Plant growth adaptation to changing rainfall patterns in a warming climate



1

A Changing World of Rainfall:

Climate change is profoundly transforming global precipitation patterns — extreme downpours and prolonged droughts are becoming the new normal.

2

Stable Totals, Shifting Reality:

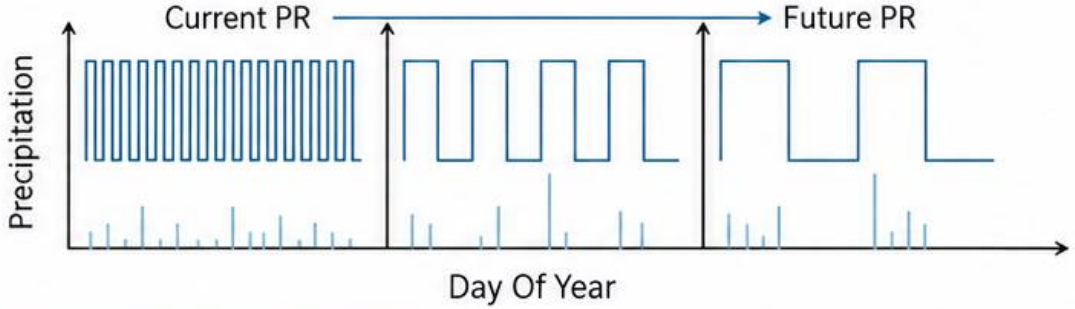
Annual rainfall may stay constant, but its timing and distribution are changing, reshaping water, ecosystems, and agriculture.

3

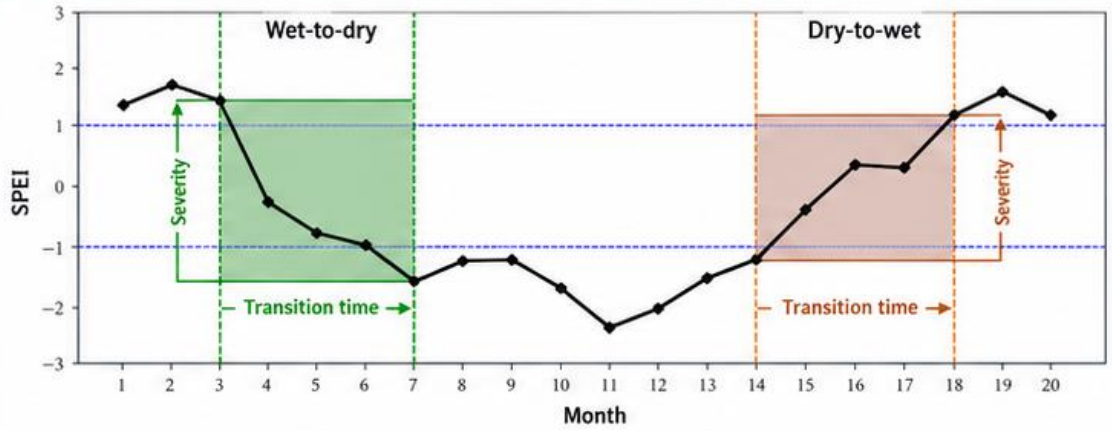
A Chance to Shape the Future:

This transformation offers a unique opportunity for researchers to understand, model, and design sustainable solutions for a climate-resilient world.

From Frequent Rain to More Variable Extremes



Shifting Seasonal Patterns: From Wet-to-Dry to Dry-to-Wet



University of Antwerp
Faculty of Science

IMPRESS

Measurements

Leaf Length Tracking (LLT) System

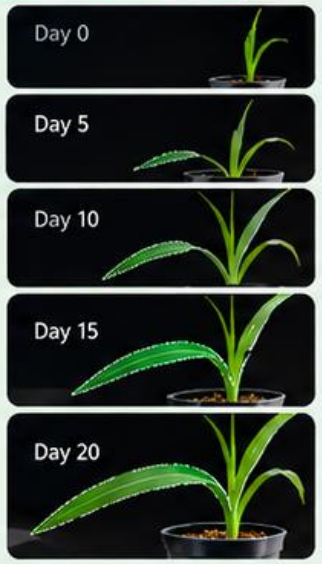
Real-time growth dynamics under alternating drought and flooding

Master Project Opportunity
Work with automated phenotyping and real data!

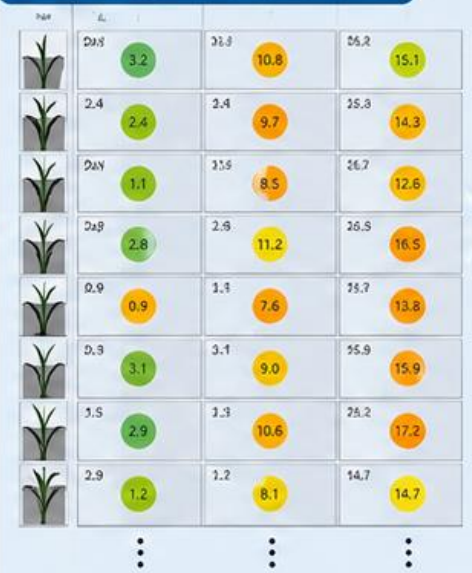


Automated leaf tracking system
Multiple plants monitored simultaneously

Image analysis



Automated measurements



High temporal resolution

Leaf elongation rates are monitored every **5 minutes** using an automated leaf tracking system.

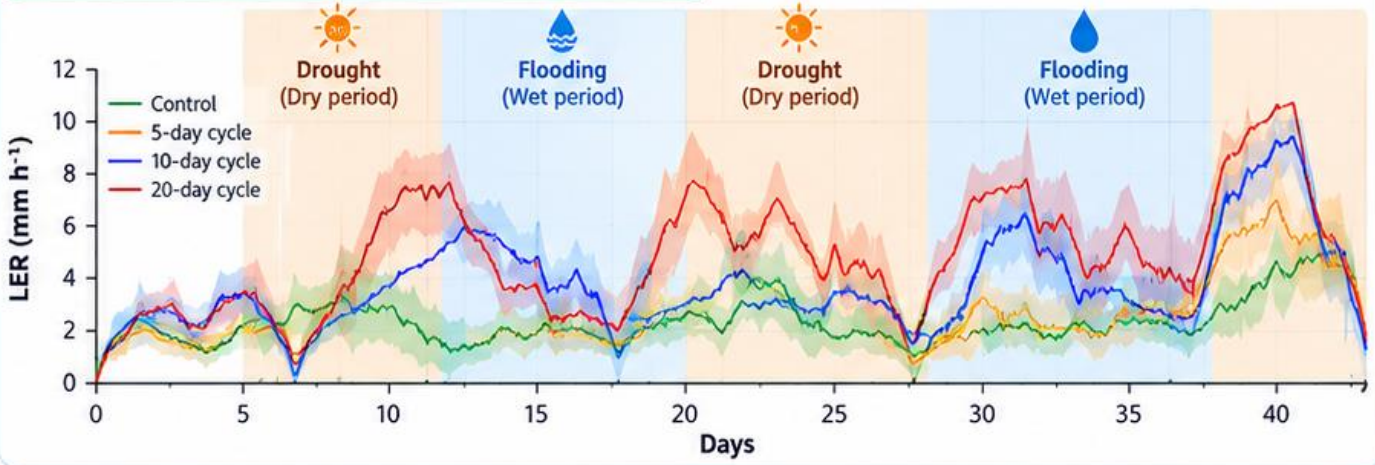
Real-time growth dynamics

Enables detailed analysis of growth responses during **wet-to-dry** and **dry-to-wet** transitions.

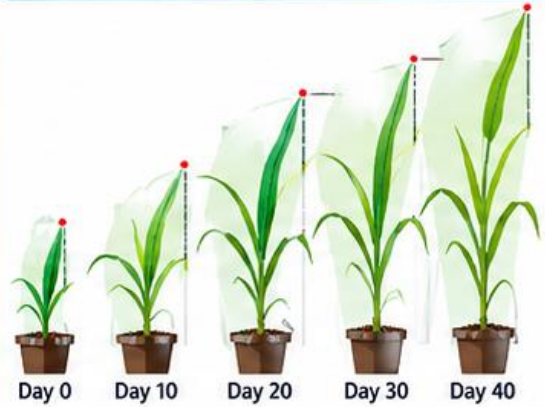
Stress and recovery analysis

Allows precise quantification of stress responses, recovery kinetics, and transitional growth behavior under fluctuating environmental conditions.

Example Output: Leaf Elongation Rate (LER)



What can you learn from LLT data?



- How **leaf growth** responds to alternating **drought and flooding**
- Differences in **growth** dynamics **between stress cycles**
- **Recovery kinetics** after stress
- Relationship between **growth** patterns and molecular/biochemical data (e.g., sulfur metabolism)
- Identify **tolerant phenotypes** with better growth stability

Photosynthesis and Photosystem Efficiency Measurements

How do maize plants maintain photosynthetic performance under alternating drought and flooding?

Master Project Opportunity
Join and work with real data!

1 Gas Exchange Measurements

Real-time photosynthetic performance

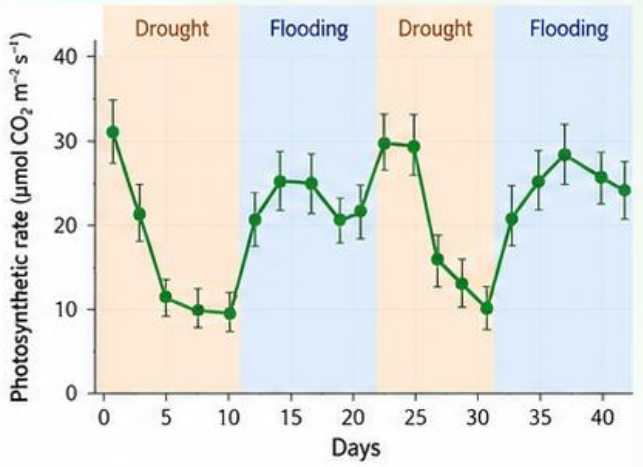
Photosynthetic rate (A), stomatal conductance (g_s), transpiration (E) and respiration rate (R) will be measured using a LI-COR 6400 portable photosynthesis system (LI-COR Inc., Lincoln, NE, USA).

A	Photosynthetic rate	(μmol CO_2 m^{-2} s^{-1})
g_s	Stomatal conductance	(mol H_2O m^{-2} s^{-1})
E	Transpiration rate	(mmol H_2O m^{-2} s^{-1})
R	Respiration rate	



LI-COR 6400
Portable Photosynthesis System

Example Output



What can we learn?

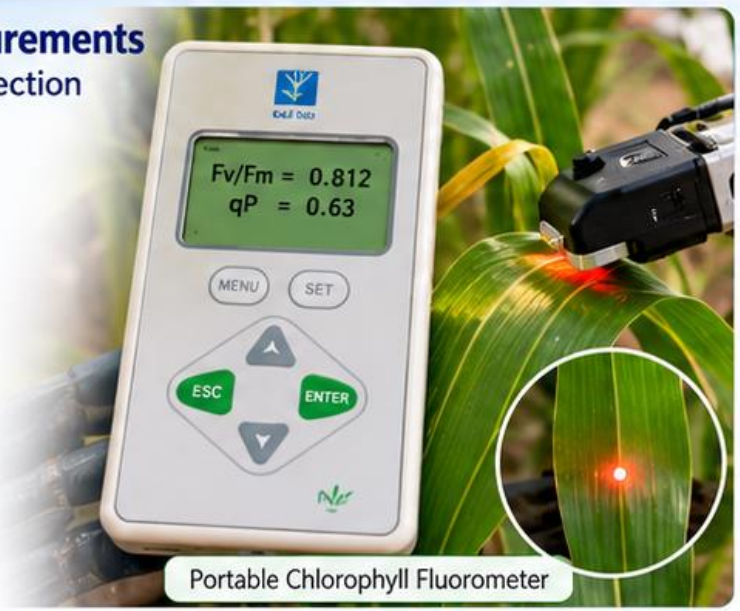
- Changes in photosynthetic capacity under stress
- Stomatal responses to drought and flooding
- Recovery dynamics after stress
- Link with gene expression and metabolic changes

2 Chlorophyll Fluorescence Measurements

Photosystem II efficiency and photoprotection

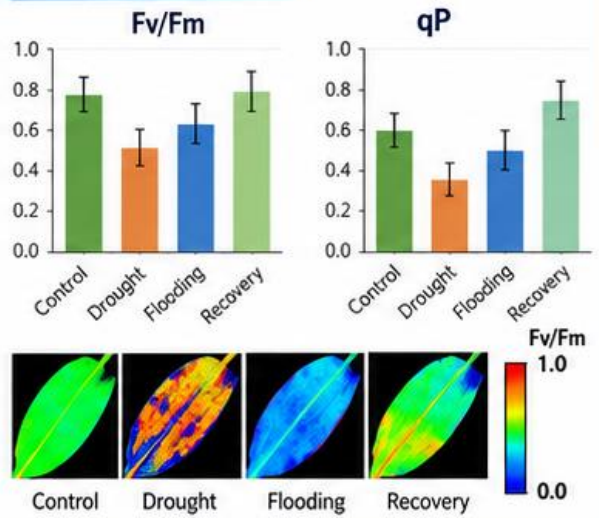
Maximum quantum yield of PSII (Fv/Fm) and photochemical quenching (qP) will be recorded using a portable chlorophyll fluorometer to evaluate photosystem II efficiency and potential photoinhibition under variable water availability.

Fv/Fm	Maximum quantum yield of PSII
qP	Photochemical quenching (PSII regulation)
	Non-photochemical quenching (stress dissipation)



Portable Chlorophyll Fluorometer

Example Output



Why is this interesting?

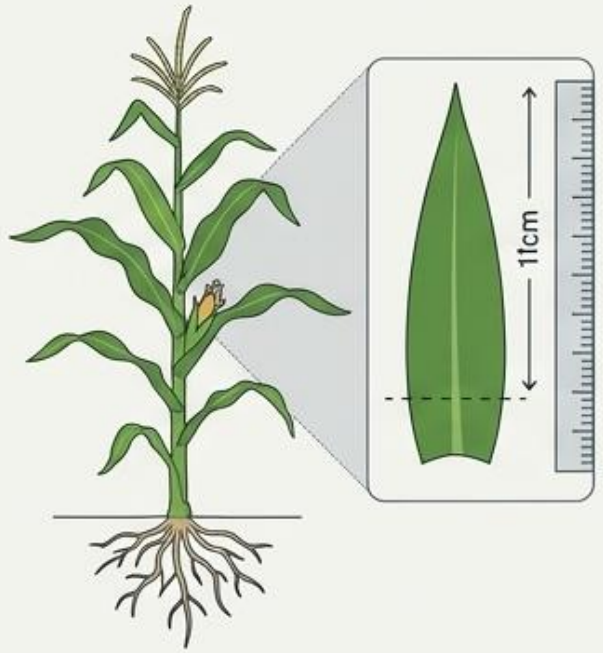
- Understand how PSII responds to alternating drought and flooding
- Identify tolerant and sensitive phases
- Combine physiological and transcriptomic data
- Opportunity to work with advanced instrumentation and real field-relevant questions



Kinematic Analysis: Deconstructing the Architecture of Growth

Visible organ development is merely an illusion. Kinematics link macro-growth directly to microscopic division and elongation rates, revealing exact failure points under fluctuating precipitation.

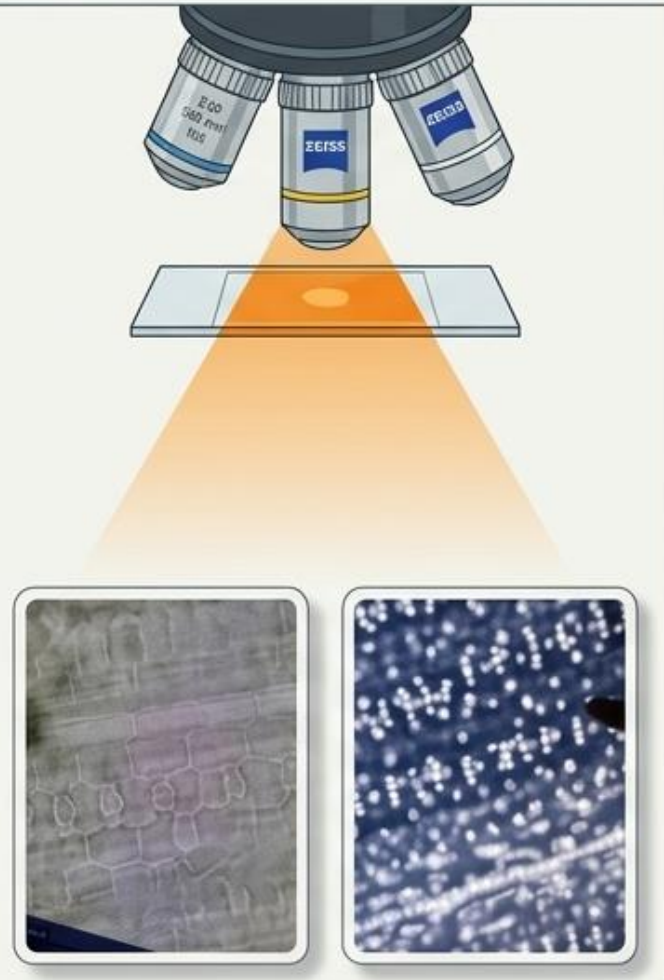
The Organ (Macro)



The Tissue Mount (Meso)



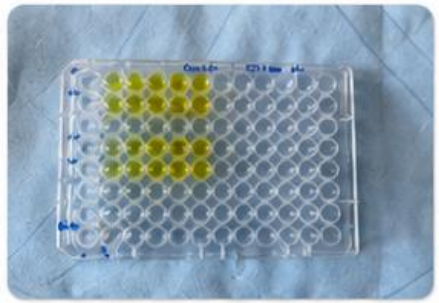
The Cellular Architecture (Micro)

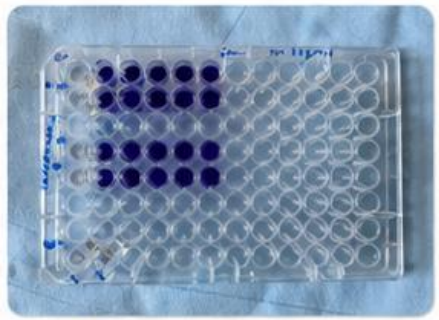


Gemini Notebook

Analysis and Interpretation











01 Physiological and biochemical adjustments

To assess the physiological and biochemical adjustments of plants to changing precipitation regimes, a comprehensive set of **biochemical and metabolic analyses** will be performed.

02 Antioxidant analyses

Quantify **antioxidant enzyme activities** (such as superoxide dismutase, catalase, and peroxidase) as well as **non-enzymatic antioxidants** (flavonoids, phenolics, and FRAP assays).

SOD | Catalase | Peroxidase | Flavonoids | Phenolics | FRAP

03 Metabolic profiling

Examine **carbohydrate metabolism** through the determination of soluble and insoluble sugars, while **hormonal profiling** (e.g., abscisic acid, auxins, cytokinins) and **primary metabolite analyses** will provide further insight into the regulation of stress adaptation and recovery.

Soluble sugars | Insoluble sugars | Hormones (ABA, auxins, cytokinins) | Primary metabolites

Transcriptomic Focus: Sulfur Metabolism

Alternating wet–dry cycles (drought/flooding) in maize

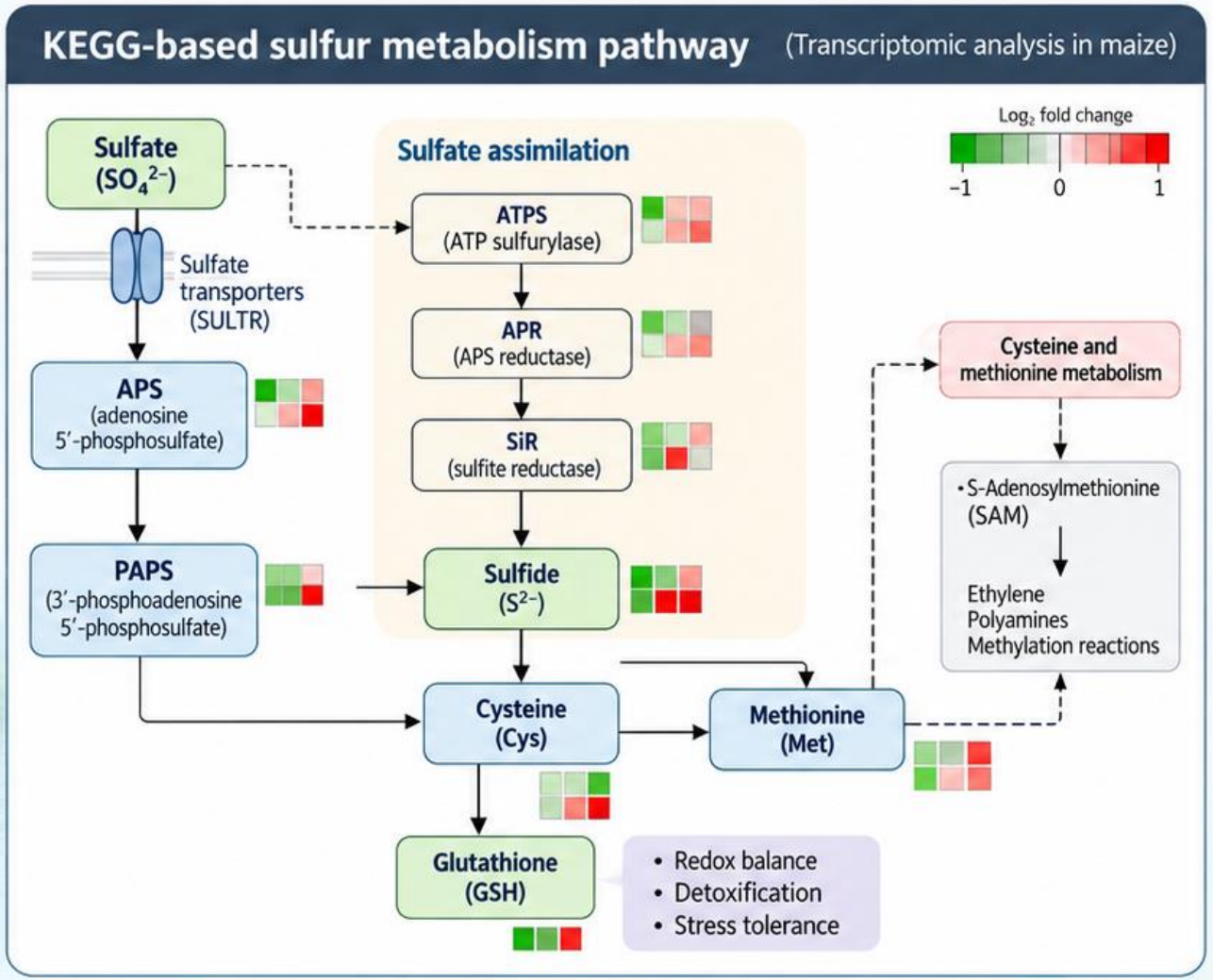
From gene expression to stress adaptation
Uncovering sulfur metabolism for resilient maize



Alternating wet–dry cycles
(drought/flooding)



KEGG-based sulfur metabolism pathway (Transcriptomic analysis in maize)



Sulfate assimilation and gene regulation
Key genes for sulfate uptake, reduction and assimilation.

Cysteine, methionine and glutathione-linked pathways
Central sulfur-containing metabolites for growth and stress response.

Redox balance and recovery
Glutathione-mediated redox homeostasis and protection under stress.

Differential expression during stress cycles
Identify genes and pathways responsive to drought, flooding and post-stress recovery.

Opportunities for MSc students

- **RNA-seq data interpretation**
  Analyze transcriptomic data from wet–dry cycle experiments.
- **Pathway analysis (KEGG / Pathview)**
  Visualize and interpret sulfur metabolism pathways.
- **Linking gene expression with physiology and biochemistry**
  Integrate transcriptomic results with sulfur content, GSH levels and stress indicators.
- **Discovering recovery-related candidate genes**
  Identify key regulators for stress resilience in maize.

Towards stress-resilient maize | Understanding sulfur metabolism to support adaptation to alternating drought and flooding

From Transcriptomics to Functional Validation

The next step in sulfur metabolism research under alternating wet–dry cycles in maize

Current stage

Transcriptomic discovery of sulfur-related genes and pathways



RNA-seq



Candidate genes and pathways

Functional validation workflow (integrating genetics, physiology and NGS)

1 Candidate genes

Identify key sulfur-related genes from RNA-seq



SULTR
ATPS
APR
SiR
...



Select high-priority candidate genes

2 Mutant studies

Test gene function using selected mutants



Wild type (WT)

Mutant (ko/knockdown)

3 Feeding experiments

Apply sulfur-related compounds to probe stress responses



Sulfate
Cysteine
Methionine
GSH
...



Dry (drought)

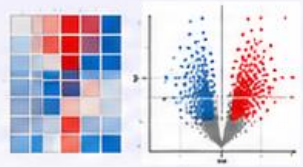
Wet (flooding)

4 NGS in mutants

Use NGS to reveal molecular mechanisms of stress adaptation and recovery



RNA-seq / Multi-omics



Compare WT and mutants under dry and wet conditions

From gene discovery to mechanistic understanding of stress resilience

What will this reveal?

- Functional roles of sulfur-related genes
- How sulfur metabolism supports drought/flooding resilience
- Mechanisms of stress recovery
- Links between gene function, physiology and biochemistry

Opportunities for MSc students

- Work with mutants and comparative phenotypes
- Contribute to feeding experiments
- Analyse NGS / RNA-seq data
- Link molecular, physiological and biochemical responses

University of Antwerp
Faculty of Science
Plant and Vegetation Ecology

IMPRES
INTEGRATED MAIZE PRODUCTION FOR A SUSTAINABLE SOCIETY