GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN IN PUBLICA COMMODA SEIT 1737

September 16, 2025

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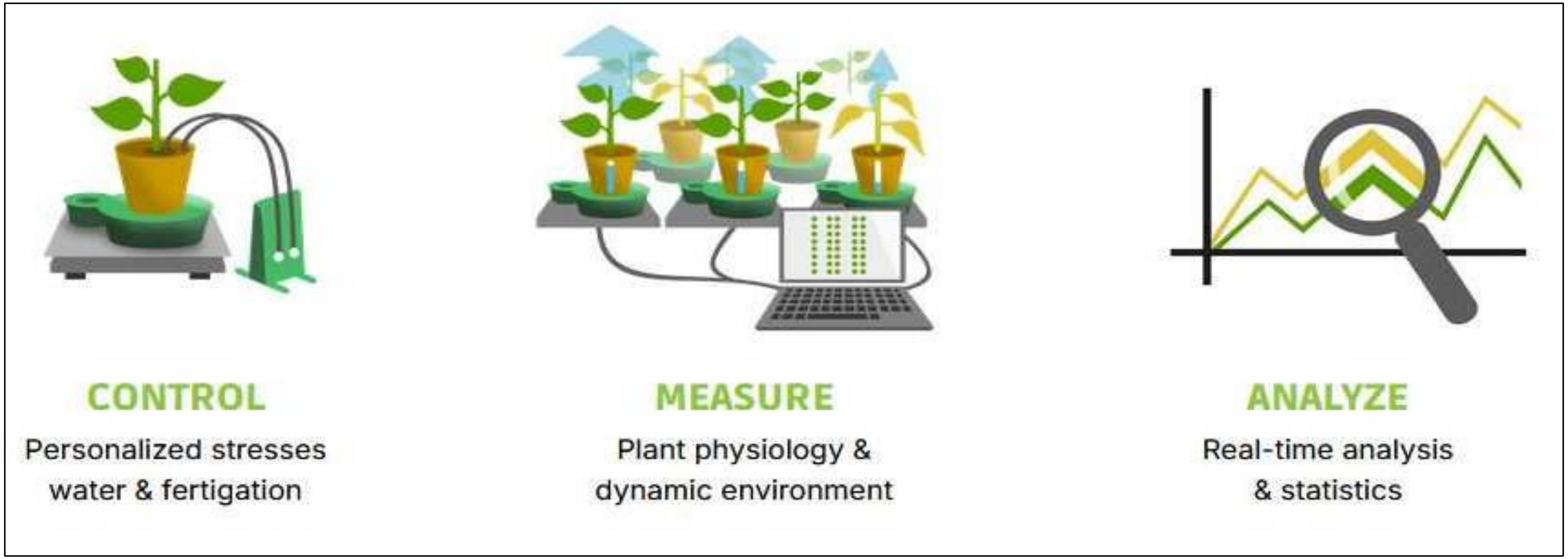
# MINI-SEMINAR:

# An emerging research framework for MultiStress crop stress research




## The Plantarray®

## A Novel plant physiology screening system

https://niederlandenachrichten.de/wp-content/uploads/2021

# High-throughput functional phenotyping data to support crop model-aided design of drought resilient crop cultivars

*Mercy Appiah, Issaka Abdulai, Elvira S. Dewi, Ahan Dalal, Menachem Moshelion, Alan Schulman, Agata Daszkowsca-Golec, Munir Hoffmann, Reimund P. Rötter*

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# Experimentation & Modelling for Ideotype Design

- process based crop simulation models (CSM)
- mathematical equations describing plant growth
- genotype x Environment x Management
- "virtual genotypes" → optimal trait combinations

- **Ideotypes for future CC conditions**

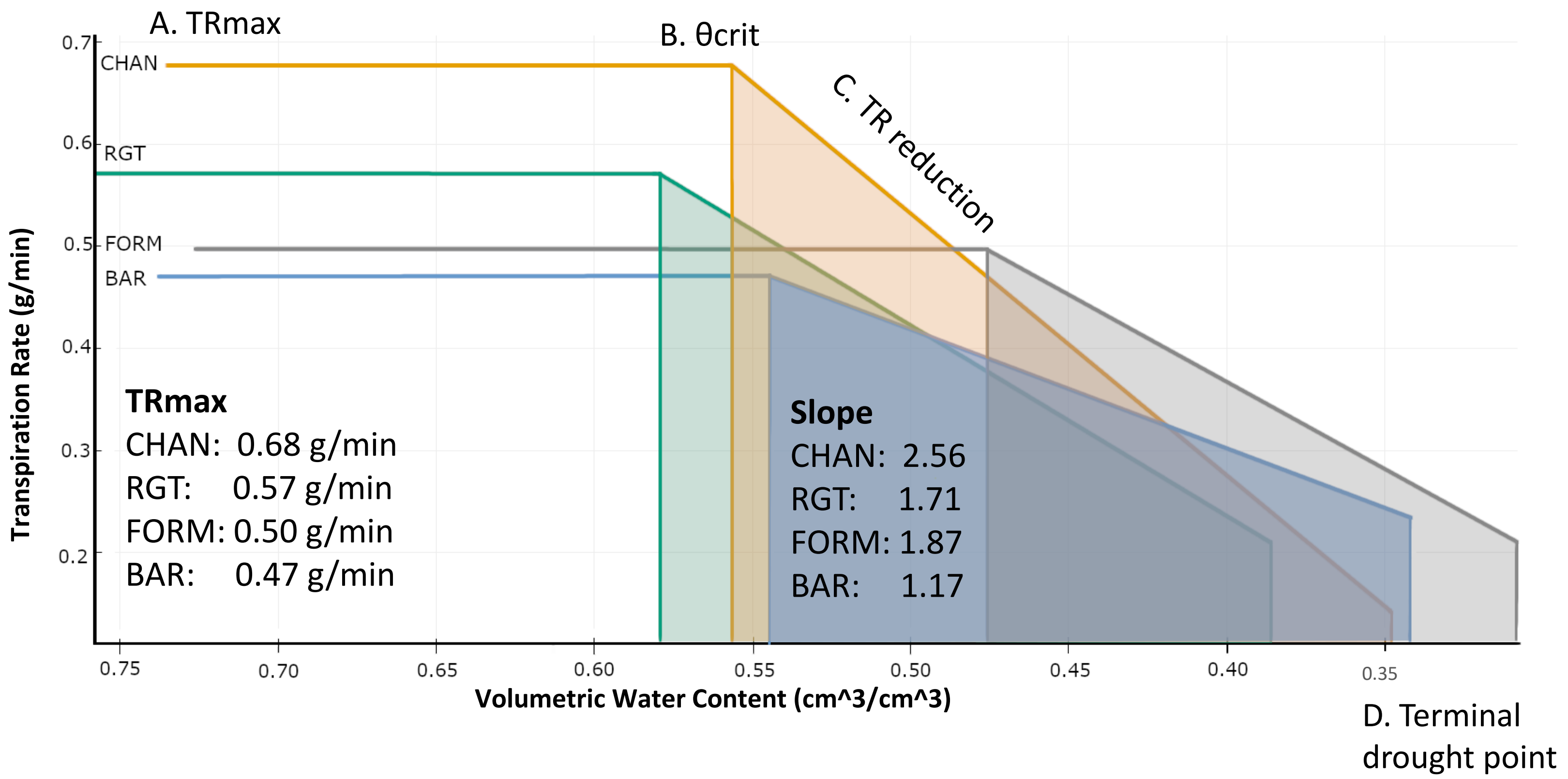
→ accurate simulation of CC impacts on crops

→ accurate process descriptions in CSM

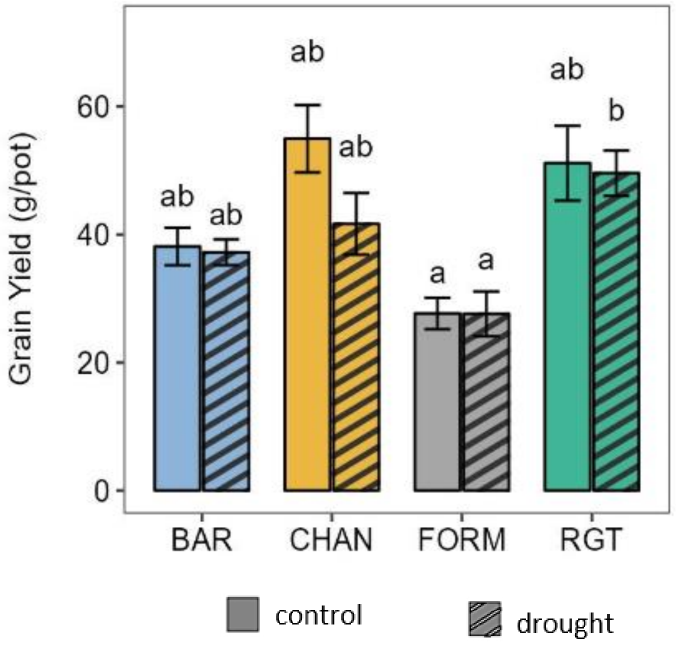
→ experimental data

→ in-depth knowledge on physiological drought responses

# Water use behavior in barley genotypes







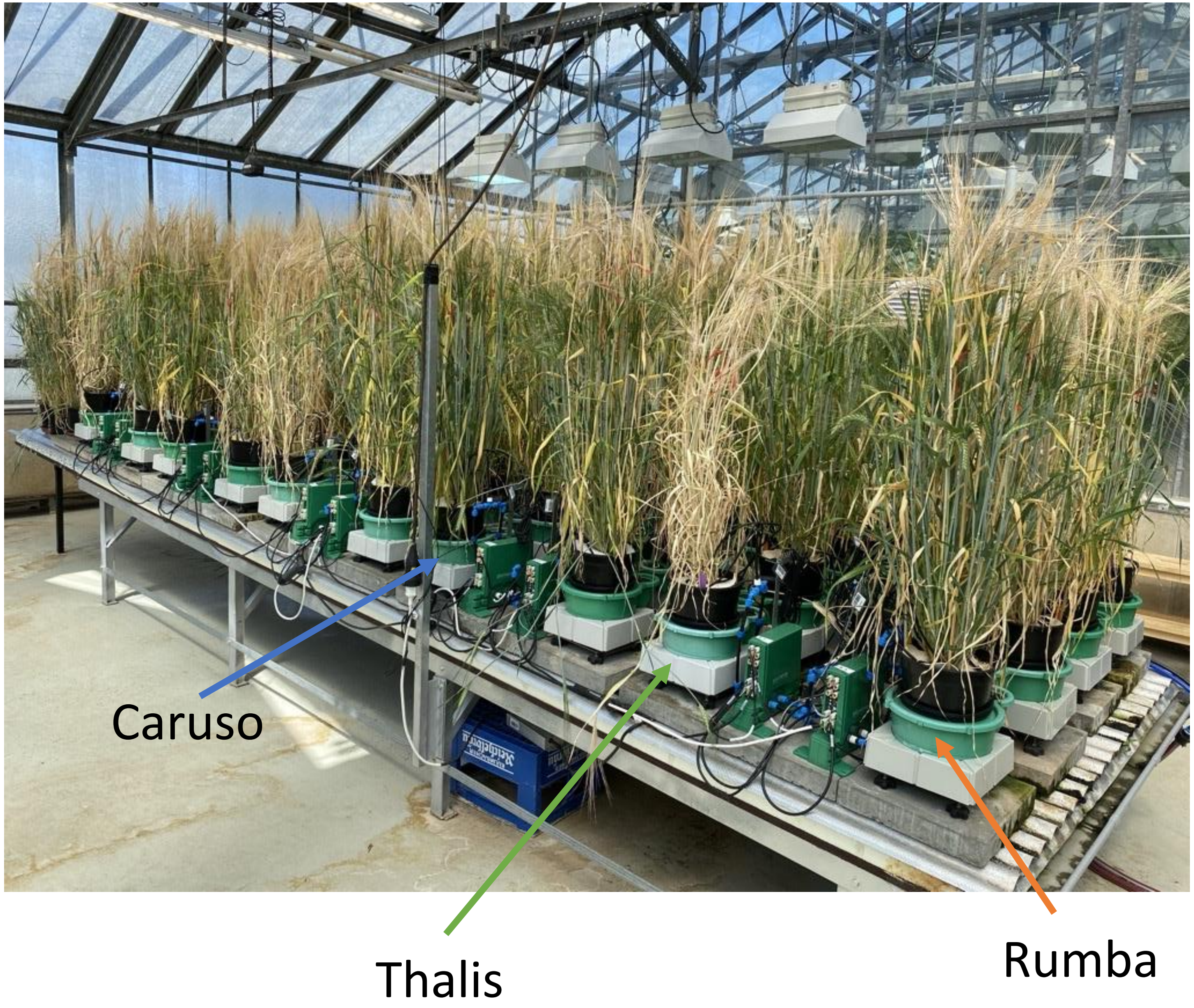
# Discovery of a new water use strategy

- Non - conserving
- Conserving

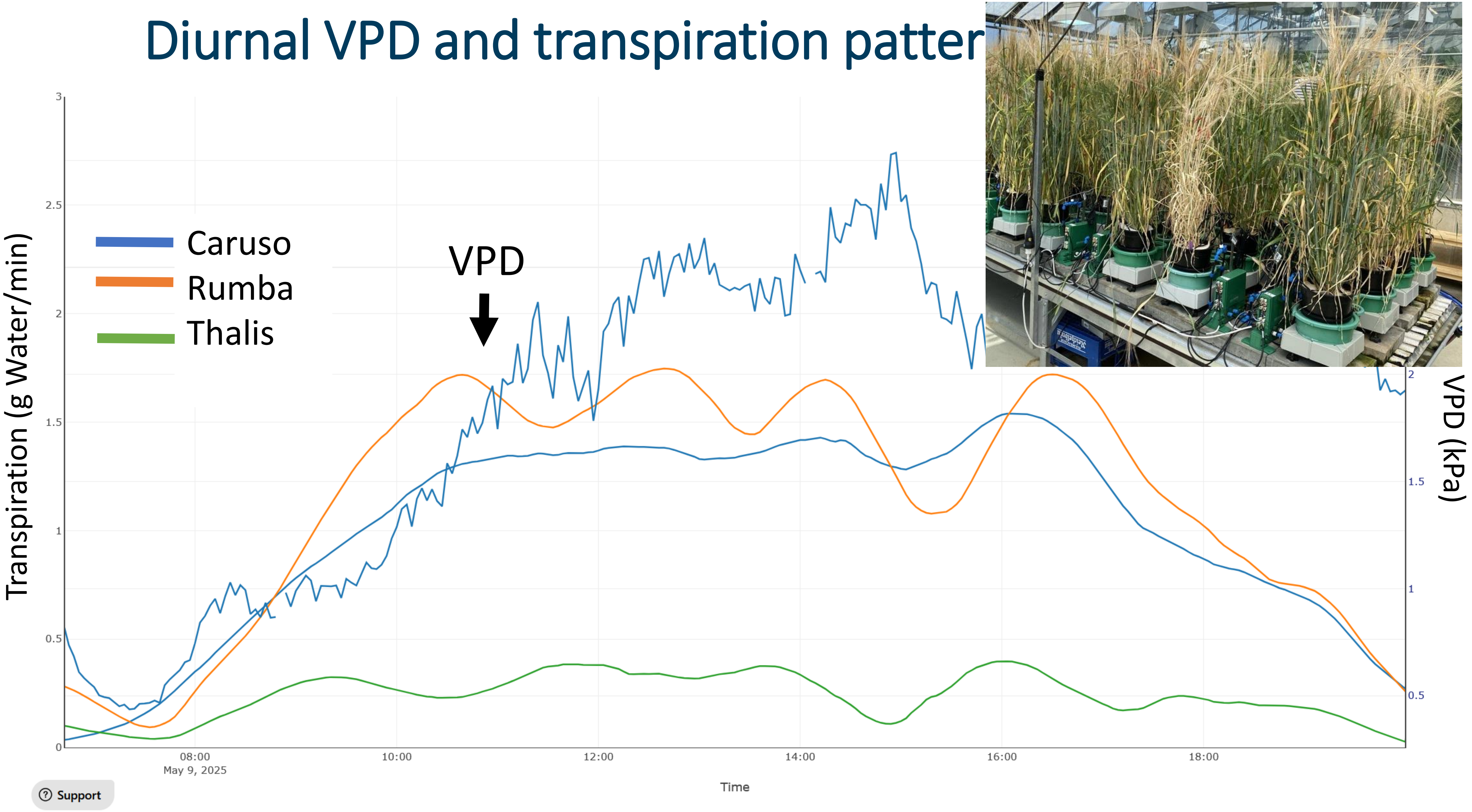
- **Dynamic water use → ideotype trait?**

- Simulate water use behavior with CSMs
- Simulation of diurnal transpiration patterns

# Barley transpiration model



# Diurnal VPD and transpiration patter



# Barley transpiration model

- Simulate water use behavior with CSMs
- Understand underlying genetics
- Link genetics with crop model parameters
- → CROP MODEL AIDED IDEOTYPE DESIGN

https://niederlandenachrichten.de/wp-content/uploads/2021

# Evaluating Drought and Salinity Stress Responses in Tropical Sorghum Cultivars using High-Throughput Phenotyping

*Elvira S. Dewi, Issaka Abdulai, Gennady Bracho-Mujica, Mercy Appiah, Reimund P. Rötter*

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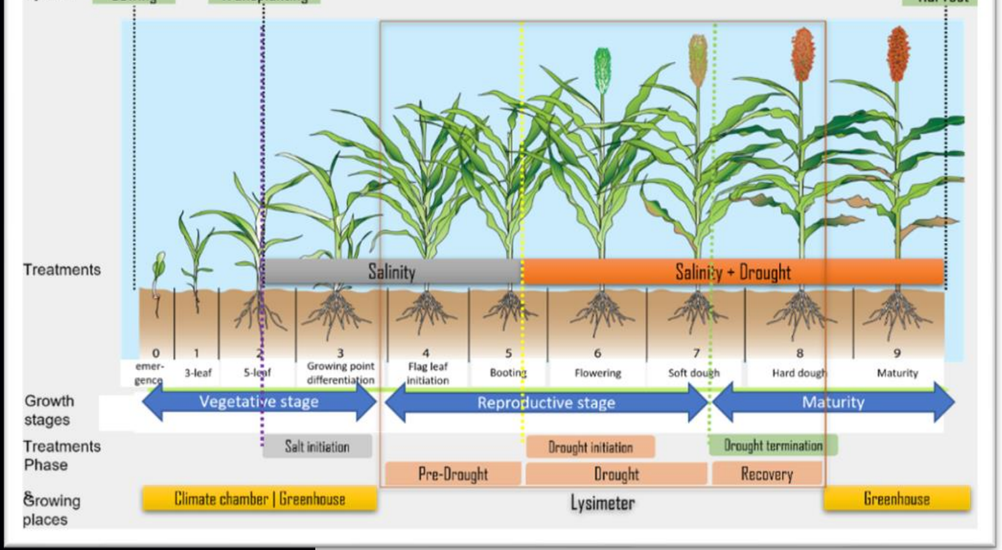
# Background & research questions

- Climate change increases drought and salinity, threatening tropical agriculture.
- Indonesian lowlands: rice production declining due to salinity, drought, tsunami aftermath.
- Need for climate-resilient crops: sorghum tolerates drought and salinity, offers food/fodder security

# Methods & Experimental Setup

- HTP Platform: Plantarray–gravimetric, real-time monitoring (SPAC-Analytics, weighing lysimeters).
- Experimental Design:
  - Semi-controlled greenhouse experiments
  - Salinity stress: EC 7, 14 dS/m; Drought: imposed at booting stage.
  - Cultivars: Numbu (dual drought & salt tolerant), Kuali (salt tolerant), Samurai2 (sensitive to both).
- Replicated, block designs; detailed trait measurement (transpiration, biomass/yield, recovery).

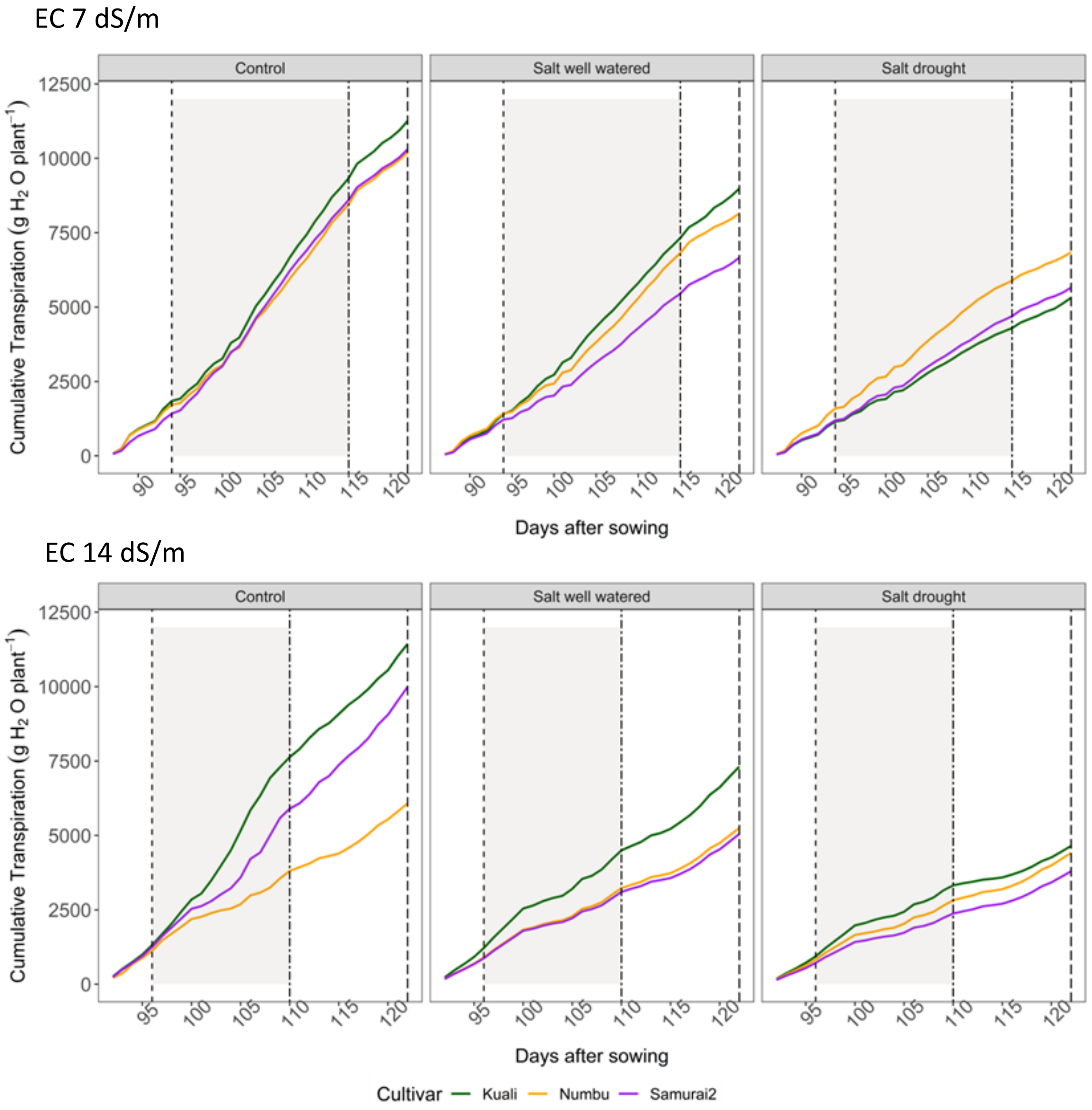
Experimental scheme




Plantarray, a high-throughput functional phenotyping (HTP) platform

# Physiological Responses

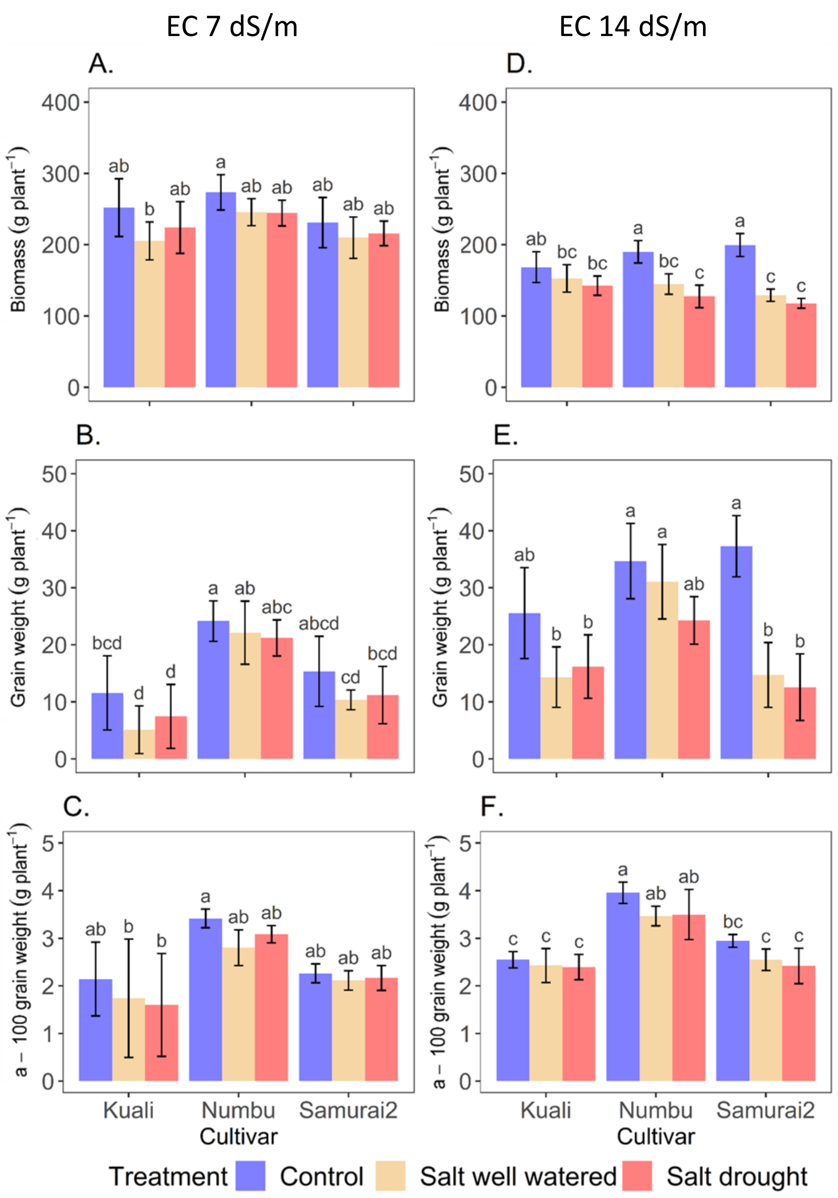
| Cultivar | Physiological Response | Transpiration Reduction |
|---|---|---|
| Numbu | Conservative water use, stable Tr under stress | ~16–33% |
| Samurai2 | Strong reduction under salinity | ~36–60% |
| Kuali | Largest decrease under combined drought + salinity | ~22–57% |




Cumulative transpiration of three sorghum cultivars under salinity and drought treatments.

# Stress Impact on Yield and Biomass

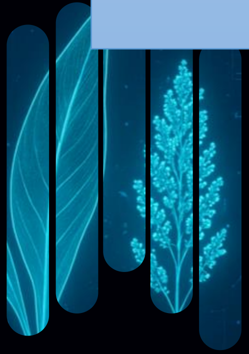
- **Moderate salinity (7 dS m⁻¹):**
  - Biomass ↓ 7–19%
  - Grain weight ↓ 8–56% (Kuali highest, Numbu lowest)
  - 100-grain weight ↓ 4–25%
- **High salinity (14 dS m⁻¹):**
  - Biomass ↓ 15–41% (Samurai2 most affected)
  - Grain weight ↓ 10–66% (Samurai2 highest loss, Numbu lowest)
  - 100-grain weight ↓ 5–18%

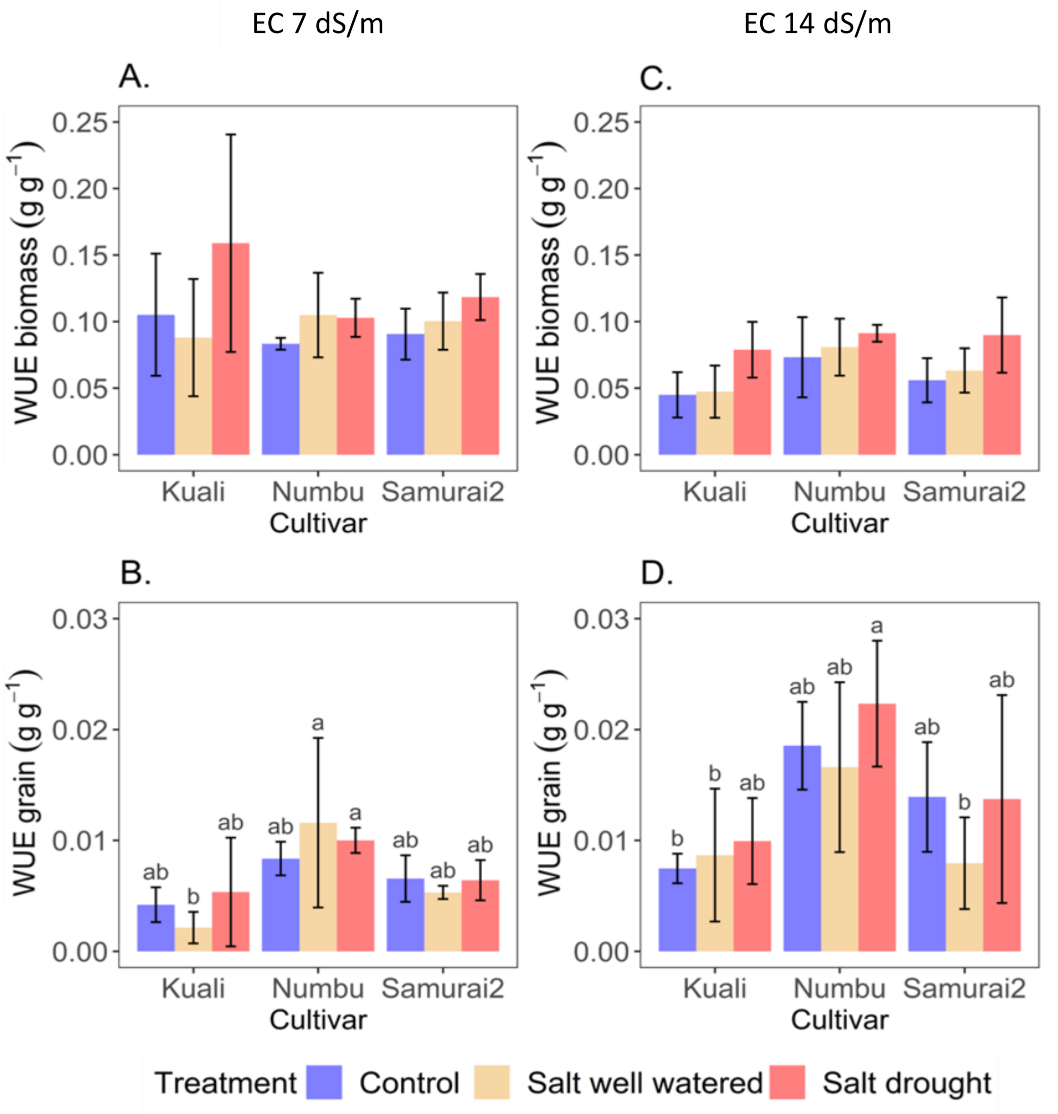



Biomass and grain traits of sorghum under two salinity levels

# Water Use Efficiency

| Cultivar | WUEbiomass | WUEgrain |
|---|---|---|
| Kuali | Max: 0.16 (+51%) under moderate; drops to 0.08 under high stress, highest proportional increase | Drops −27% under moderate, +33% under high salinity |
| Numbu | Moderate/stable increase; highest under high salinity | Stable/improved (0.010–0.022; +20%), top values |
| Samurai2 | Moderate increase under stress, high under severe | Stable/slightly improved, ~0.009–0.014 |





# Conclusion & Outlook

- Sorghum stress responses are highly cultivar-dependent.
  - *Numbu: Most tolerant, stable performance under drought and salinity.*
  - *Samurai2: Most sensitive, large yield and transpiration reductions.*
  - *Kuali: Mixed, sensitive to combined stress.*
- Yield and WUE generally decline with increasing stress
- Integrated testing of diverse cultivars, focusing on key physiological traits, to breed climate-resilient lowland varieties.
- High-throughput phenotyping helps identify superior genotypes for future crop improvement.

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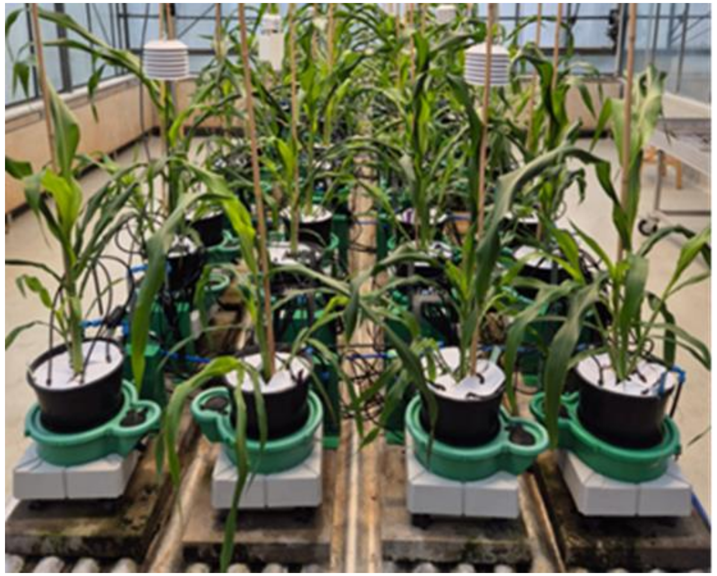
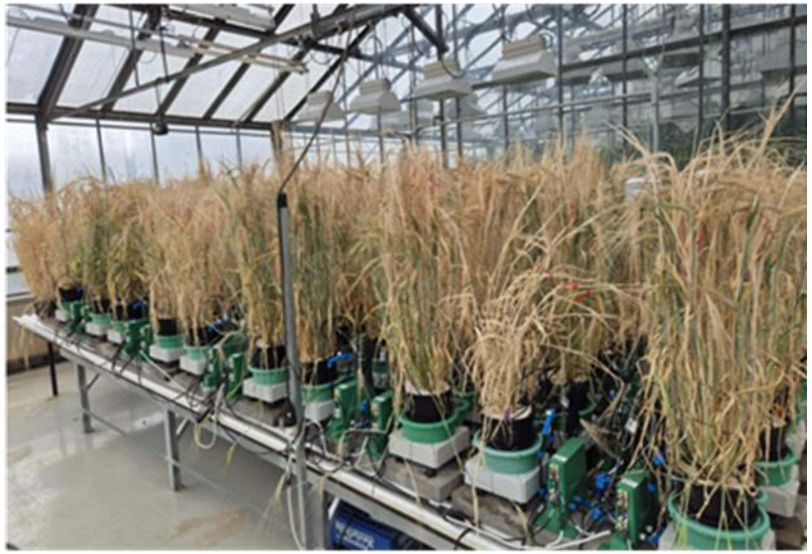
# TROPAGS Plantarray Plant water stress research





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# Understanding water stress response Mechanisms in maize:

## Does recurrent drought improves resilience?

# Hypotheses

Hypotheses:

- H1: Plants that experience drought at vegetative growth stage are more resilient than plants that experience drought only at flowering "Legacy effect"

- H2: Drought resilience response to recurrent drought are functional traits (phenology, root, leaf anatomical …)dependent.

Research Question

- To what extent does recurrent drought influence water use?
- Which traits are associated with maize plant response to recurrent drought?
  - Collaborative analysis (water use, physiological, molecular, … measurements)

# Experimental Setup

- Tropical vs Temperate maize cultivars exposed  to single (DS1) and recurrent (DS2) drought stress at vegetative and tasseling:

✓Water use traits/behavior (transpiration)

✓Morphological traits (stomatal density, biomass and yield traits)

✓Biomass and grain quality….traits: phenolics, carotenoids…?
✓Physiological traits (Hyperspectral imaging, leaf temp
✓Hormonal (ABA, …? ) water use relations

# Experimental Setup

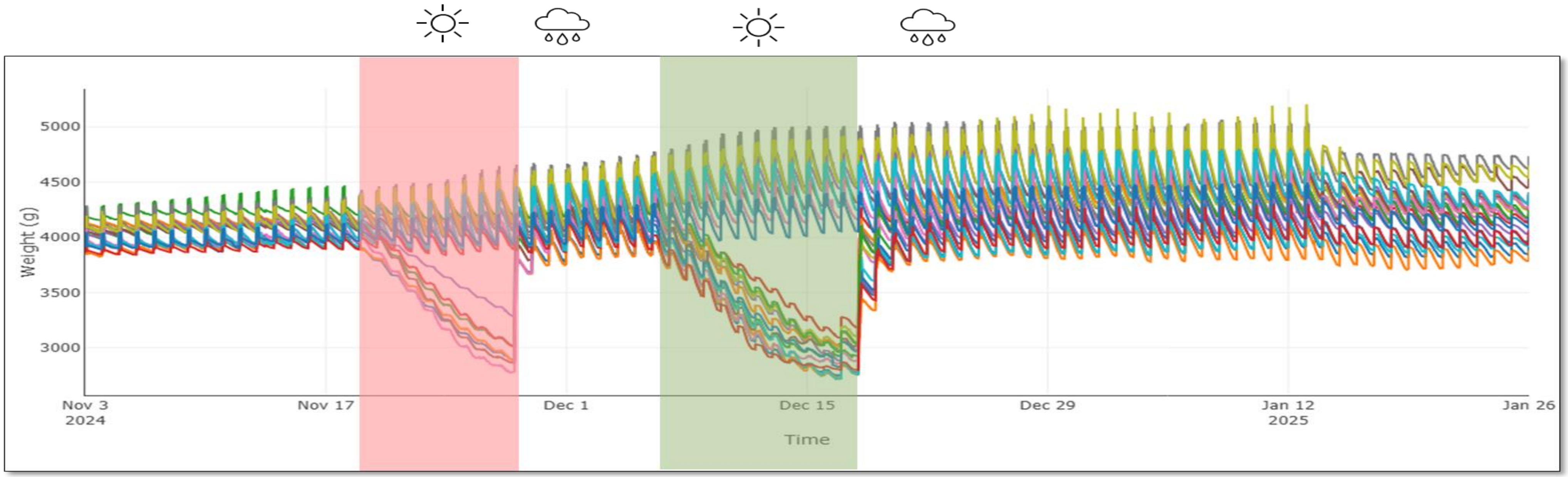
- Cultivars: Dekalb8031 (Tropical origin); Likeit (Temperate origin)
- Drought Treatments:
  - Control: Well-watered
  - DS2: Recurrent drought stress (vegetative + reproductive stages)
  - DS1: Single drought stress (reproductive stage)

- Experimental Design
  - Platform: Plantarray 3.0 HTP phenotyping system
  - Total Units: 42 lysimeters
  - Design: Randomized complete block design
  - Replications: 7 replicates × 6 treatment combinations = 42 plants

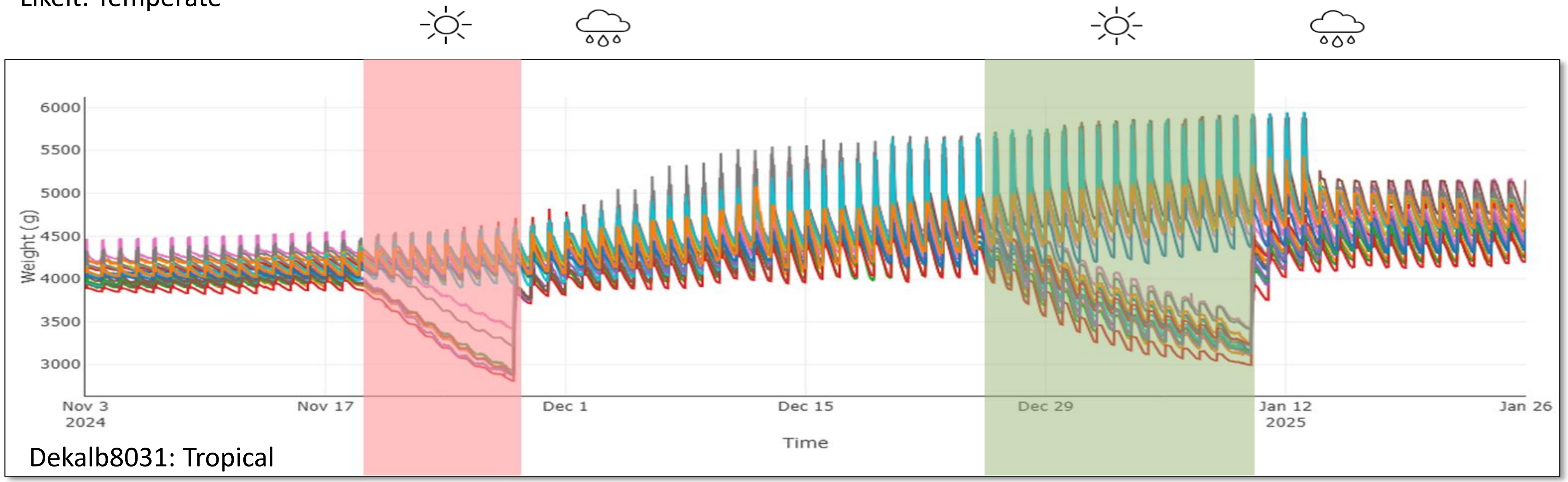
# Experiment Timeline

| Date | Event | Cultivar |
|---|---|---|
| 30-Sep-24 | Sowing BBCH 00 | Both |
| 28-Oct-24 | Transfer to lysimeter BBCH ~13 | Both |
| 18-Nov-24 | 1st drought (DS1) BBCH 15 | Both |
| 27-Nov-24 | Recovery 1 (R1) BBCH 32–33 | Both |
| 05-Dec-24 | 2nd drought (DS2) BBCH 61 | Likeit |
| 17-Dec-24 | Recovery 2 (R2) BBCH 85 | Likeit |
| 19-Dec-24 | 2nd drought (DS2) BBCH 61 | Dekalb |
| 09-Jan-25 | Recovery 2 (R2) BBCH 85 | Dekalb |
| 03-Feb-25 | End of lysimeter phase | Both |
| 06-Feb-25 | Harvest BBCH 89 | Likeit |
| 04-Mar-25 | Harvest BBCH 89 | Dekalb |

# Experiment Timeline

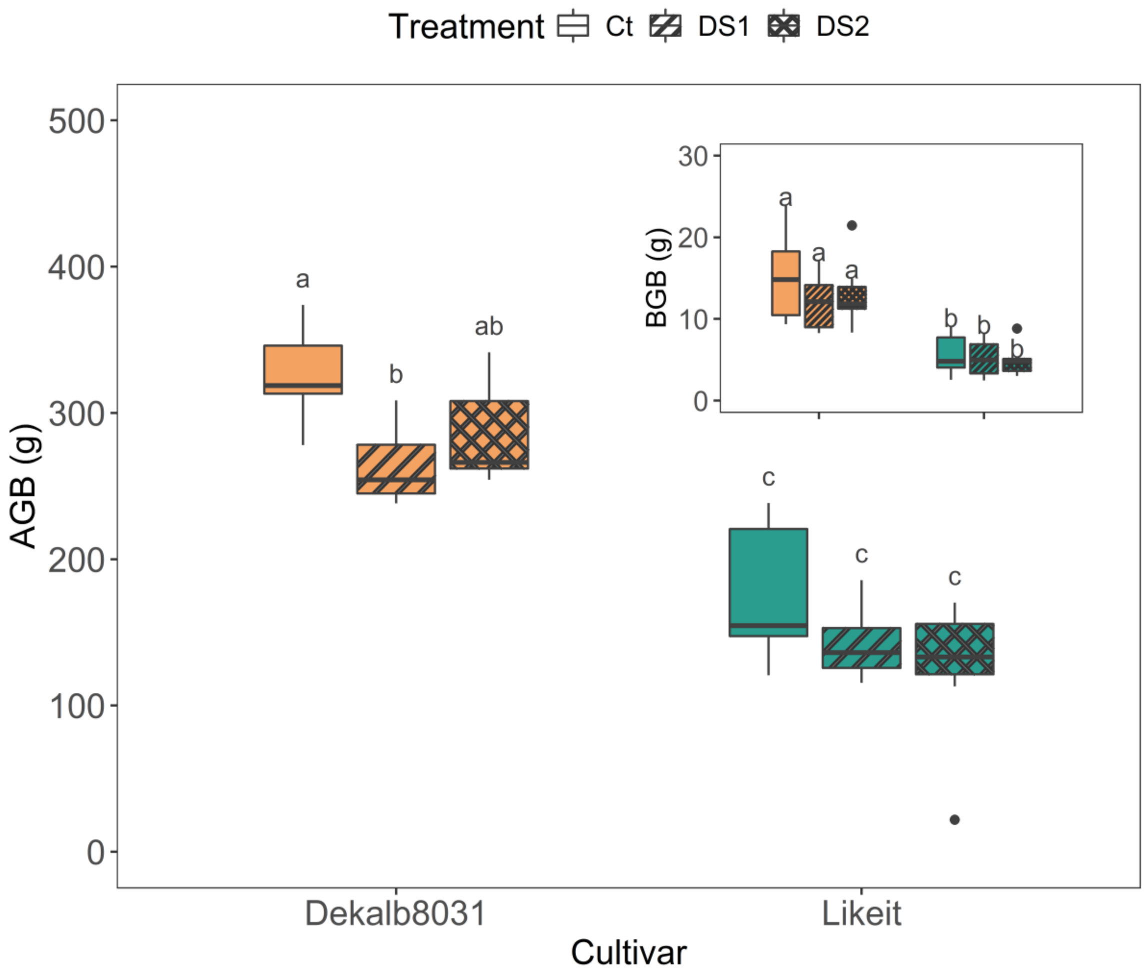


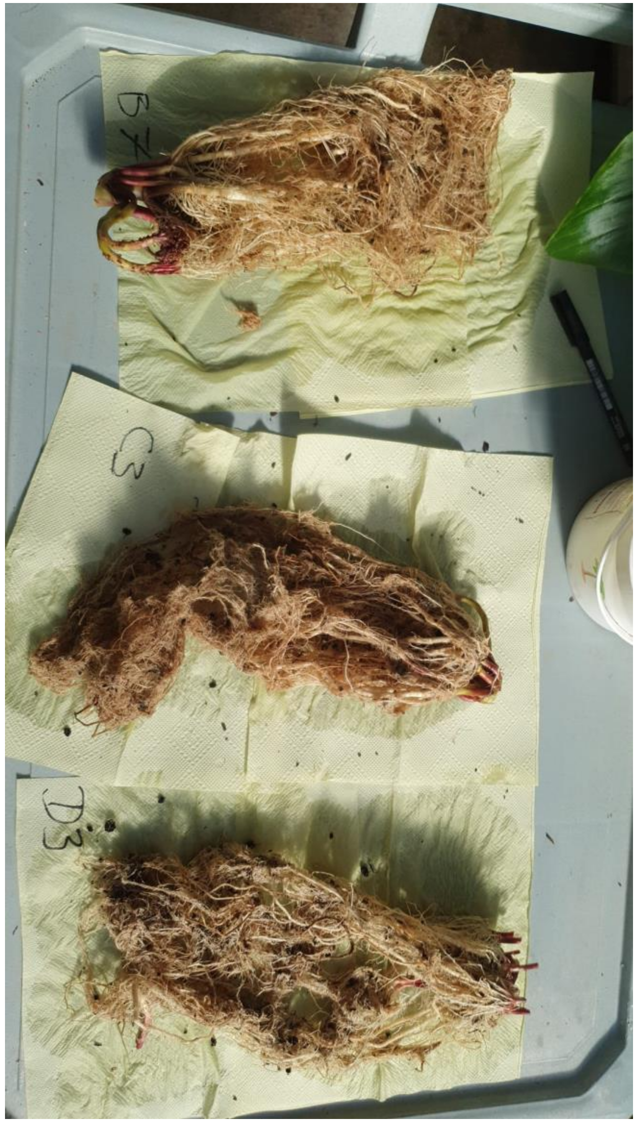

Likeit: Temperate



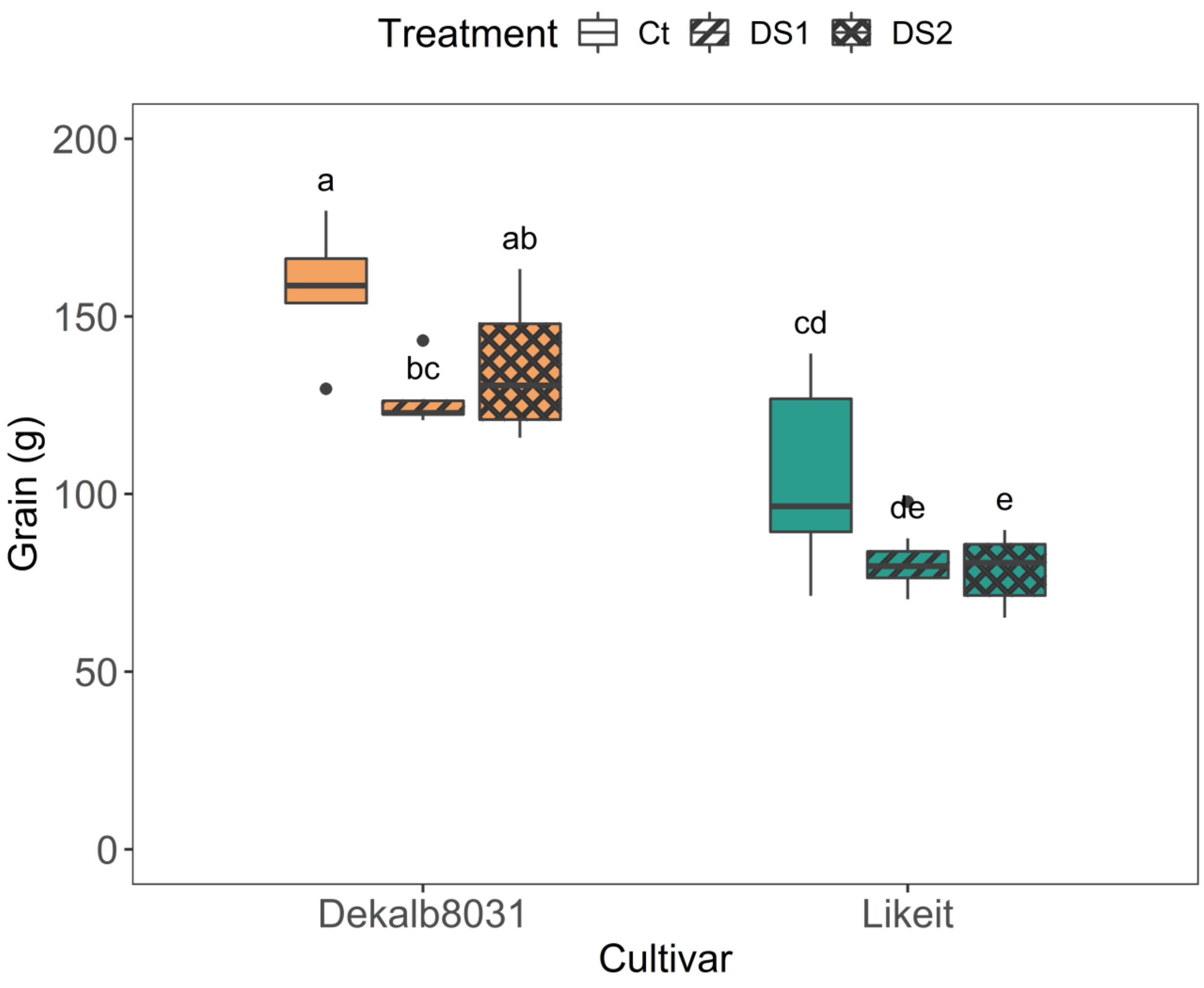

Dekalb8031: Tropical

# Results: Impact of single (DS1) and recurrent (DS2) drought stress on biomass



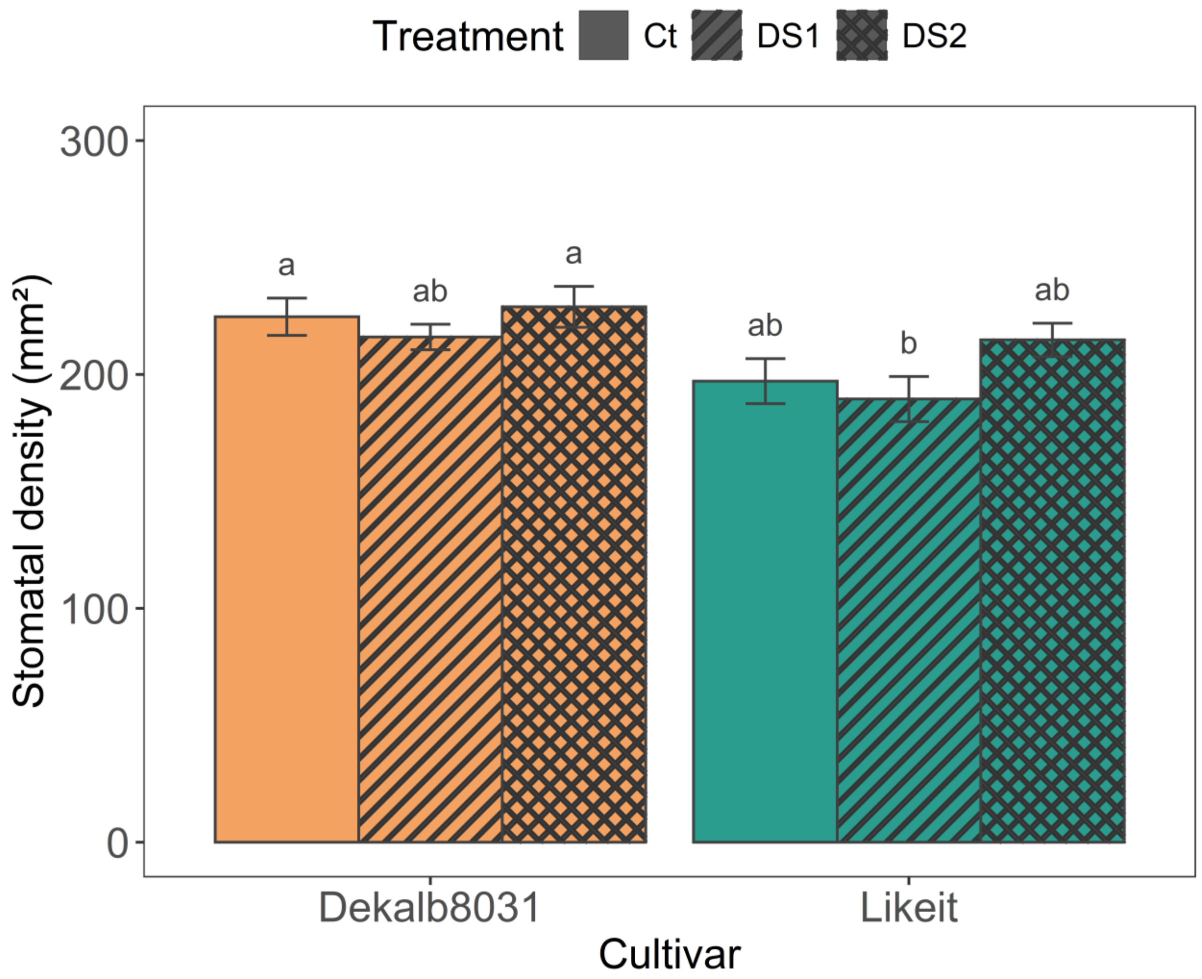



# Results: Impact of single (DS1) and recurrent (DS2) drought stress on grain yield




The total grain weight of one cob/plant

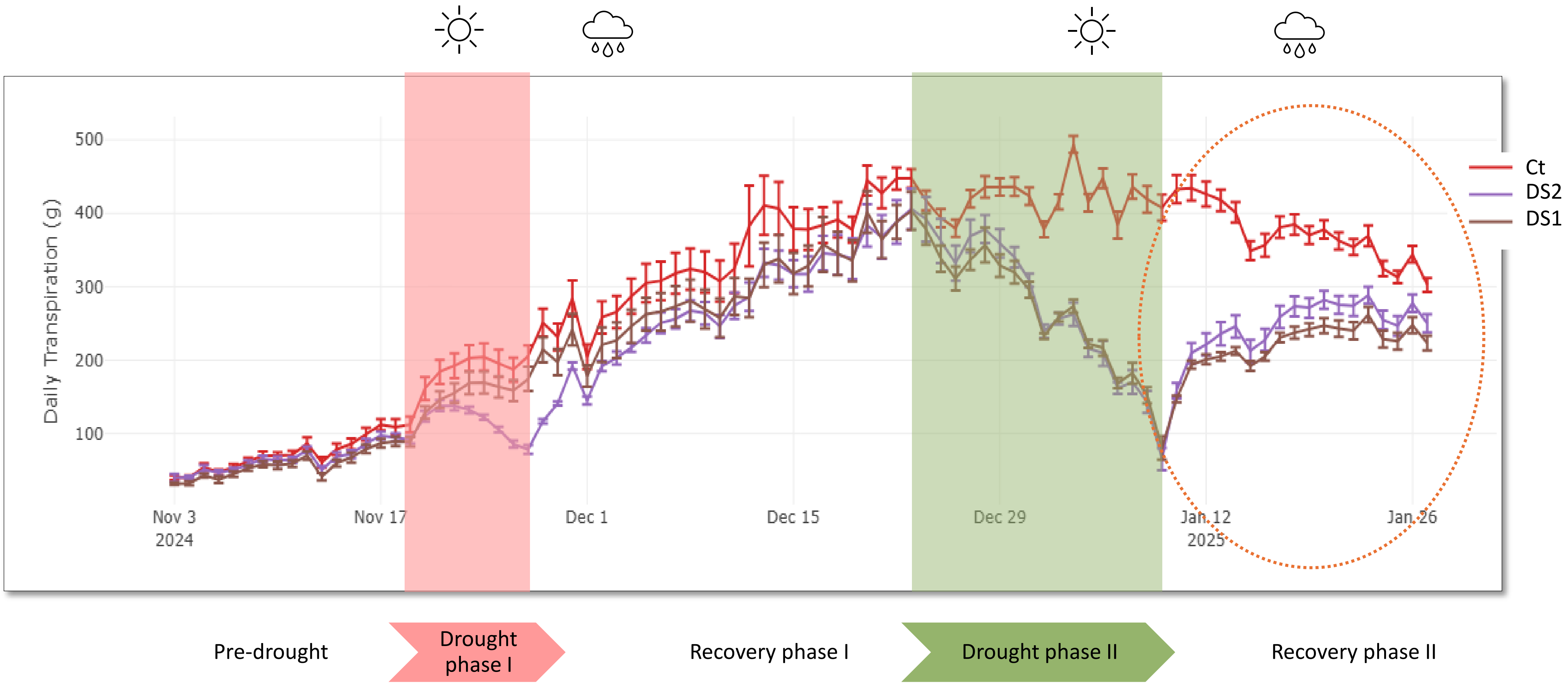
# Results: Stomata density




| Cultivar | Treatment | mean | Tukey |
|---|---|---|---|
| Dekalb8031 | Ct | 224.70 | a |
| Dekalb8031 | DS1 | 216.02 | ab |
| Dekalb8031 | DS2 | 228.92 | a |
| Likeit | Ct | 197.17 | ab |
| Likeit | DS1 | 189.48 | b |
| Likeit | DS2 | 214.78 | ab |

- Stomatal density was calculated as the average number of stomata counted in four microscopic fields per impression, expressed per $mm^2$.

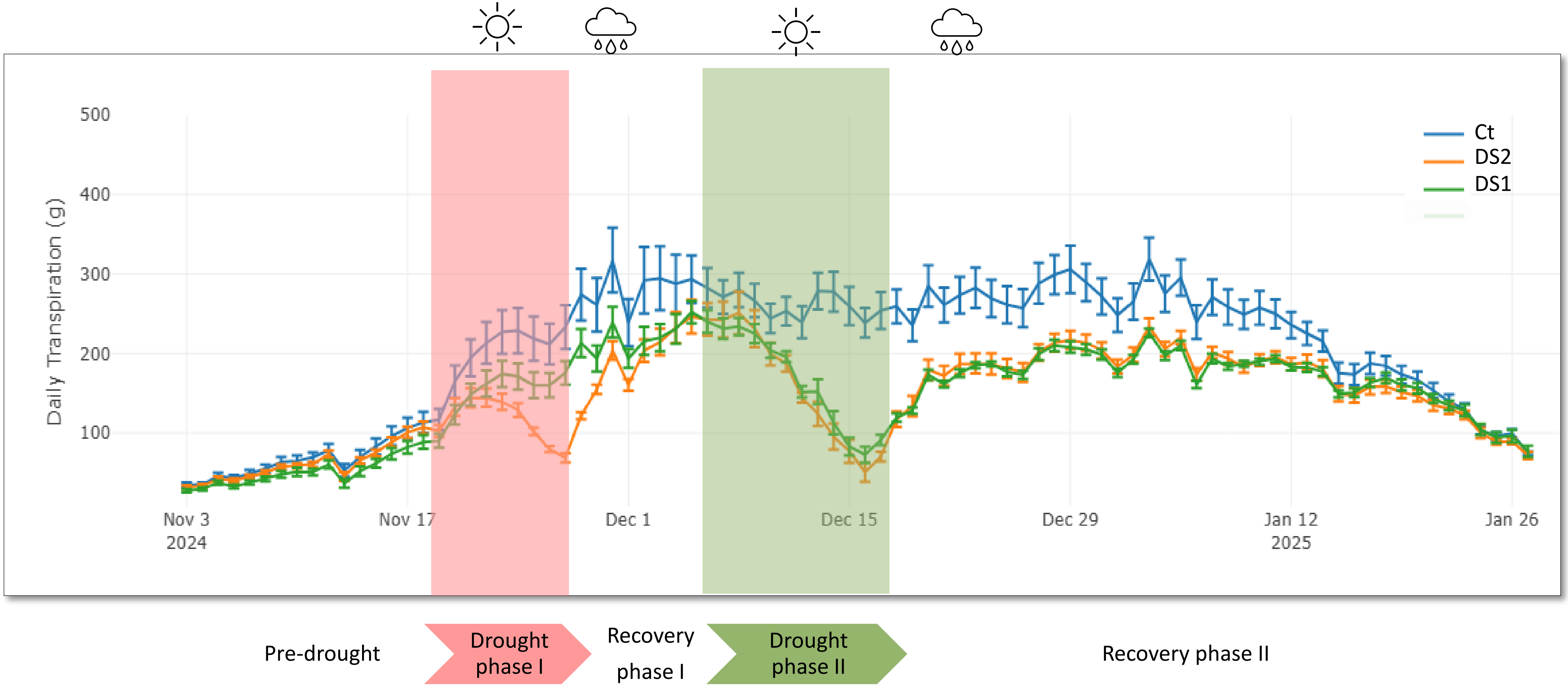
# Results: Transpiration/water use dynamics




Drought phase I: 19-28.11.2024, 9d; Recovery phase I: 29.11.2024-24.12.2024, 27d; Drought phase II: 25.12.2024-09.01.2025, 18d; Recovery phase II: 10-25.01.2025.

Tropical-Dekalb8013

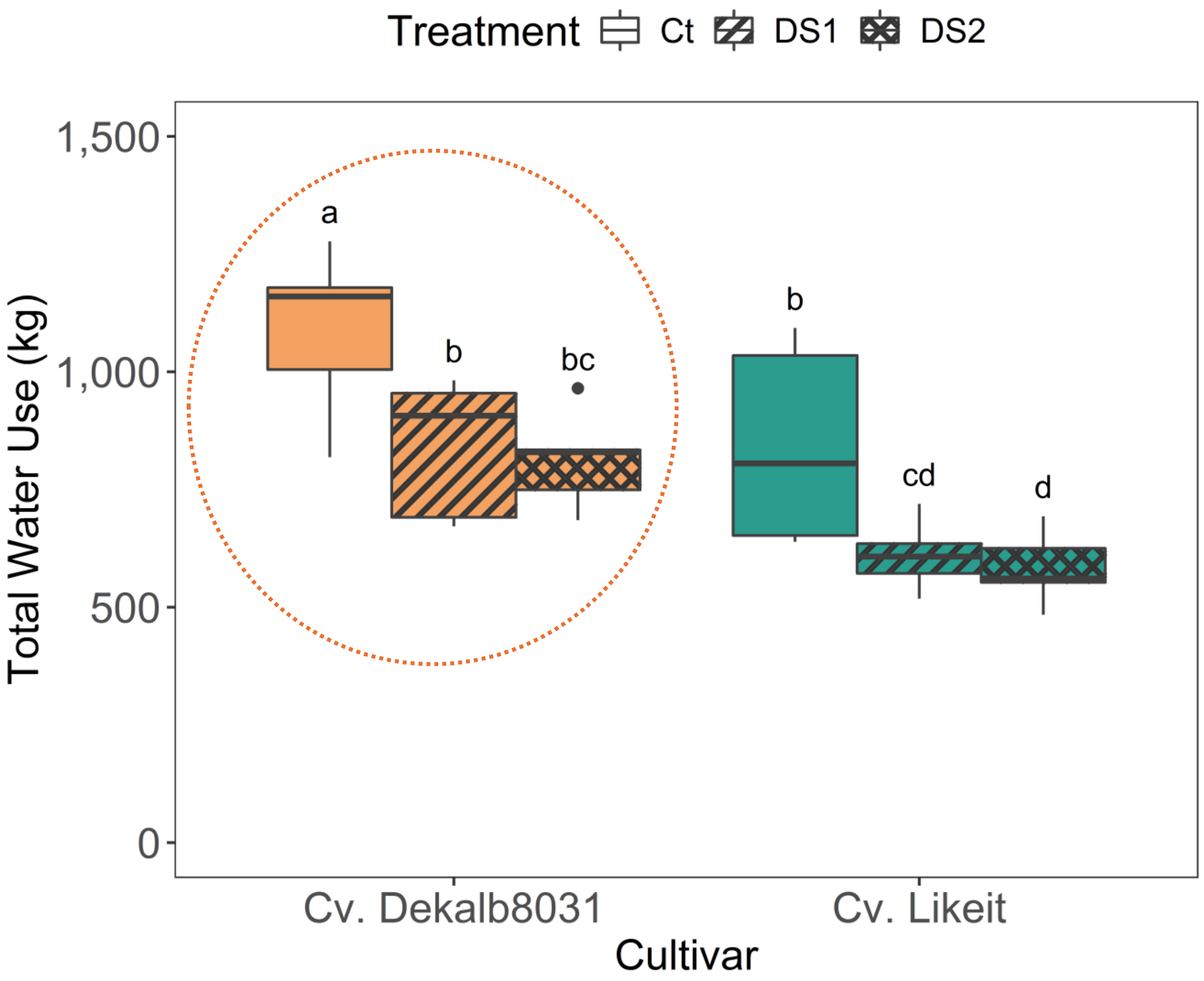
# Results: Transpiration/water use dynamics

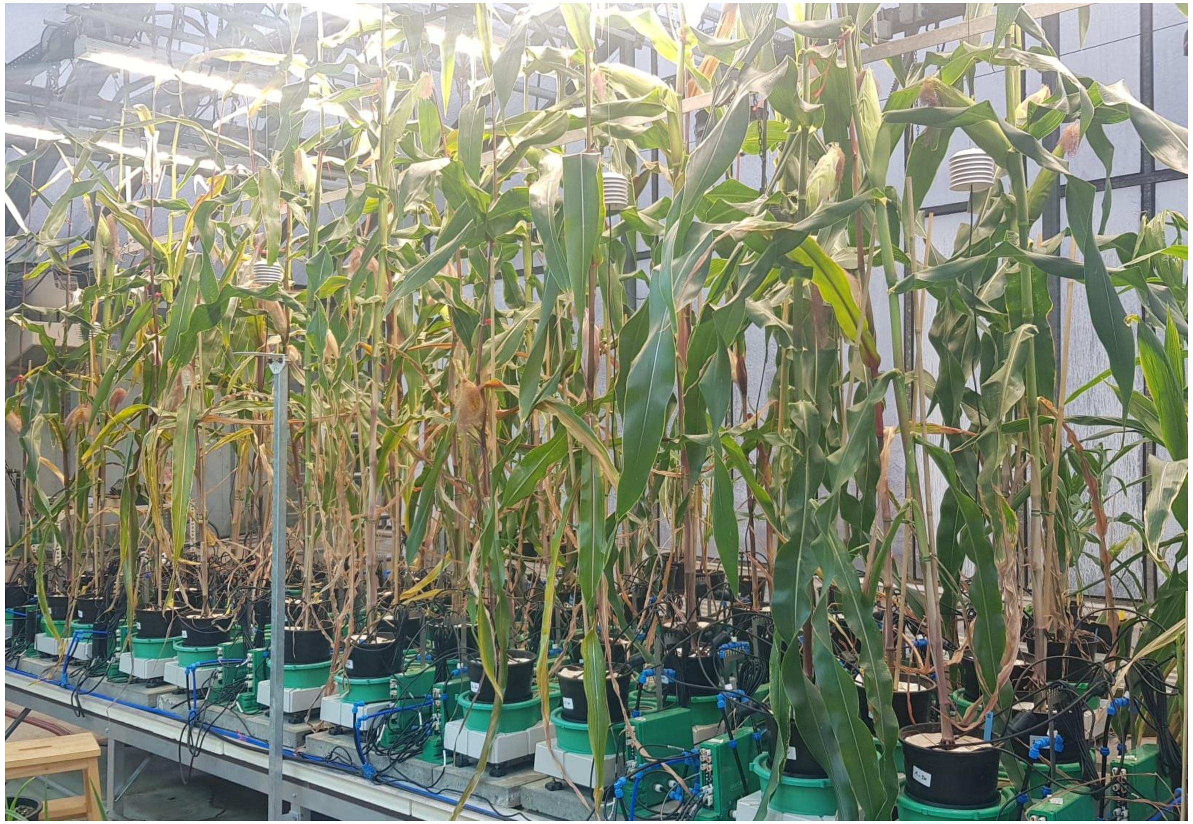



Drought phase I: 19-28.11.2024, 9d; Recovery phase I: 29.11.2024-05.12.2024, 7d; Drought phase II: 06-17.12.2024, 11d; Recovery phase II: 18-24.12.2024.

Temperate-Likeit

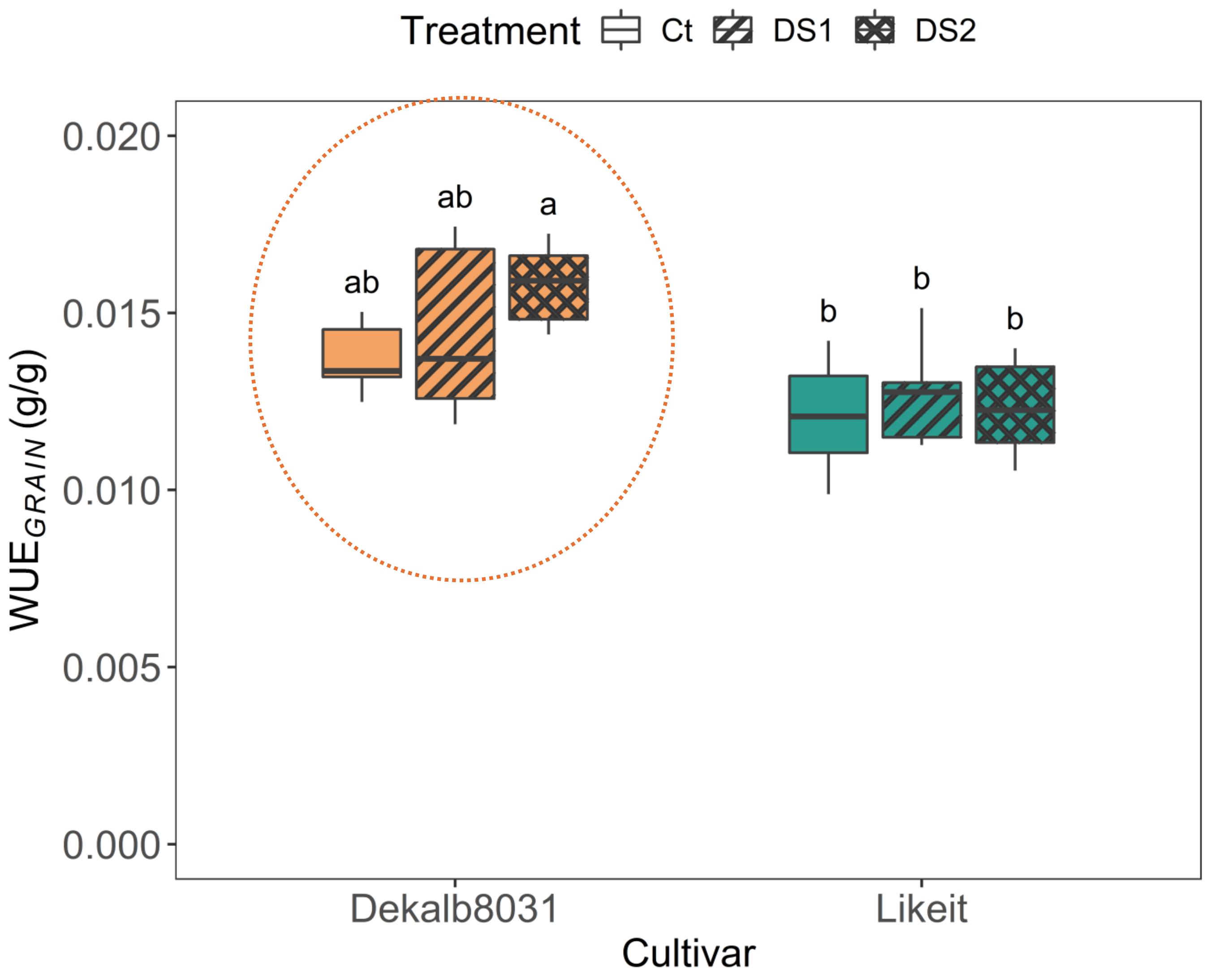
# Results: Total water use and WUE

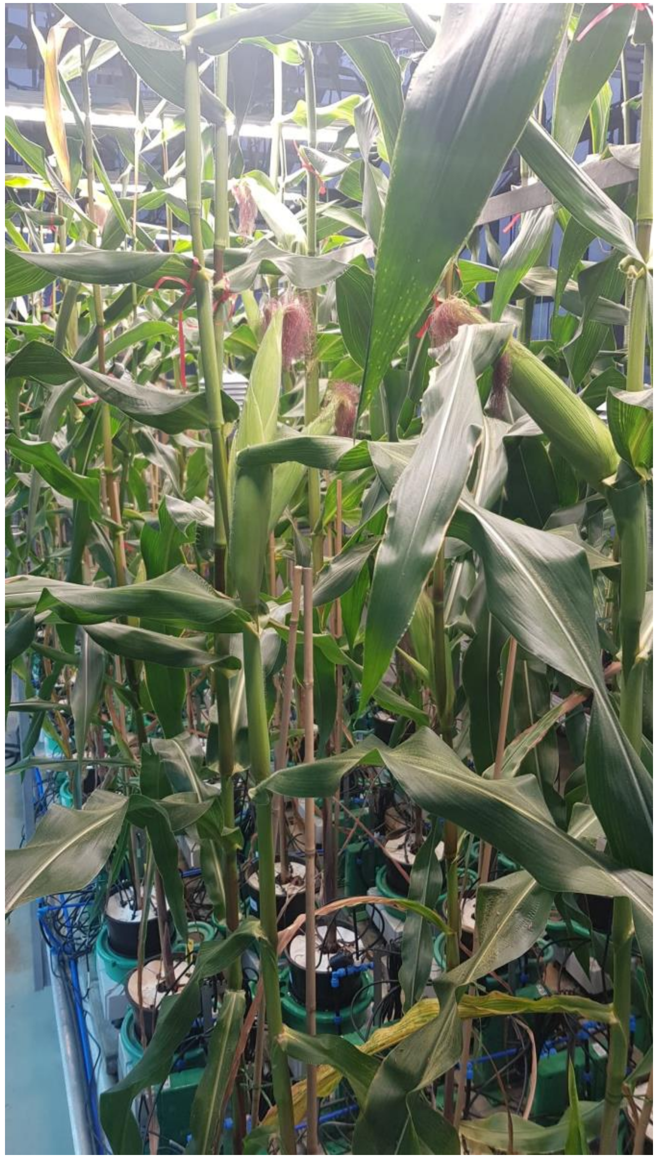


cumulative daily transpiration (-- measured during plants were in the Plantarray)

# Results: Total water use and WUE



The total grain weight of one cob/plant Wue grain (total grain weight/cdt)

# Conclusion and outlooks

Hypotheses:

- H1: Plants that experience drought at vegetative growth stage are more resilient than plants that experience drought only at flowering “Legacy effect”:
  - ❖Yes but the maturity duration could play important role.
  - ❖Longer duration could allow better recovery and better response to recurrent drought

- H2: Drought resilience response to recurrent drought are functional traits (phenology, root, leaf anatomical …) dependent.
  - ❖traits associated with maize plant response to recurrent drought: variations in stomatal density
  - ❖Further analysis (physiological, molecular, metabolomics ongoing: Interdisciplinary approach from MultiStress consortium)

# Conclusion and outlooks

<u>Outlook:</u>

- Biotic (stem borer) and abiotic (water stress) interactions ongoing in the context of MultiStress

- Effect of biochar on water use and drought response in cocoa.

- Water use and drought response study of wheat cultivars from Ethiopia. Toward cultivar selection for climate change adaptation in the highland wheat cultivation systems.