3rd APPN Meeting

Exploitation of photosynthetic diversity for the improvement of drought tolerance in cereals

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Hot topic:

Can the variation of **photosynthesis** be used to increase **crop yield**?

Can be used to increase the resistance to specific kinds of **stress**?

Drought stress

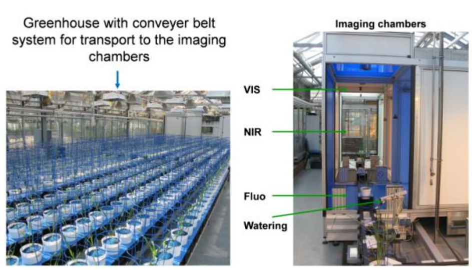
Drought is a major cause of yield loss worldwide.

It is worsening even in temperate zones, such as central Europe.

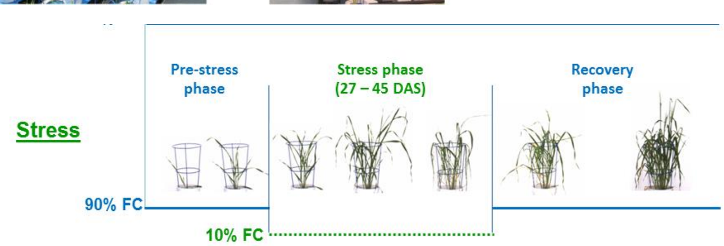
In central Europe **spring drought events** are frequent.
Drought during vegetative stage affects growth and photosynthesis.

Exploration of growth under contrasting water regimes by non-invasive imaging in controlled conditions revealed importance of photosynthesis

In drought stress condition (but not in control) the photosynthetic activity could explain about 8% of grain yield variation (in preparation)



PAM fluorometer
(Photon Systems Instruments (PSI), Czech Republic)
Integrated into a LemnaTec system



Field experiment at the IPK institute, Gatersleben, Germany

102 genotypes:

A set of 100 diverse two-rowed spring barley accessions described by Neumann et al. (2017) Plus 2 six-rowed genotypes (parents of a DH-population)

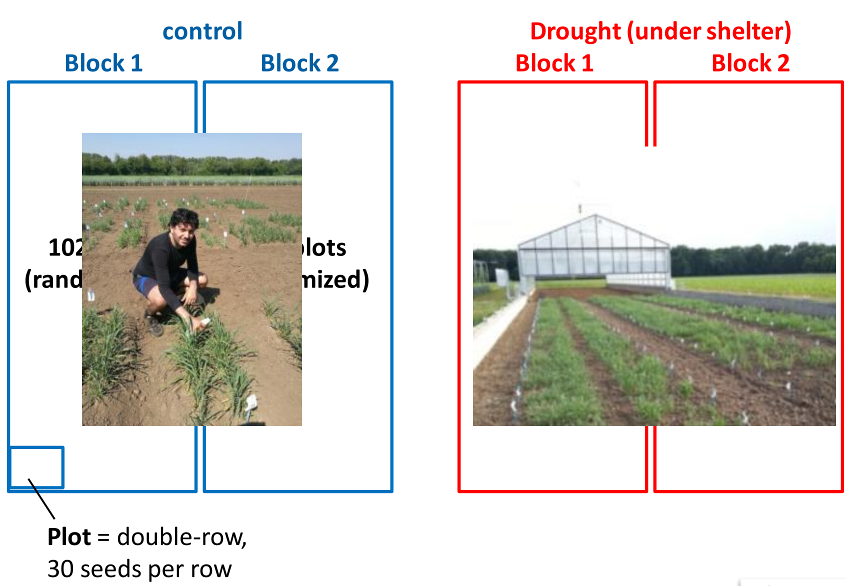
Selected for a reduced range in flowering time under field conditions (Pasam et al. 2012)

Year: 2017

Automatic rain-out shelter in IPK field

Drought (water withdrawal) : from week 7 after sowing until harvest

Experimental design



Measuring photosynthetic activity on the field

Multispeq v 1.0

Developed by Prof. David Kramer and coworkers
Michigan State University, Photosynq platform (photosynq.org)

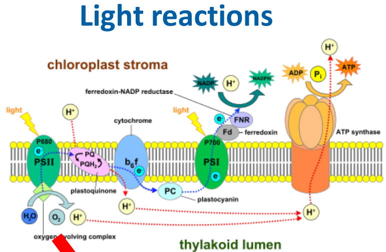
- **Light reactions activity** at incident sunlight intensity
- Many other parameters

  (SPAD, leaf thickness, leaf angle, etc...)
- Measuring time: 12 sec (default protocol)

Photosynthetic linear electron flow (LEF)

Feedback
down-regulation

Light reactions



electrons → CO_2

electrons → O_2

Decreased capacity for
accepting electrons

Chlorophyll fluorescence

Photosystem II efficiency
→ LEF

Easy, fast and non-invasive way for monitoring stress

stress

Limitations

- Labor intensive
- Uncertainty of weather conditions (not possible on wet leaves; optimal if wide range of sunlight intensity)

Advantages

- It measures traits you **cannot acquire by remote sensing** (because a saturating flash has to be applied)
- Cheap (999 USD per device)
- Very easy to use (no expertise is required)

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Aim: estimate the **photosynthetic** (light reactions) **activity for every field plot** in the chosen time period

2 people (not full time)

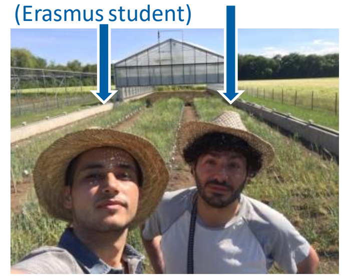
Every day of measurements:

- 4 hours to scan all blocks in both treatments (2 blocks at morning, 2 blocks at afternoon)
- 1 randomly chosen leaf per plot

We did not measure every day

3,625 measurements in 6 weeks

Muzo (Erasmus student) **me**



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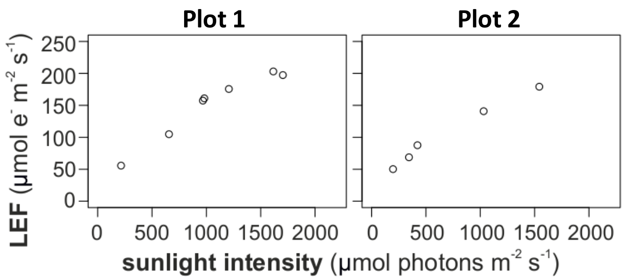
Values of photosynthetic activity (LEF) are not directly comparable, because acquired at different light intensities.

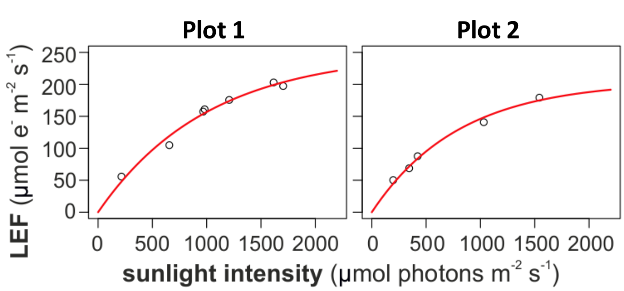


Every point = single measurement on one leaf

Necessity of a fitting model for comparing photosynthesis among field plots.

Fitting model: exponential saturation

$$\text{LEF} = \textbf{LEFmax} * (1 - \exp(- \textbf{k} * \text{SI}))$$



Every point = single measurement on one leaf

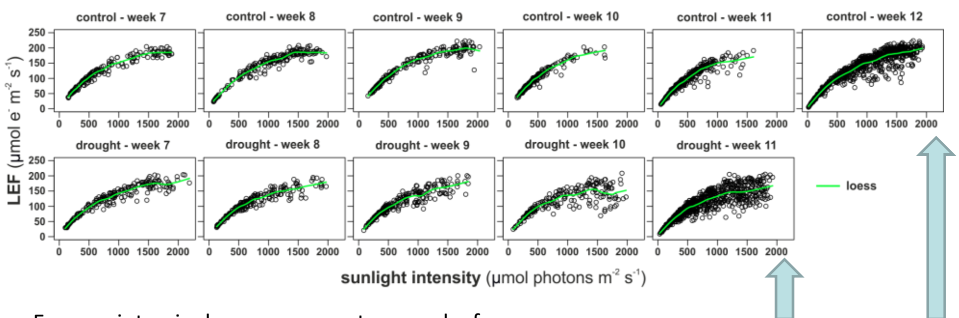
Necessity of a fitting model for comparing photosynthesis among field plots.

The fitting model was validated on the whole population

Time: weeks after sowing

Drought (water withdrawal): from week 7 until harvest

Photosynthesis measurements: from week 7 until flowering



Every point = single measurement on one leaf

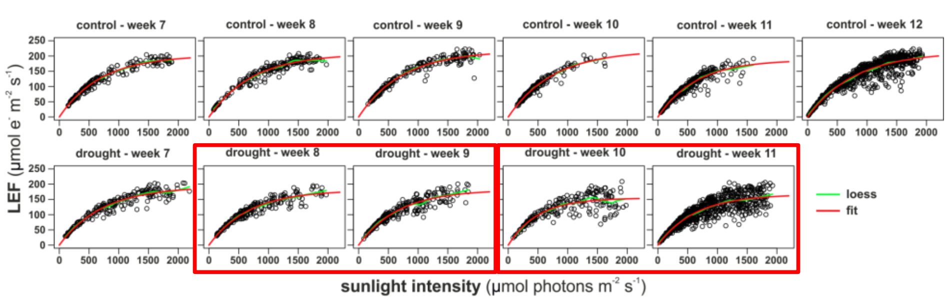
Flowering time
(senescence starts)

Fitting model: exponential saturation

Time: weeks after sowing

Drought (water withdrawal): from week 7 until harvest

Photosynthesis measurements: from week 7 until flowering



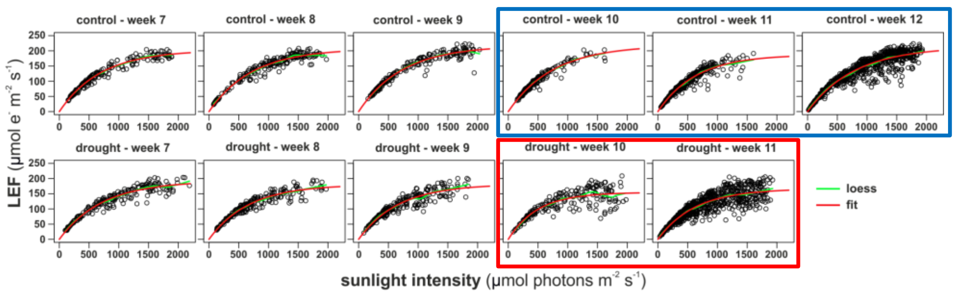
2 phases of photosynthesis decrease in drought

Fitting model: exponential saturation

Time: weeks after sowing

Drought (water withdrawal): from week 7 until harvest

Photosynthesis measurements: from week 7 until flowering



Measuring points were collected in this interval

The data of **each plot from the defined interval** (control week 10-12, stress week 10-11) were used for fitting to obtain a representative value of **LEFmax** and **k** for each plot

Number of measurements per plot

control: 7 points (= 7 leaves)

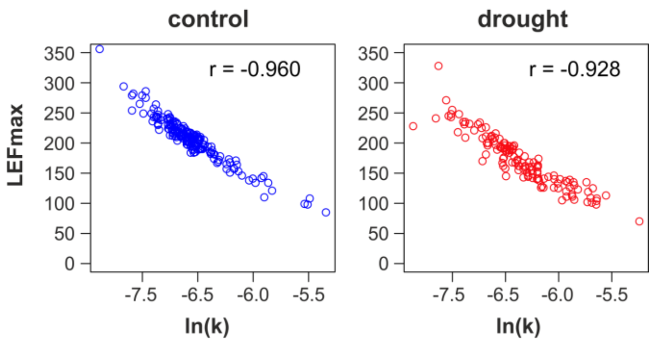
drought : 5 points (= 5 leaves)

Accepted fit results: both **LEFmax** and **k** p-values < 0.05

control = 87% (100 genotypes out of 102)

drought = 66% (92 genotypes out of 102)

LEFmax and k are highly correlated



Then I focussed more on LEFmax

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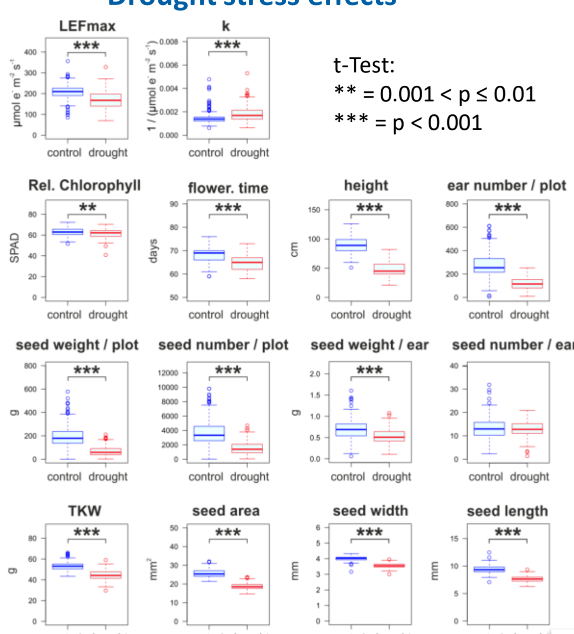
Drought stress effects

Photosynthesis

Physiology and biomass

Yield-related

Seed features



t-Test:
** = 0.001 < p ≤ 0.01
*** = p < 0.001

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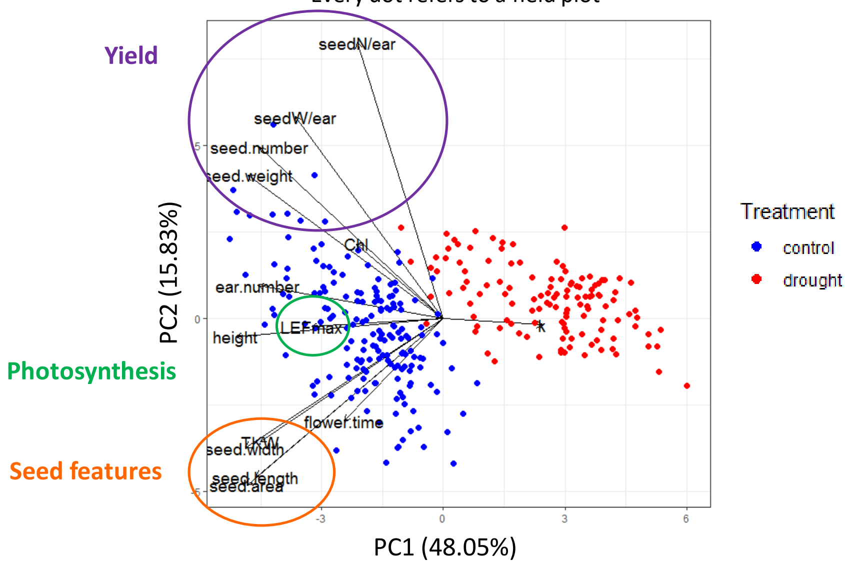
Principal components analysis

Every dot refers to a field plot



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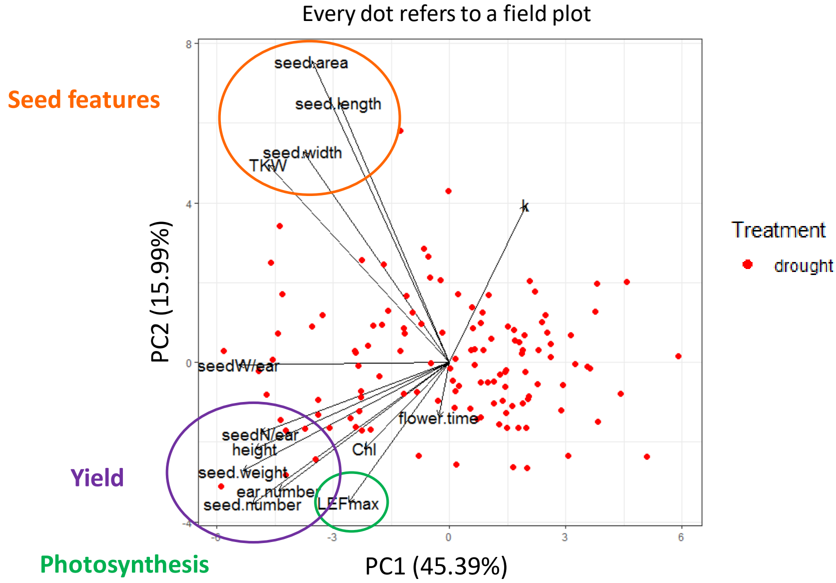
Under drought LEFmax is highly correlated to yield-related traits

Every dot refers to a field plot



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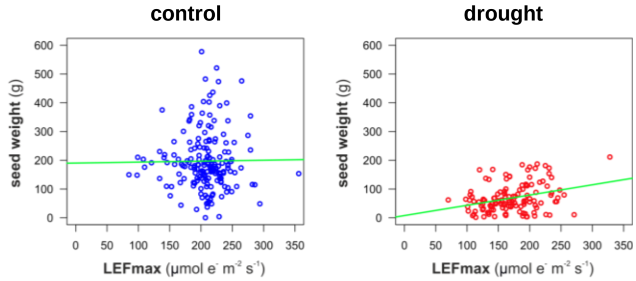
A significant fraction of grain yield under drought is explained by photosynthesis



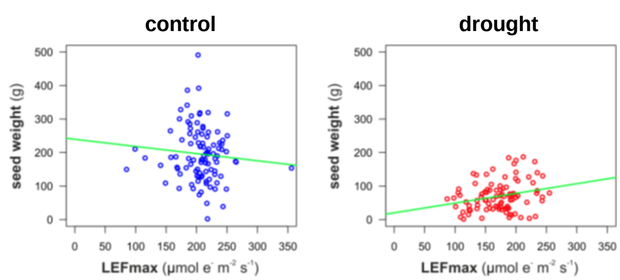
Every point= one plot

Regression for drought:

seed weight = **0.36** * LEFmax
(R2 = 0.0970; Adj.R2 = 0.0899; p-value = 0.000311)

seed weight = **-1.96** * flower.time + **0.41** * LEFmax
(Adj.R2 = 0.106; p-value = 0.000319; LEFmax-coeff. p-value = 6.63e-05)

First indication of high genotypic variation for LEFmax in the barley collection



Every point= one genotype

Regression for drought:

seed weight = **-1.88** * flower.time + **0.35** * LEFmax
(Adj.R2 = 0.0569; p-value = 0.0274; LEFmax-coeff. p-value = 0.00781)

At least two experiments are required to quantify the **genetic** and **environmental** components.

Conclusions

The major limiting factor for the method is the **number of measurements**.
It has to be adjusted to **your scientific question** (time resolution, factors to be included, etc…).

There is **variation for photosynthetic performance** in a diverse barley collection, especially under drought.

The variation of photosynthetic activity has **potential to increase cereal yield under drought stress** for future yield stability under the climate change challenge.

Ackowledgments

Genome diversity group (GED):
- Prof. Andreas Graner,
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- Technicians of GED

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- Dr. Henning Tschiersch

Acclimation Dynamics and Phenotyping group:
- Dr. Astrid Junker
- Ingo Muecke

Alexander von Humboldt Foundation

Photon Systems Instruments (PSI)

LemnaTec

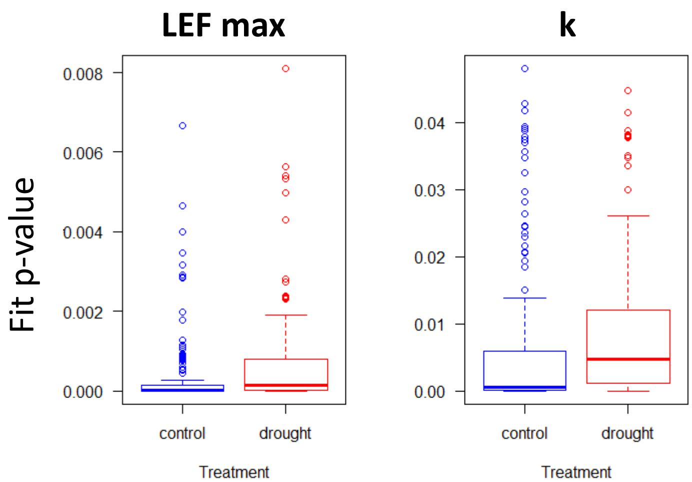
Thank you
for your attention

$$LEF = Y(II) * PAR * Abs * 0.5$$

LEF = photosynthetic linear electron flow

Y(II) = photosystem II efficiency

Abs = absorptivity (fraction of light absorbed by the leaf



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