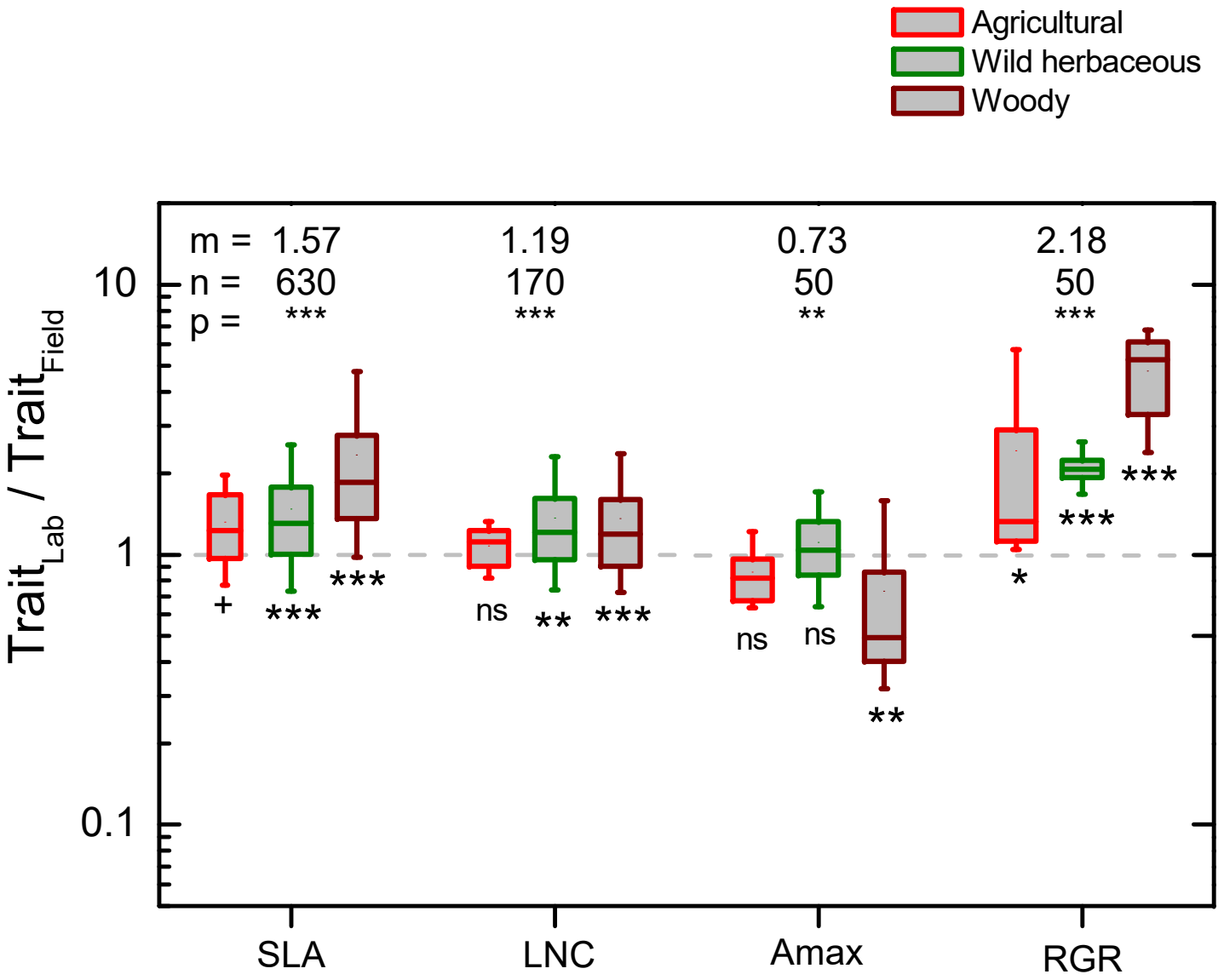
- field data
> 1500 species
~ 27 traits

Other compilations & sources:

- Niinemets (2001)
- Wright et al. (2004)
- Poorter et al. (2009)
- Many additional papers (crop species!)

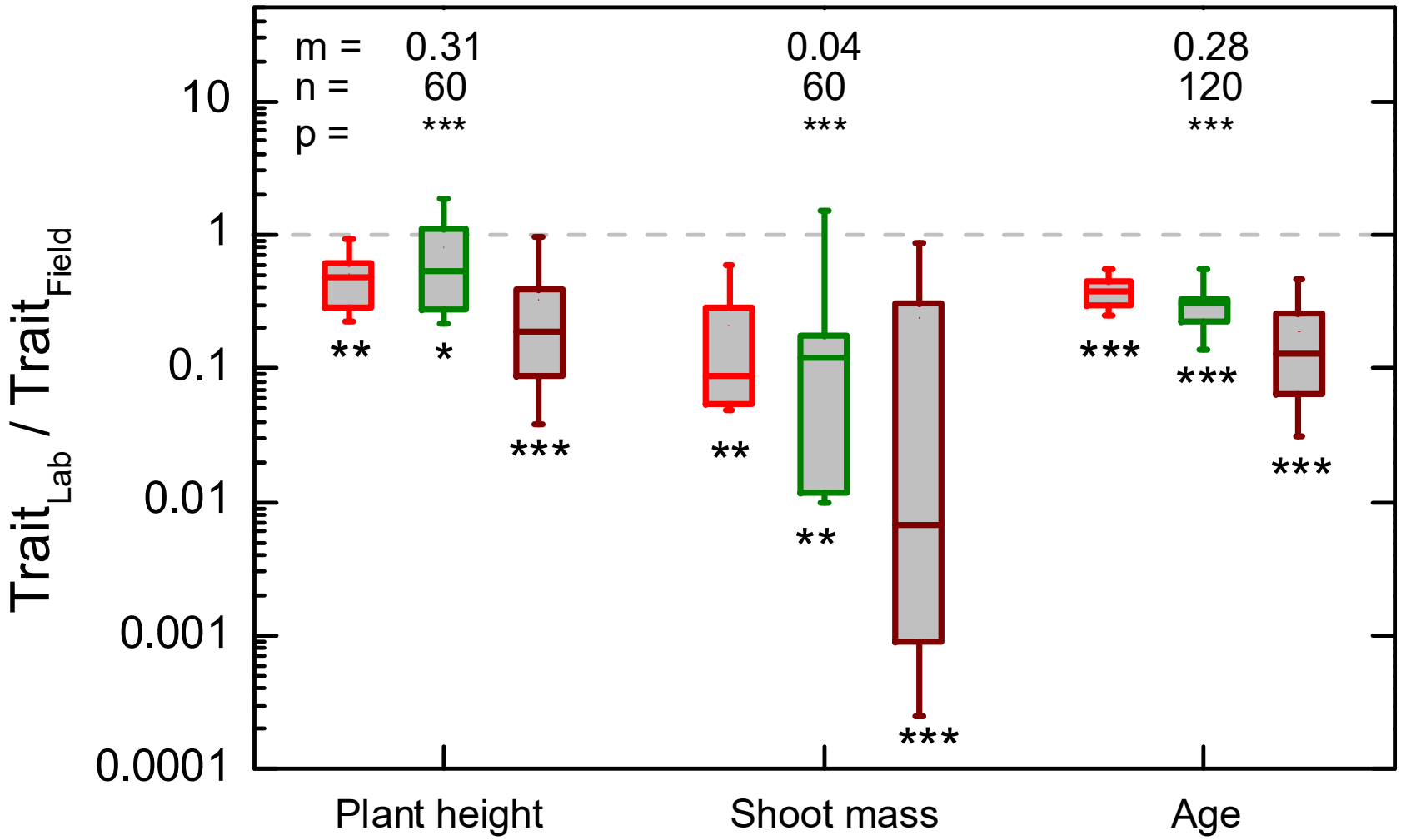
Targeted database:
- 7 traits
- 20000 records
> 5500 species
> 1500 references

A meta-analysis across species:



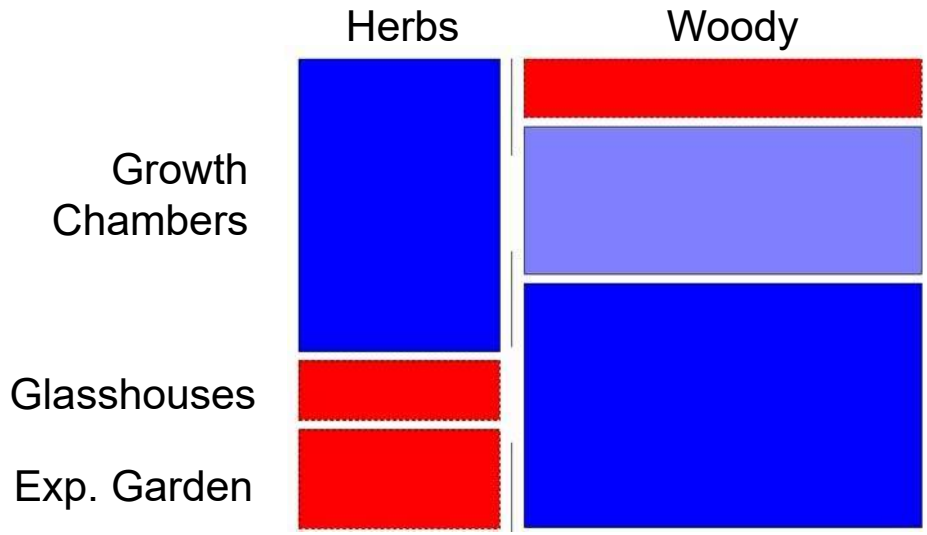
Size-related parameters:

Median life span in GC:
39 days



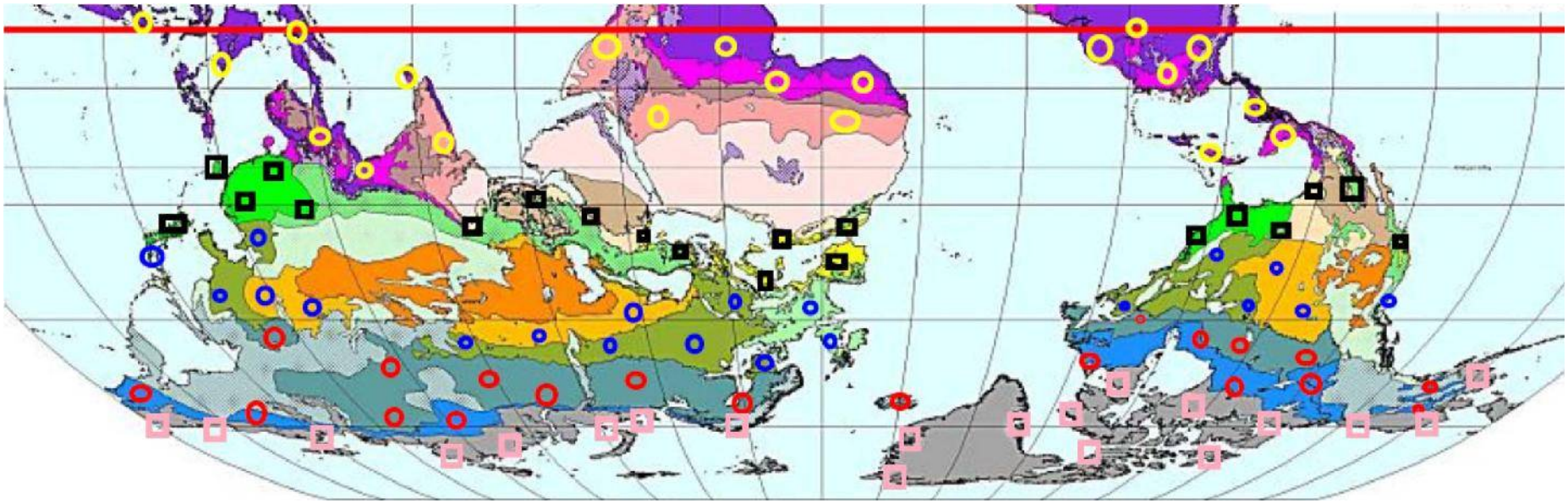
Duration of experiments:

Growth facility	Experimental duration (days)	n
Growth chamber	39	3100
Glasshouse	95	3500
Field	550	700



2. What causes the phenotypic differences?
a. Field conditions

FAO (2012)



Global ecological zones:

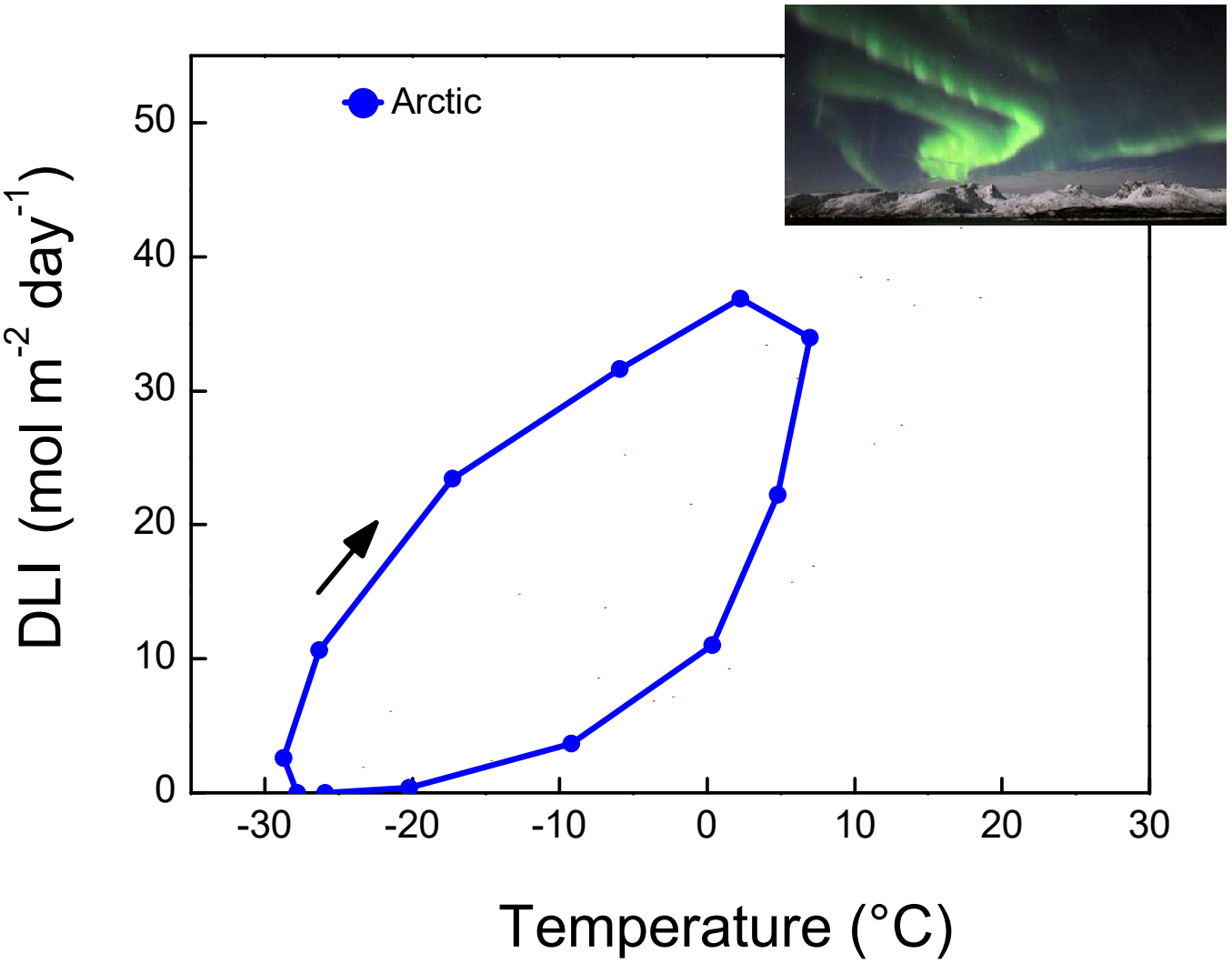
1. Arctic
2. Boreal
3. Temperate
4. Subtropical
5. Tropical

Excluded:

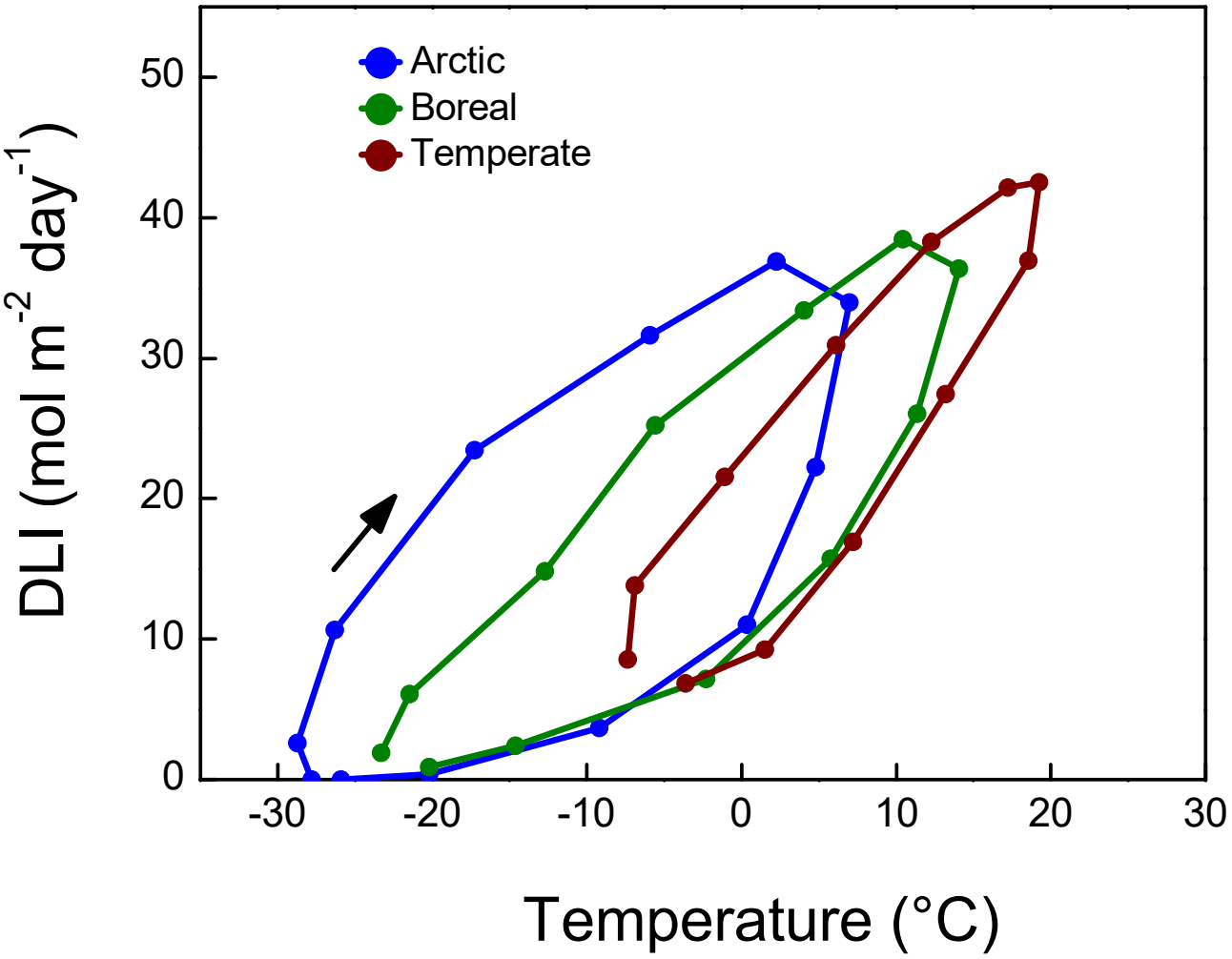
- Southern hemisphere
- mountains
- deserts

a. Field conditions:

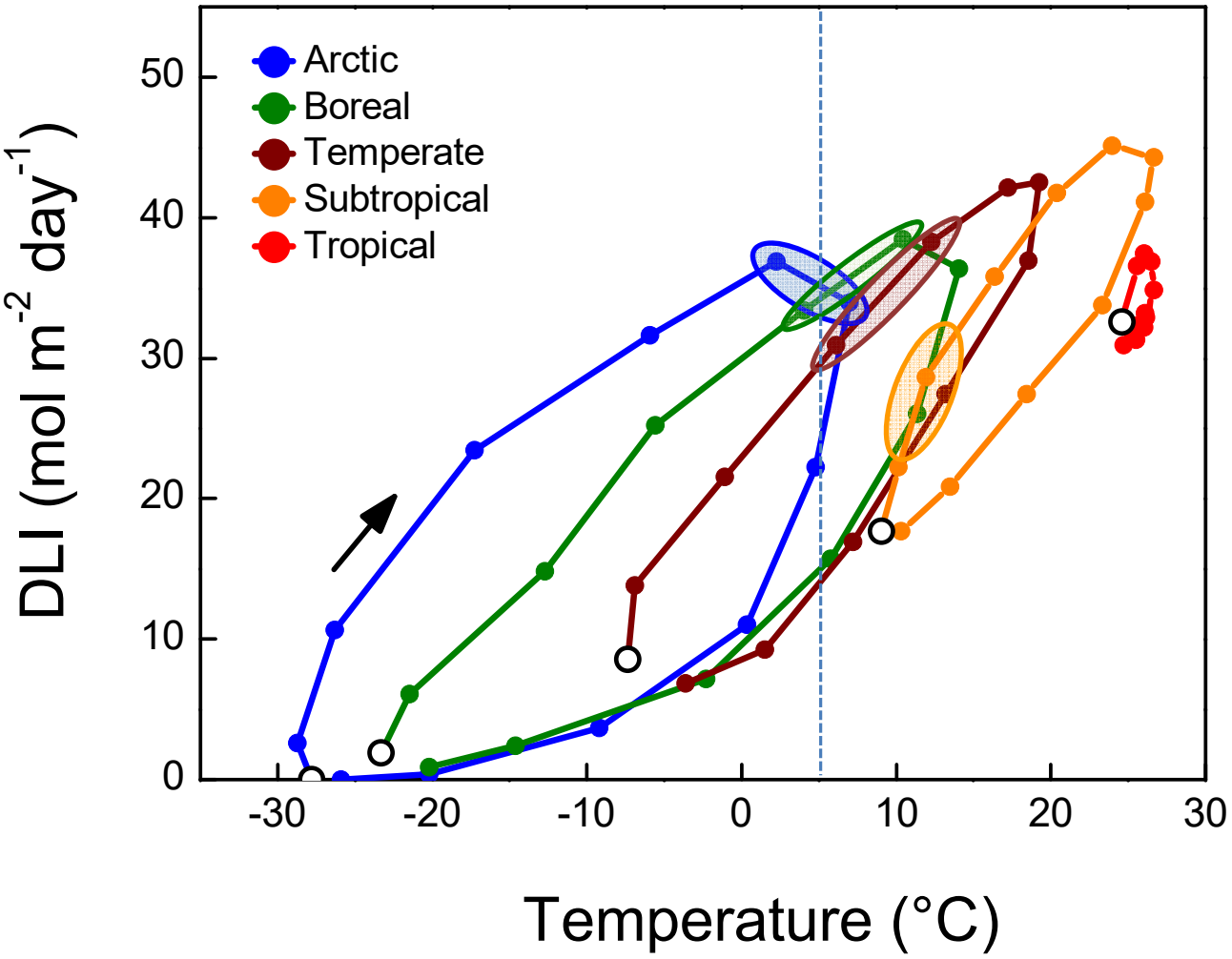
New et al. (1999)
Data for 1960-1990



b. Field conditions:

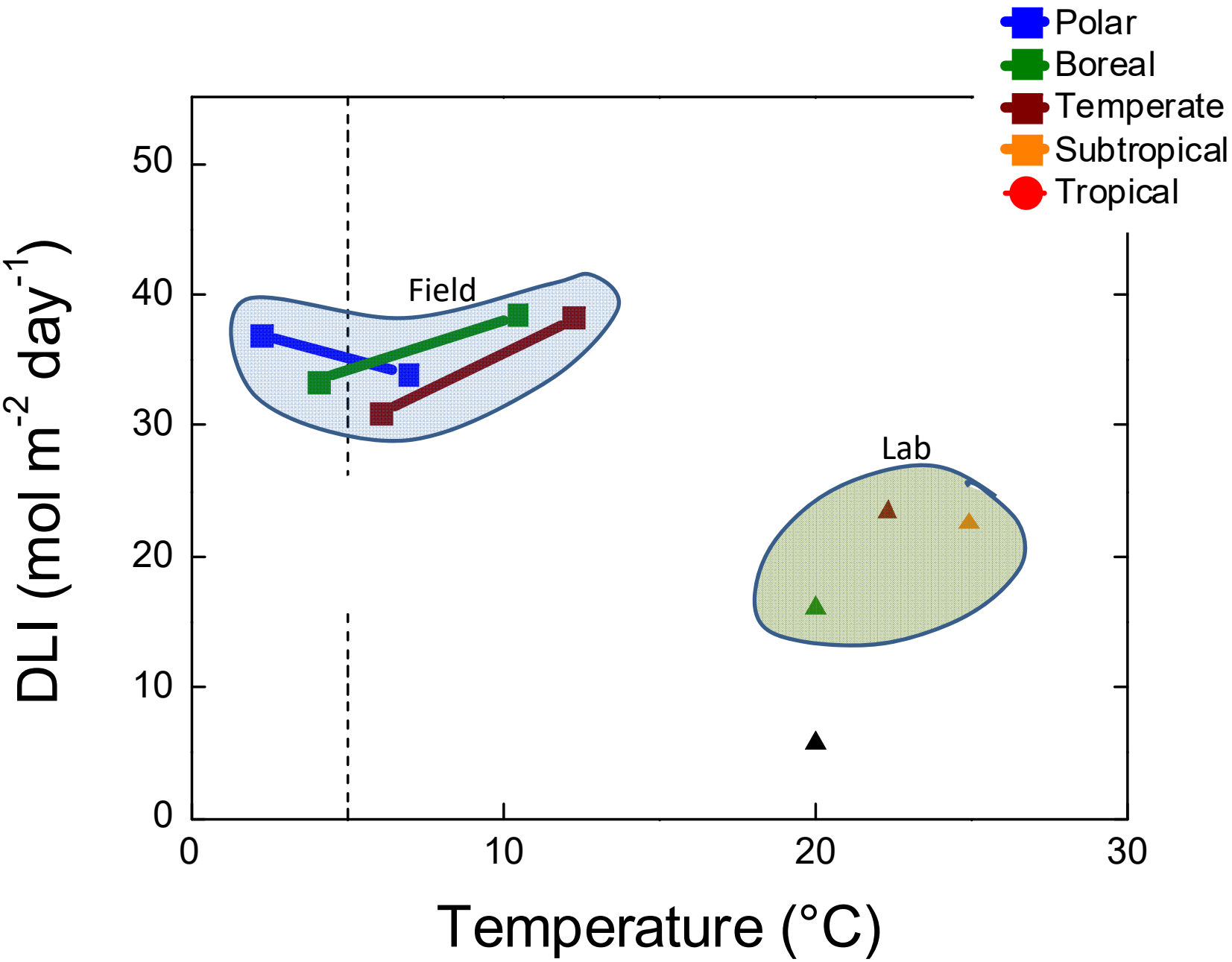


c. Field conditions:



2. Growth chamber conditions:

Species	Light (mol m^{-2} day^{-1})	Temperature (°C)
Arctic / Boreal	16	20
Temperate	23	22
(Sub)-tropical	23	25


Polar
Boreal
Temperate
Subtropical
Tropical
Field
Lab
DLI (mol m-2 day-1)
Temperature (°C)
0
10
20
30
40
50
0
10
20
30

Source- vs. sink-limitation:

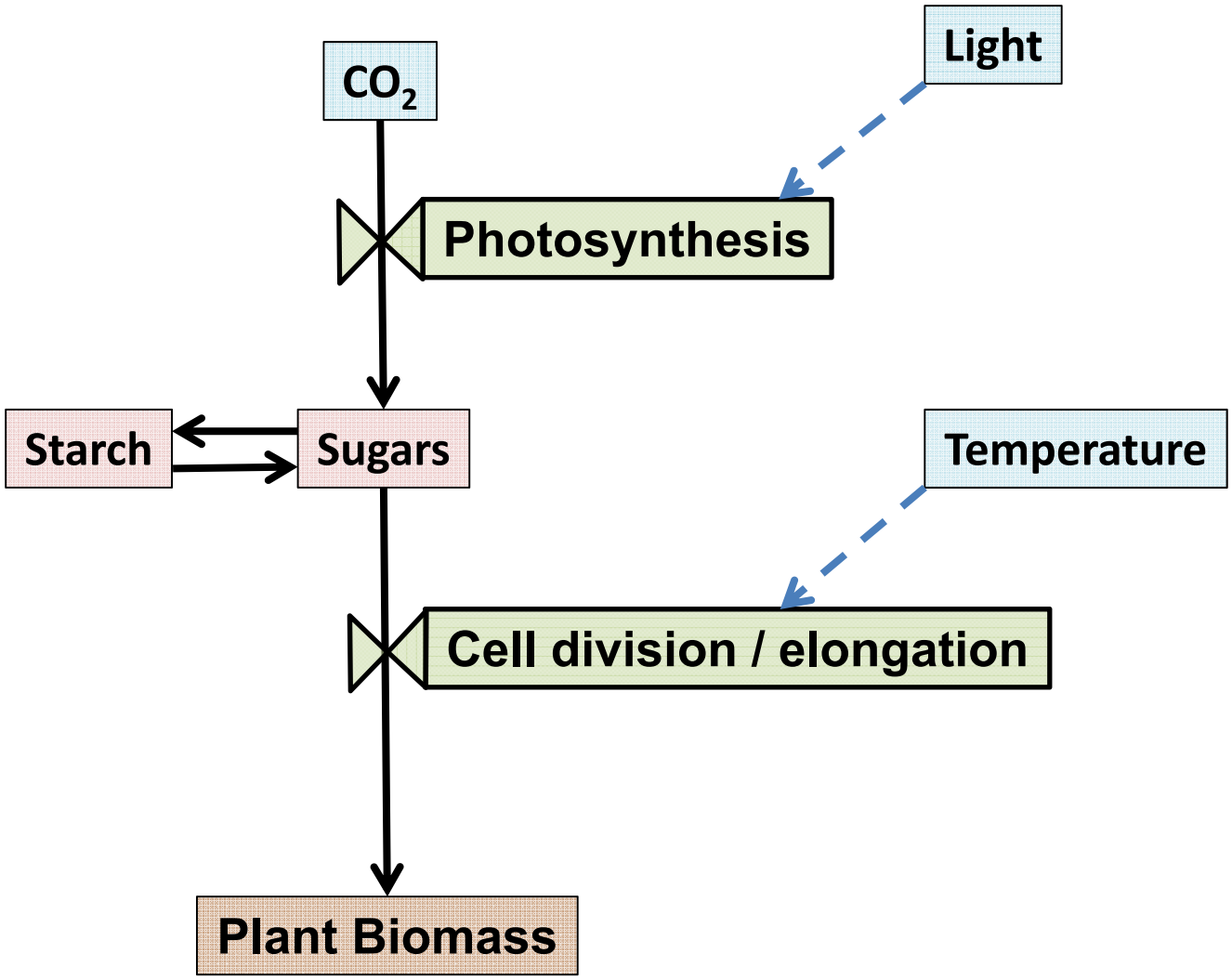
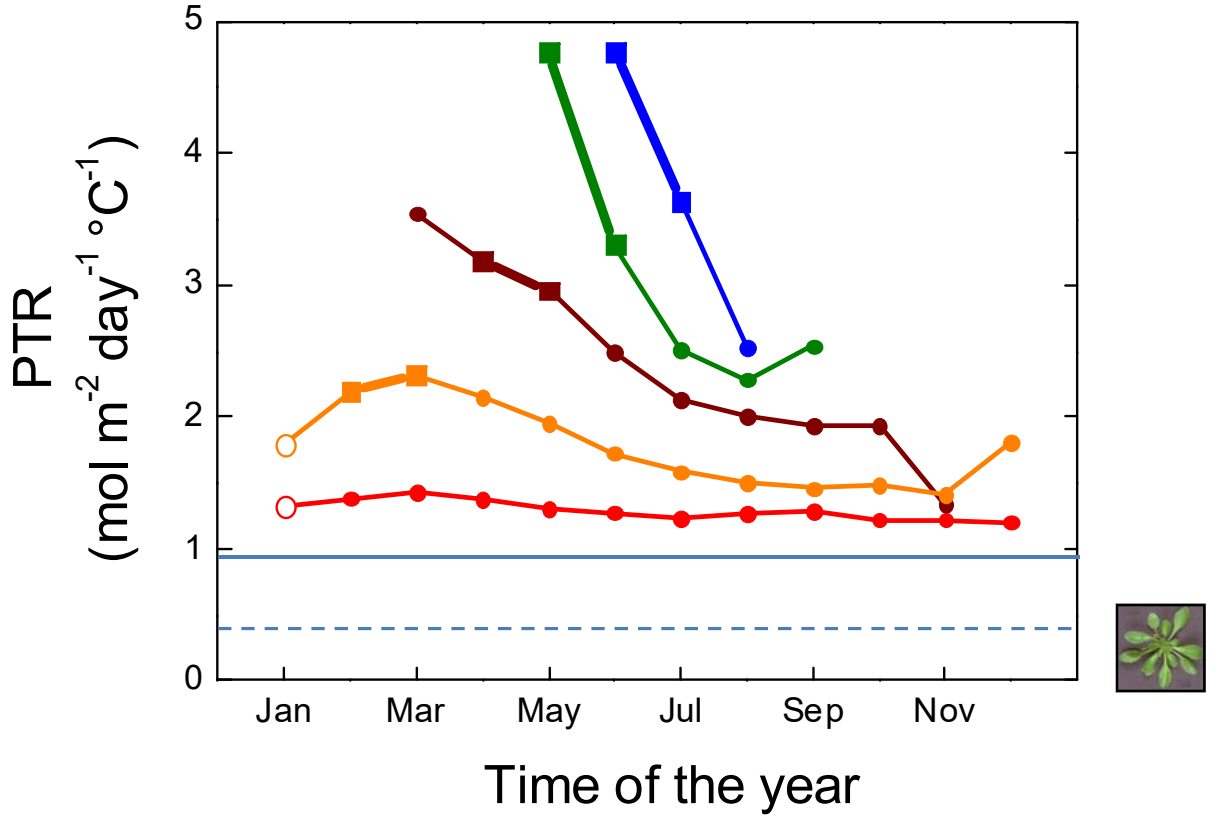


Photo-thermal ratio:

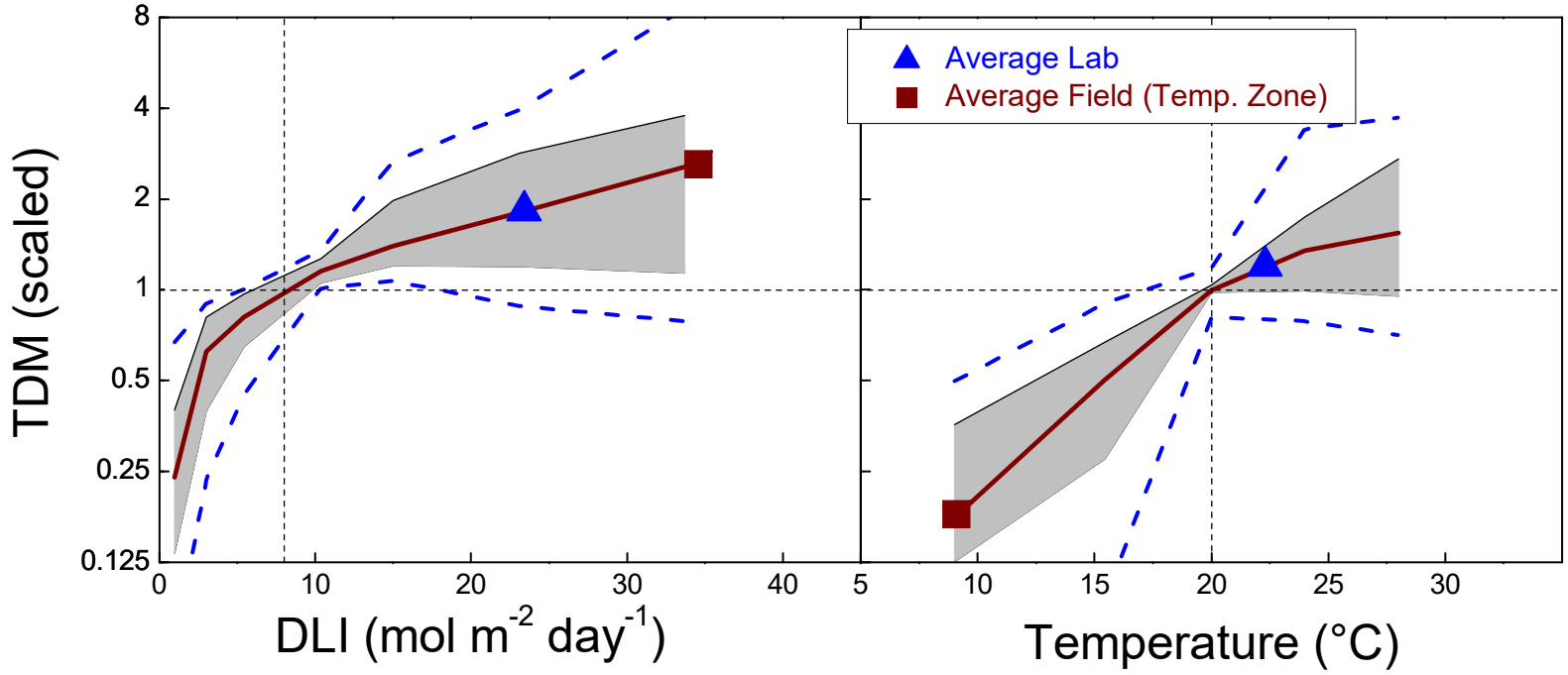
$$PTR = \frac{\overline{DLI}}{\overline{T}}$$

Fischer
(1985)

Heins
(1997)



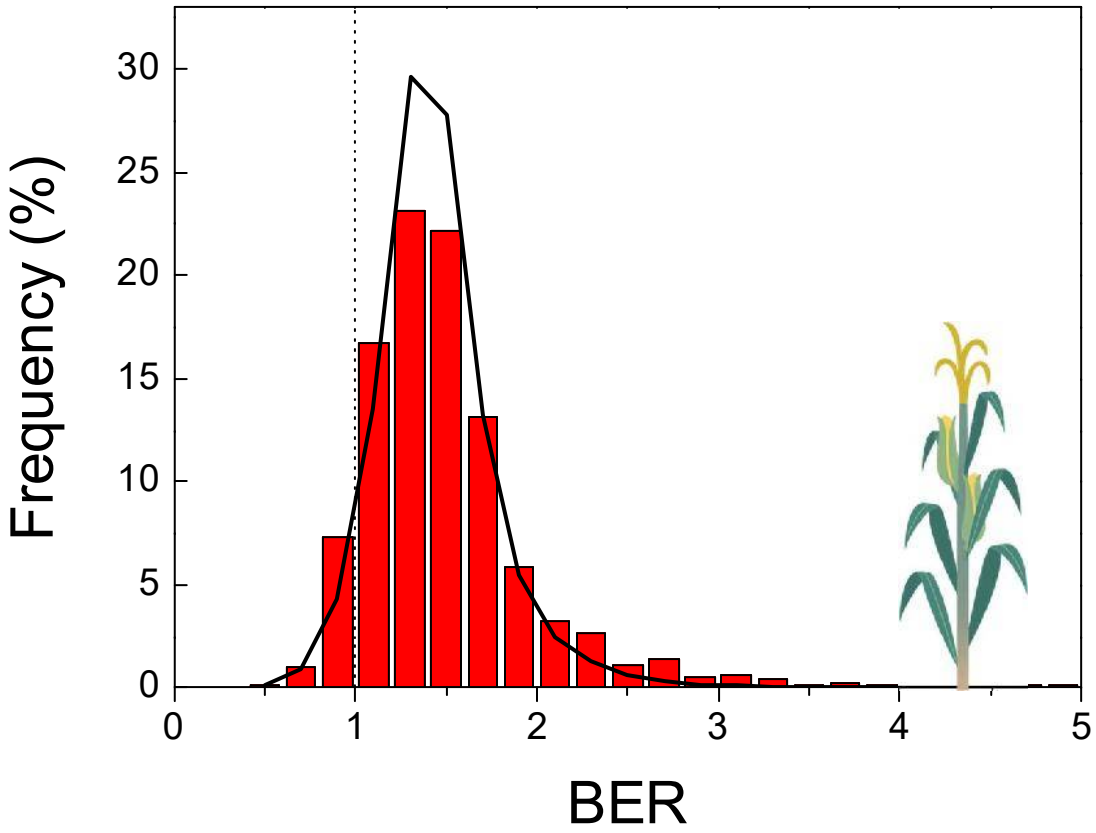
Field vs. Lab:


TDM (scaled)
8
4
2
1
0.5
0.25
0.125
0
10
20
30
40
DLI (mol m-2 day-1)
Average Lab
Average Field (Temp. Zone)
5
10
15
20
25
30
Temperature (°C)

3. Plants in the field grow at higher densities than in the lab:

3. How useful is the analysis of individual plants?
The case of elevated CO_2

Marie-Laure Navas

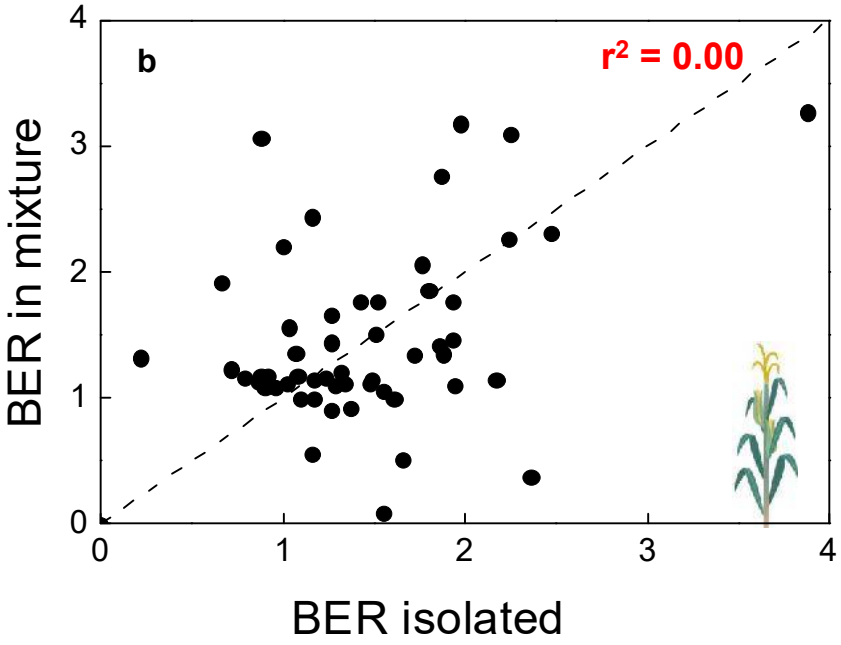


800 ‘experiments’
350 species

New Phytol. 157: 175

3. Can we now forecast the CO_2 response in a vegetation?

Marie-Laure Navas

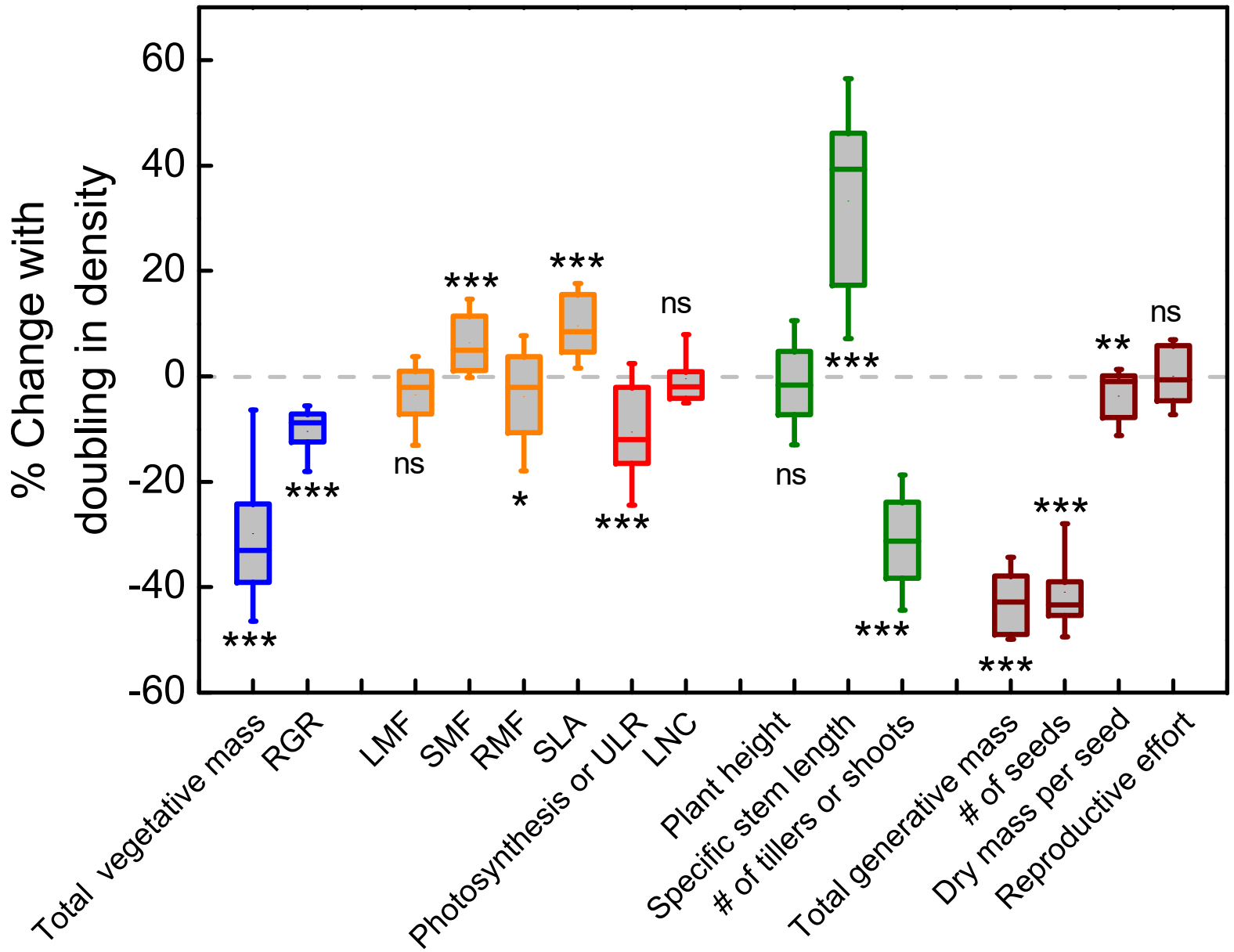


3. Plants in the field grow at higher densities than in the lab:

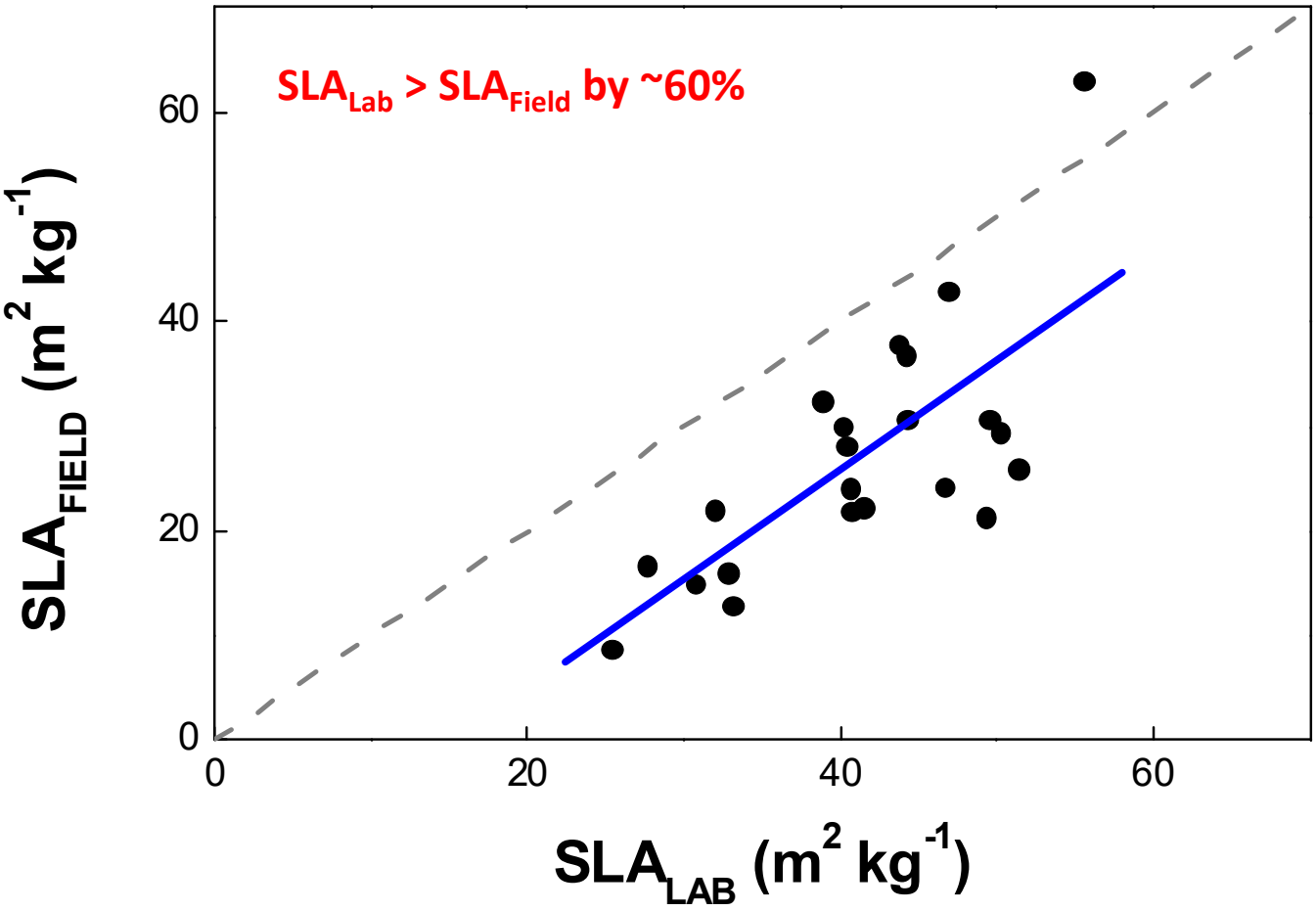
- Plants with high growth rates in the lab
do not necessarily produce high crop yields in the field
(Donald & Hamblin 1976; Cannell 1979).

- Modern *Zea mays* cultivars produce more
because they perform better ar high densities
(Tollenaar & Wu 1998).

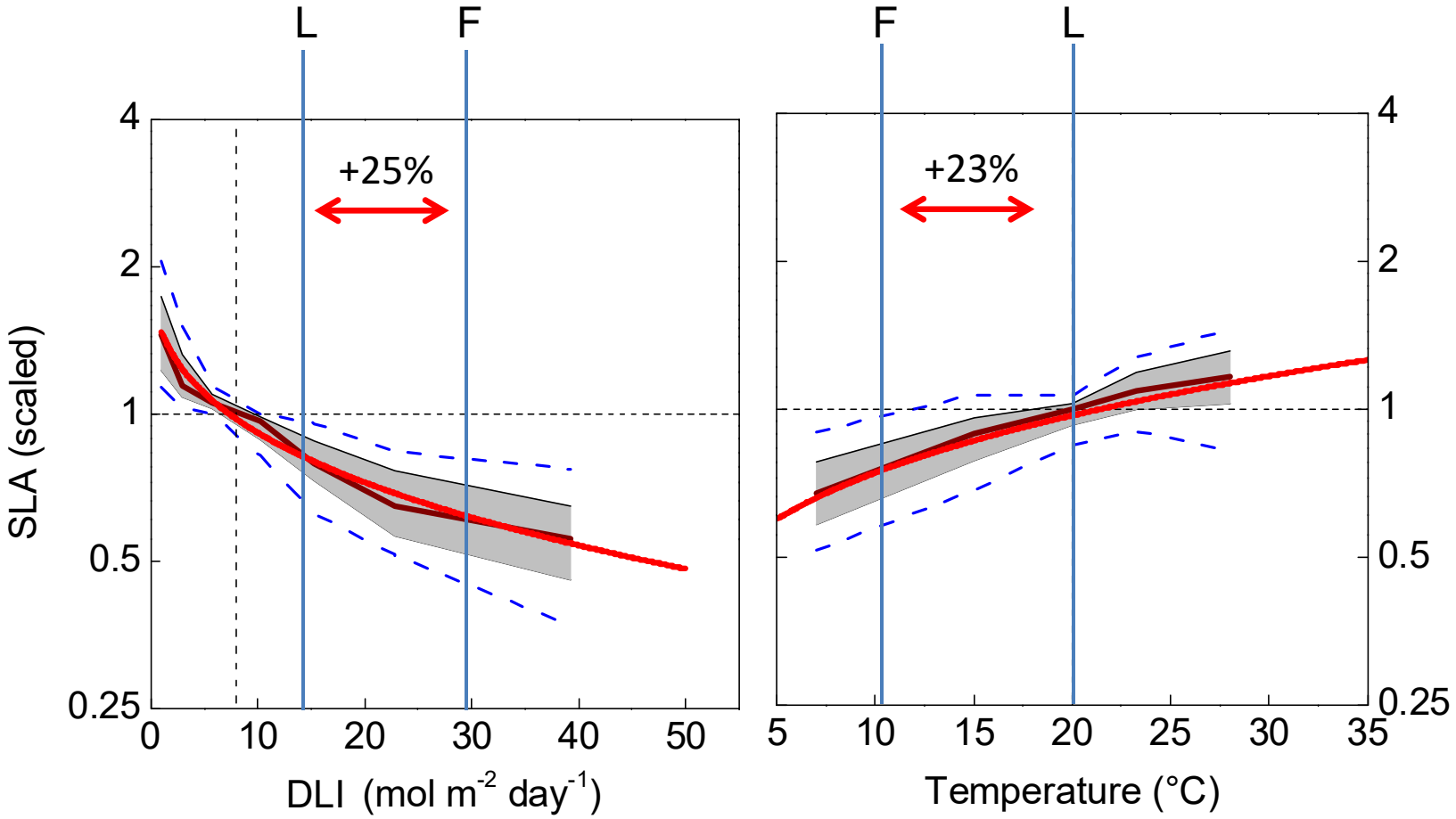
3. Effect of density:



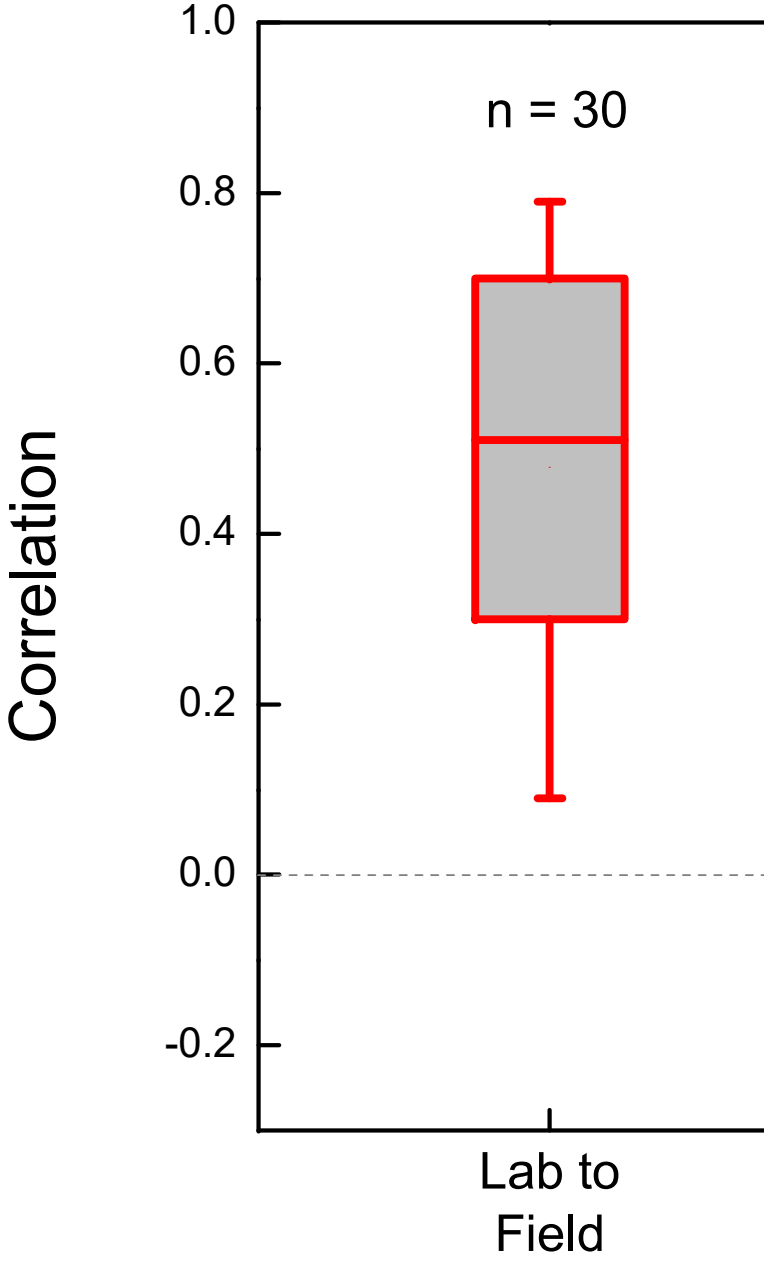
So can DPI and T explain the 60% difference between field and lab?

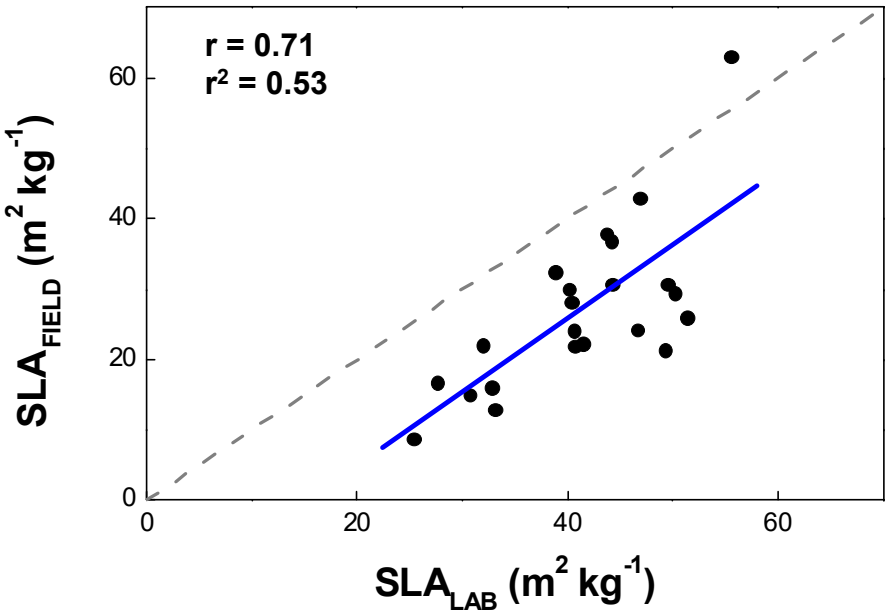


Can DPI and T explain the SLA difference between lab and field?



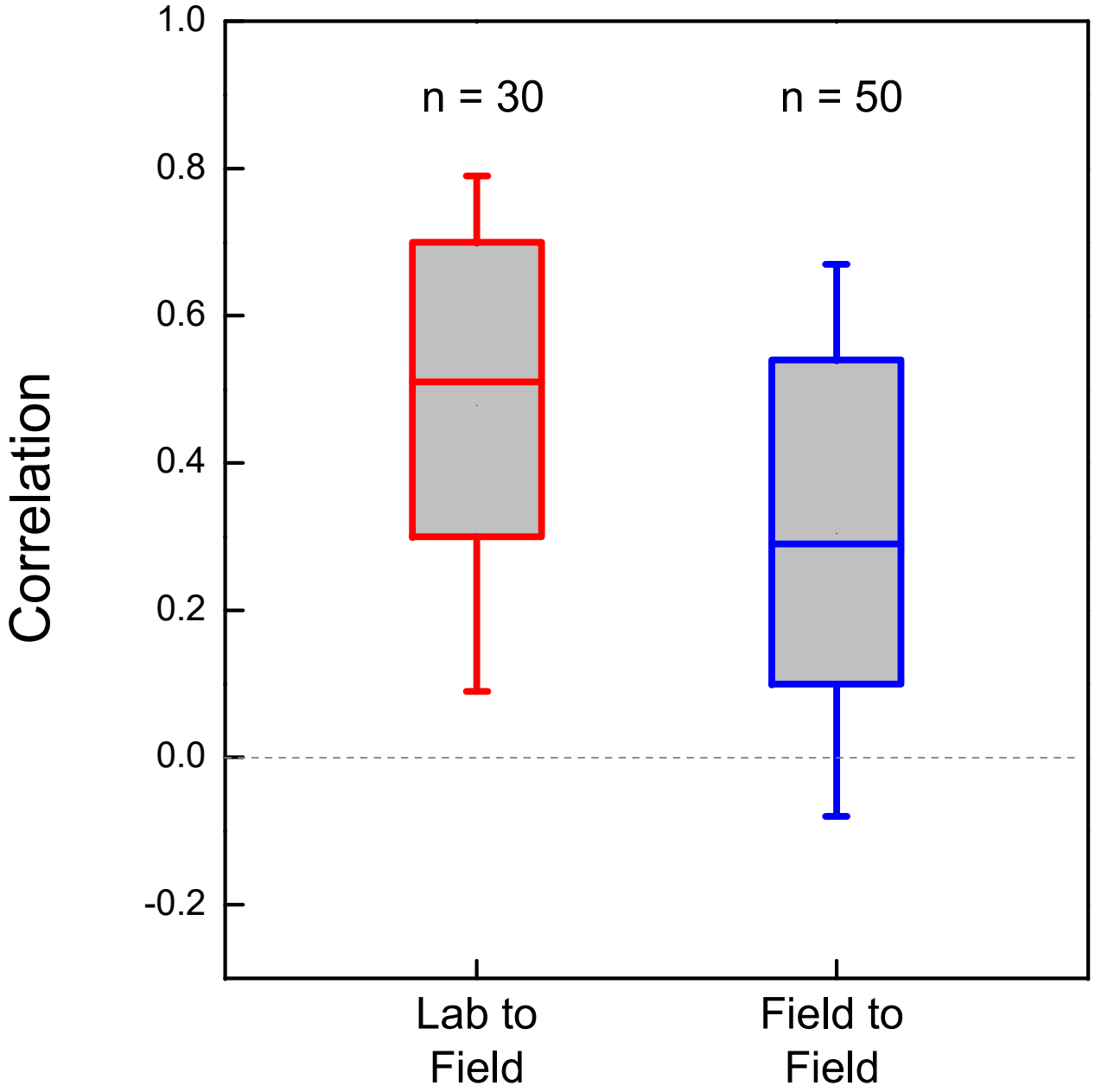
4. Correlation between lab and field results:





Median r^2
0.26

4. Correlation between lab and field results:

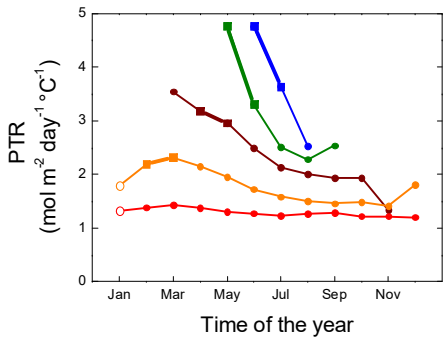


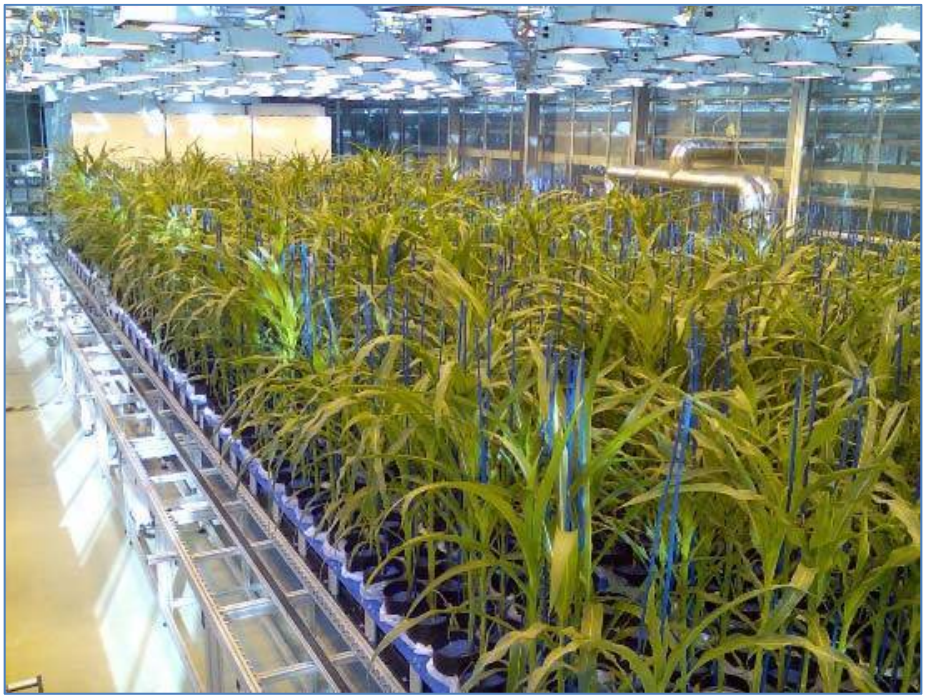
Median r^2
0.26
0.08

Improve the translation from lab to field:

Junker et al. (2015) FiPS

1. Use higher PTR



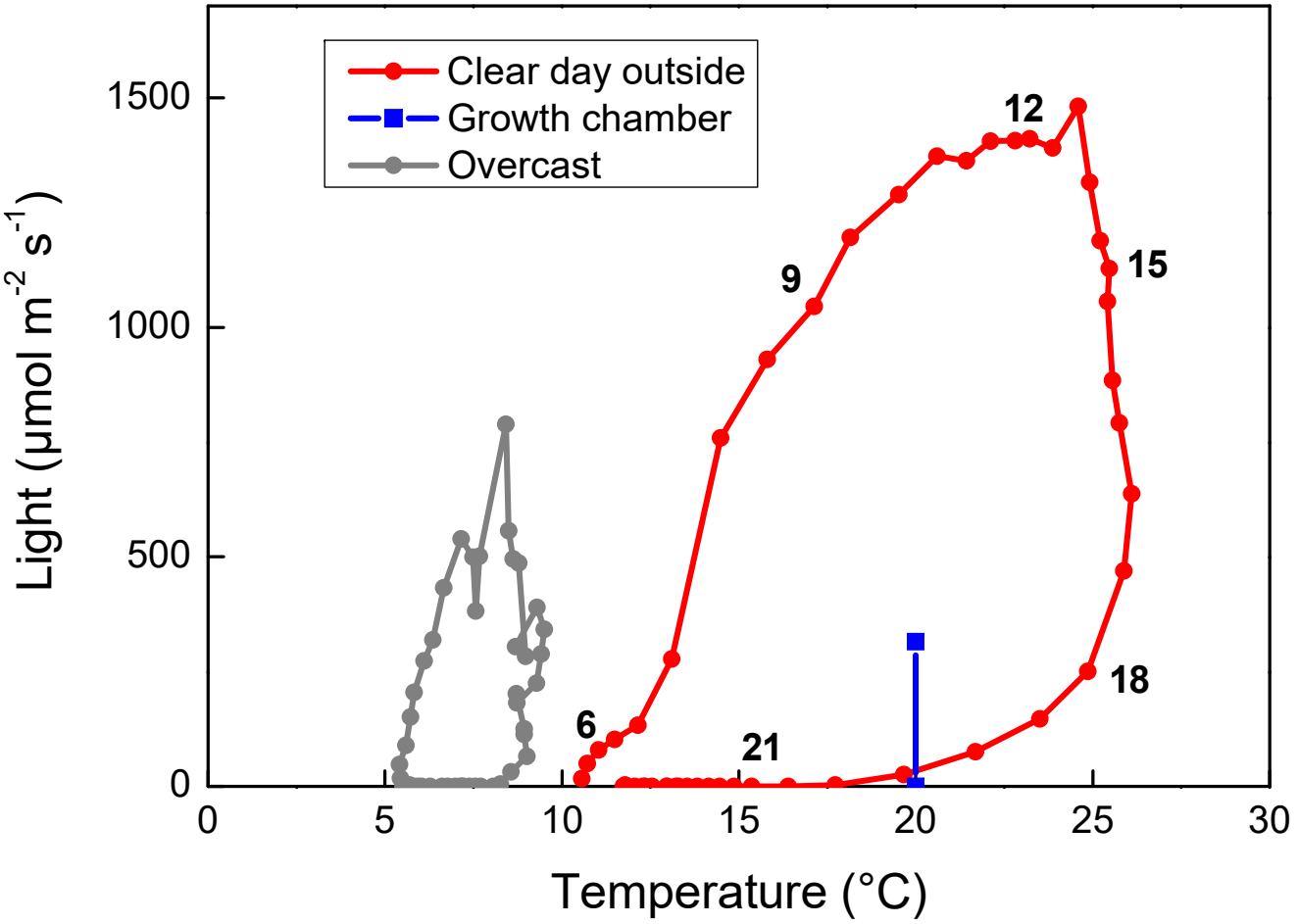


Lab-Field r^2

0.26 ➔ 0.50

Improve the translation from lab to field:

3. Use conditions that fluctuate from day to day



How about applying the environmental conditions from outside?

Improve the translation from lab to field:

Hohmann et al. (2016) PCE

4: Grow plants at higher densities

(& big pots & foil house)

Lab - Field r^2
0.41 – 0.63

Other ways to improve the translation from lab to field:

presse.inra.fr
ciwr.ucanr.edu

5. Use stepping stones:
   - Field soils
   - Experimental gardens, OTC's, mesocosms

6. Lab and field: Better characterisation of soil and atmospheric conditions

7. Think in dose-response curves

8. Use simulation models

Conclusions:

1. In growth chambers:
   Light levels are low
   Temperature is high
   ➔ strongly source limited

2. Responses of plants to environmental stresses are generally maintained

3. Correlations across species/genotypes are maintained to some extent

See also:
Poorter et al. (2016)
Pampered inside, pestered outside? Differences and similarities between plants growing in controlled conditions and in the field.
New Phytol. 212: 838-855

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