

Unraveling the Nonlinear Dynamics of Photosynthesis and Fluorescence under Stress

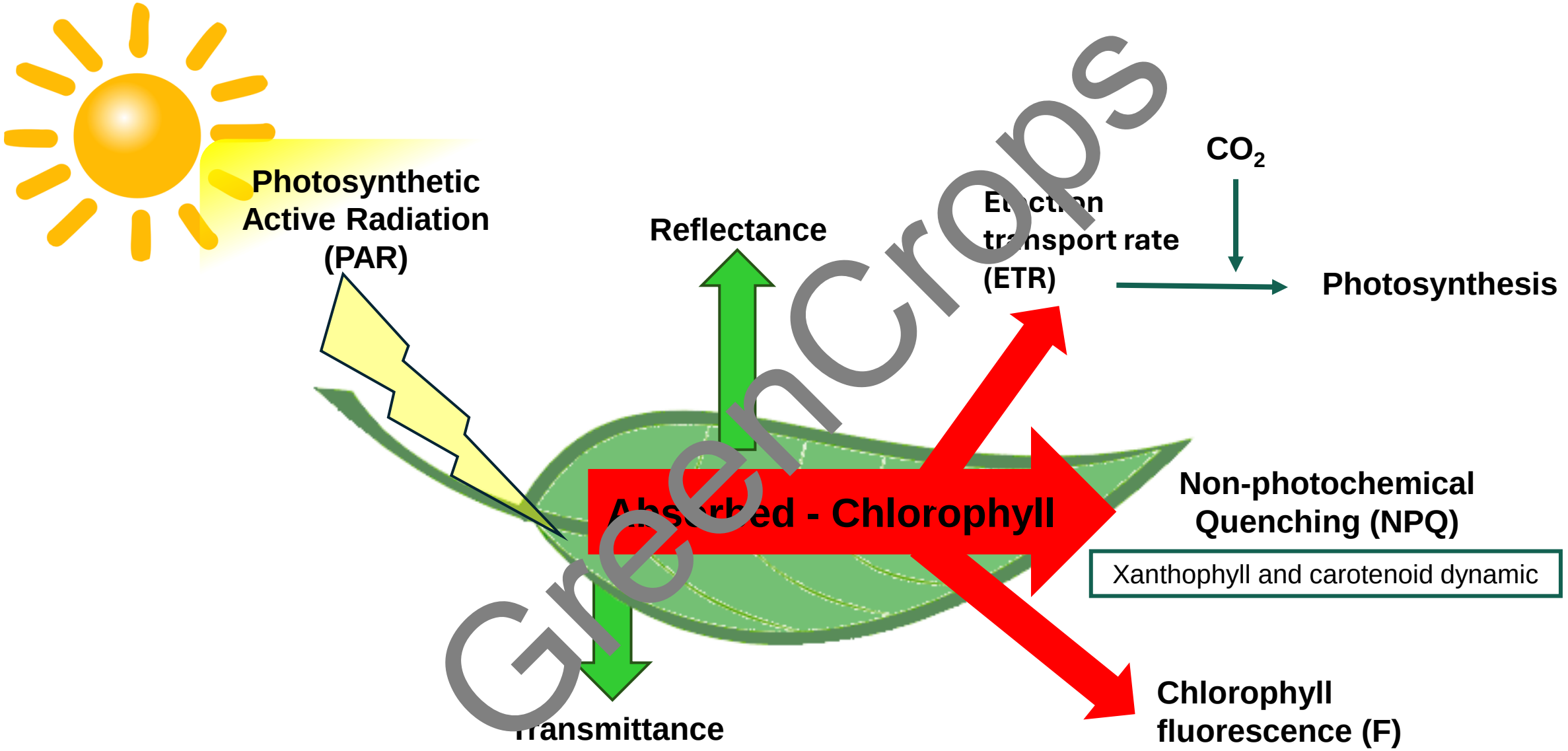
Cynthia Chardí-Raga, M. Pilar Cendrero-Mateo

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Plan de Recuperación, Transformación y Resiliencia
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https://stockcake.com/i/sunlit-green-fields_553857_590858

Photosynthesis and Light Reactions



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Mission FLEX

Earth Explorer mission to observe vegetation fluorescence

- Photosynthesis rate
- Early stress detection

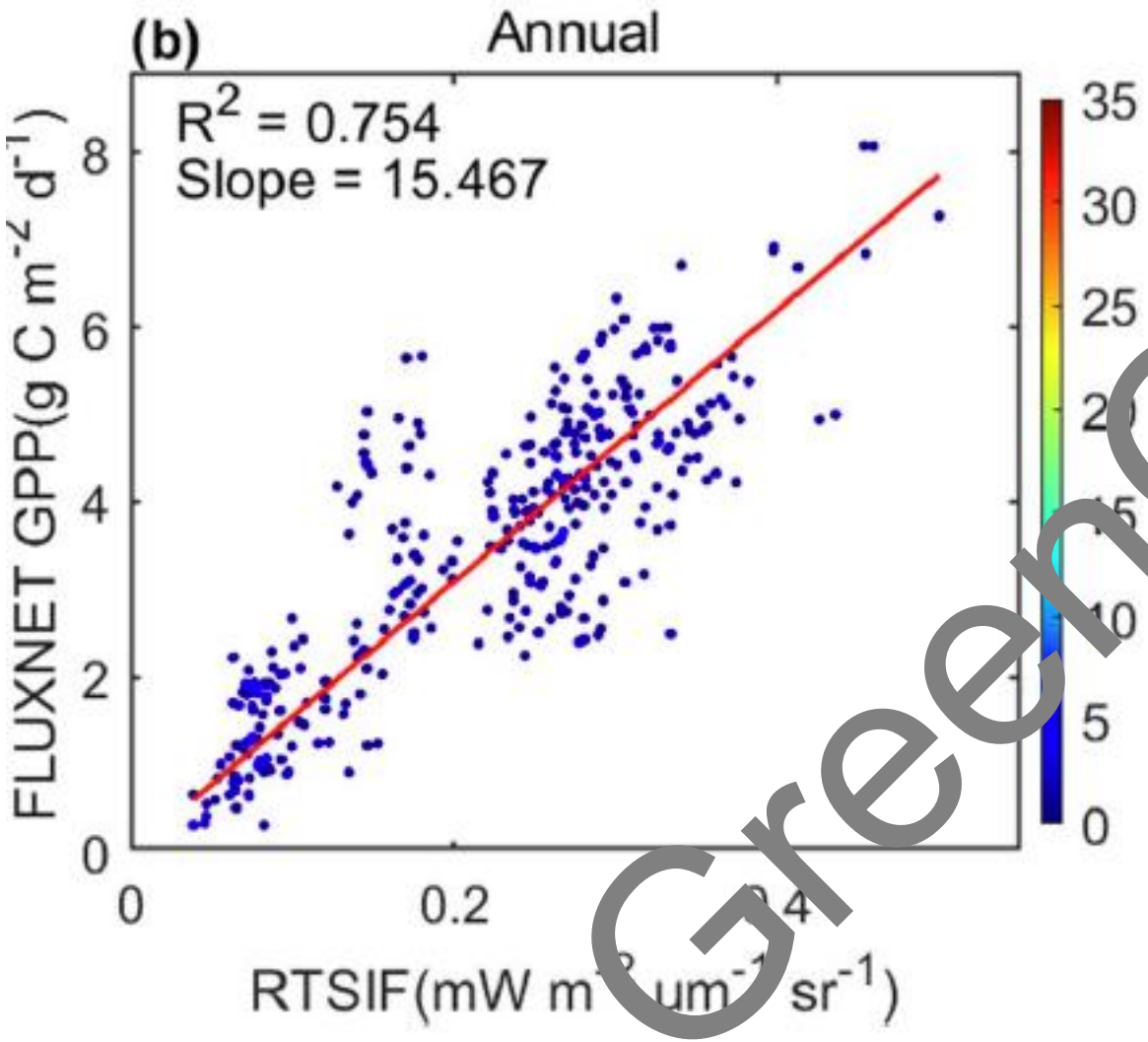
SpaFLEXCal/Val

The **LEO group** leads the Spanish Cal/Val activities.



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SIF | GPP trends some literature examples

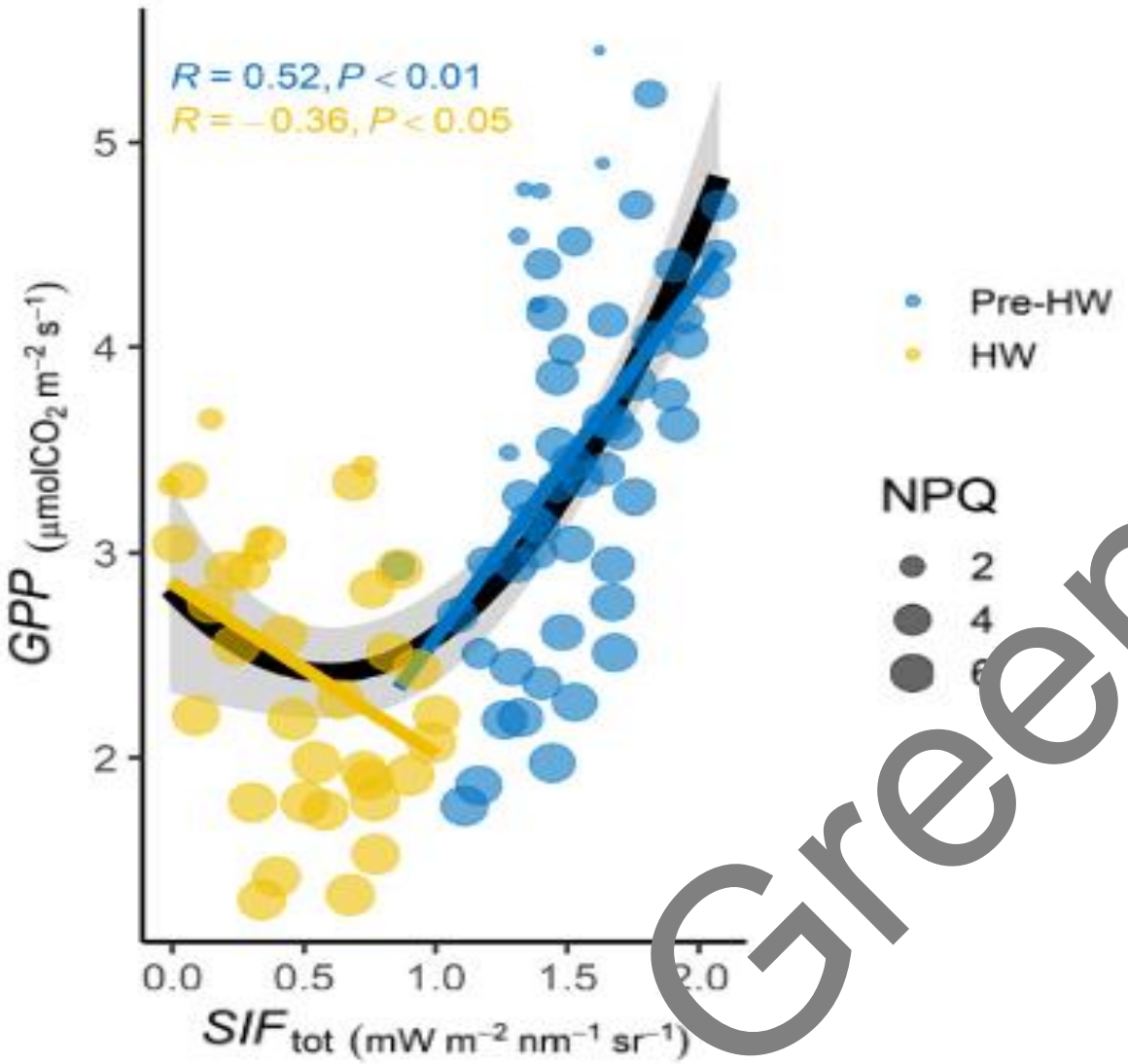


- Annual/Seasonal.
- Linear relationship.
- Driven by **long-term seasonal changes** link to pigment pools.

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Ref: Chen et al.2022.Scientific data

SIF | GPP trends some literature examples

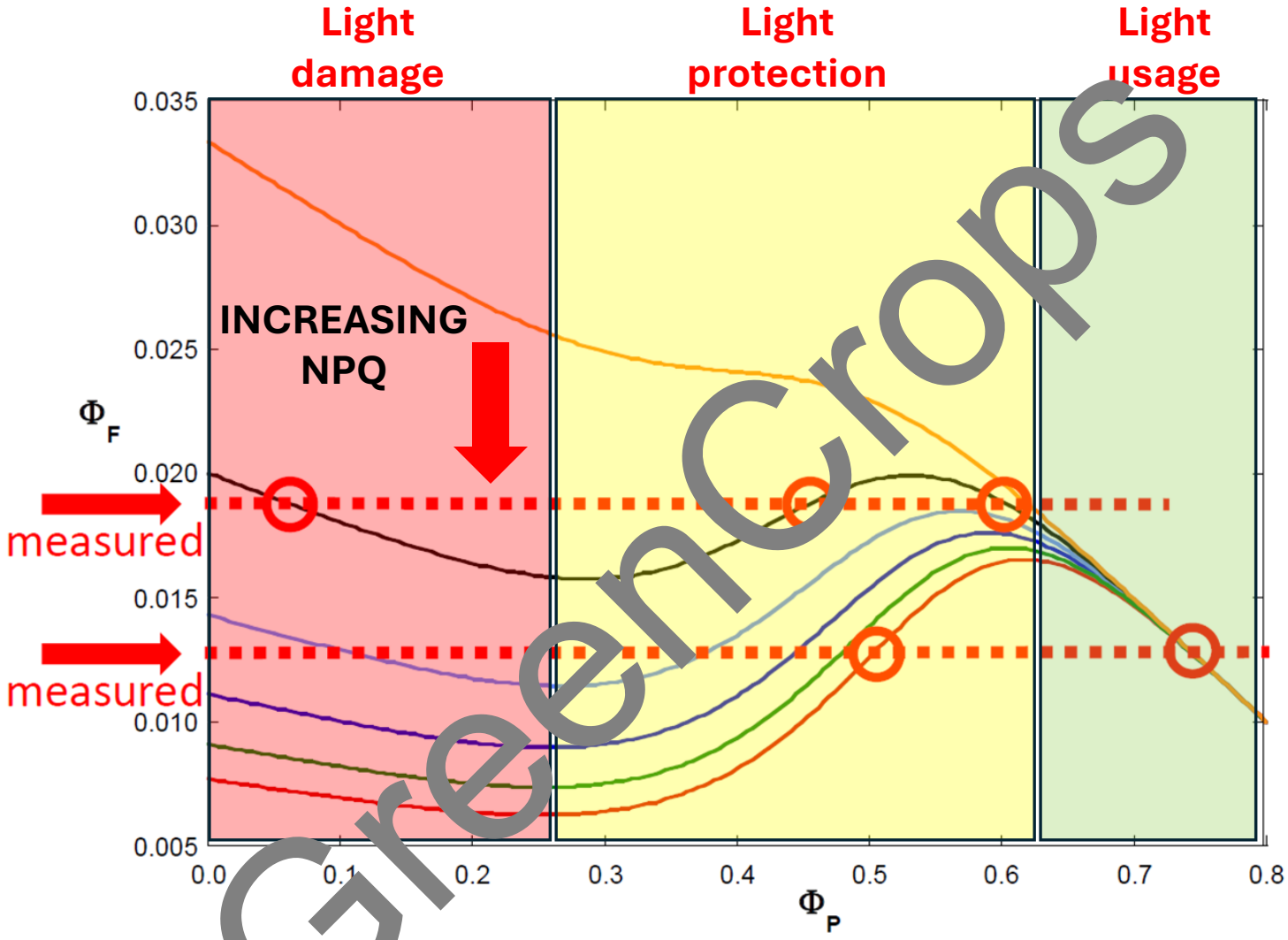


- Daily.
- Non-Linear relationship.
- Driven by dynamic changes in the **light reaction** energy dissipations pathways.
- Link to **short term changes** in PAR, temperature, and water/nutrients availability.

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Ref: Martini et al.2022. New Phytologist

Relationship between fluorescence and photosynthesis



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Additional information is needed to disentangle the ambiguity

Research question

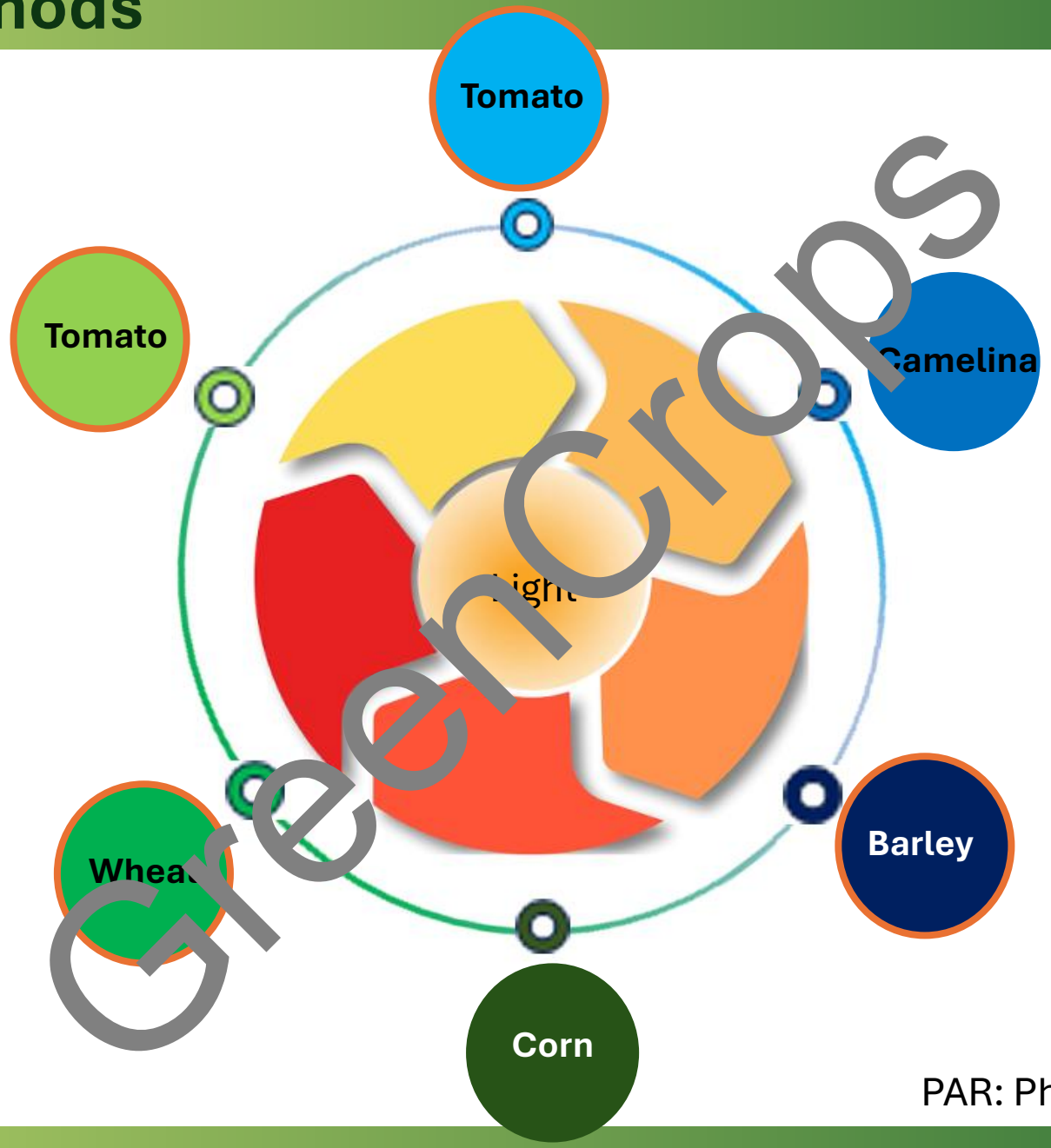
- **Stress factors** play **key role** in the **fluorescence** and **photosynthesis relationship**.

- This study aims to **parameterize and model** the dynamic relationship between **fluorescence and photosynthesis** to enhance **SIF FLEX** interpretation for **early stress detection**.

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Materials and Methods

- Low PAR
- Intermediate PAR
- High PAR
- Drought
- Nitrogen Def.
  - LOW
  - MEDIUM
  - HIGH



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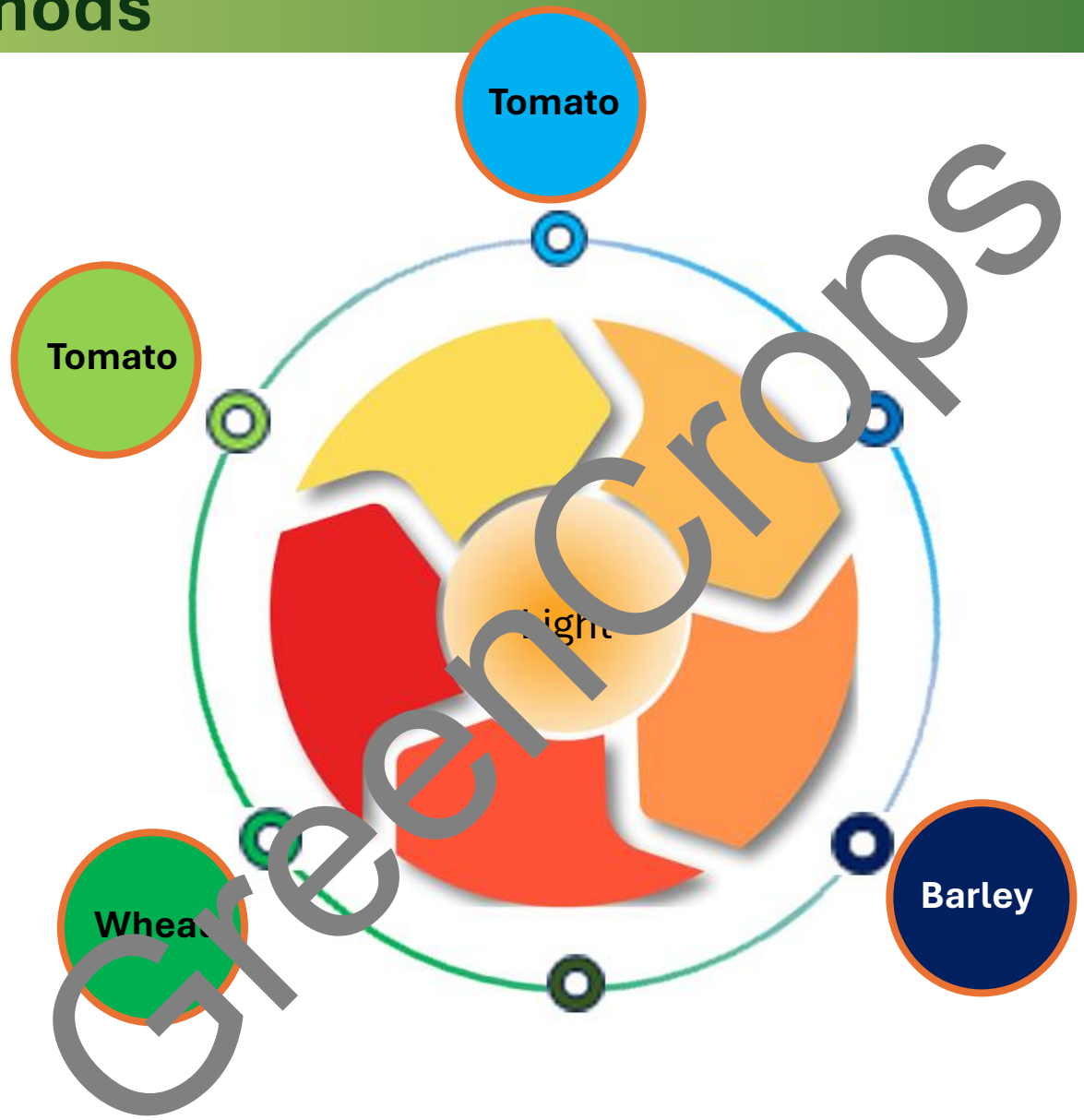
Species

- *Solanum lycopersicum*
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- *Camelia sativa*
- *Hordeum vulgare*
- *Zea mays*
- *Triticum aestivum*

PAR: Photosynthetical active radiation

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PAR: Photosynthetical active radiation

Materials and Methods



https://www.licor.com/

Licor 6400 | Light Curves

PAR range **0-1800 (µmol $m^{-2}s^{-1}$)**

Measured parameters:

- Net photosynthesis (**Anet**)
- Stomatal conductance (**gs**)
- Electron transport rate (**ETR**)
- Fluorescence quantum efficiency (**ΦPSII**)
- Steady-state fluorescence (**Fs**)
- Non-photochemical quenching (**NPQ**)

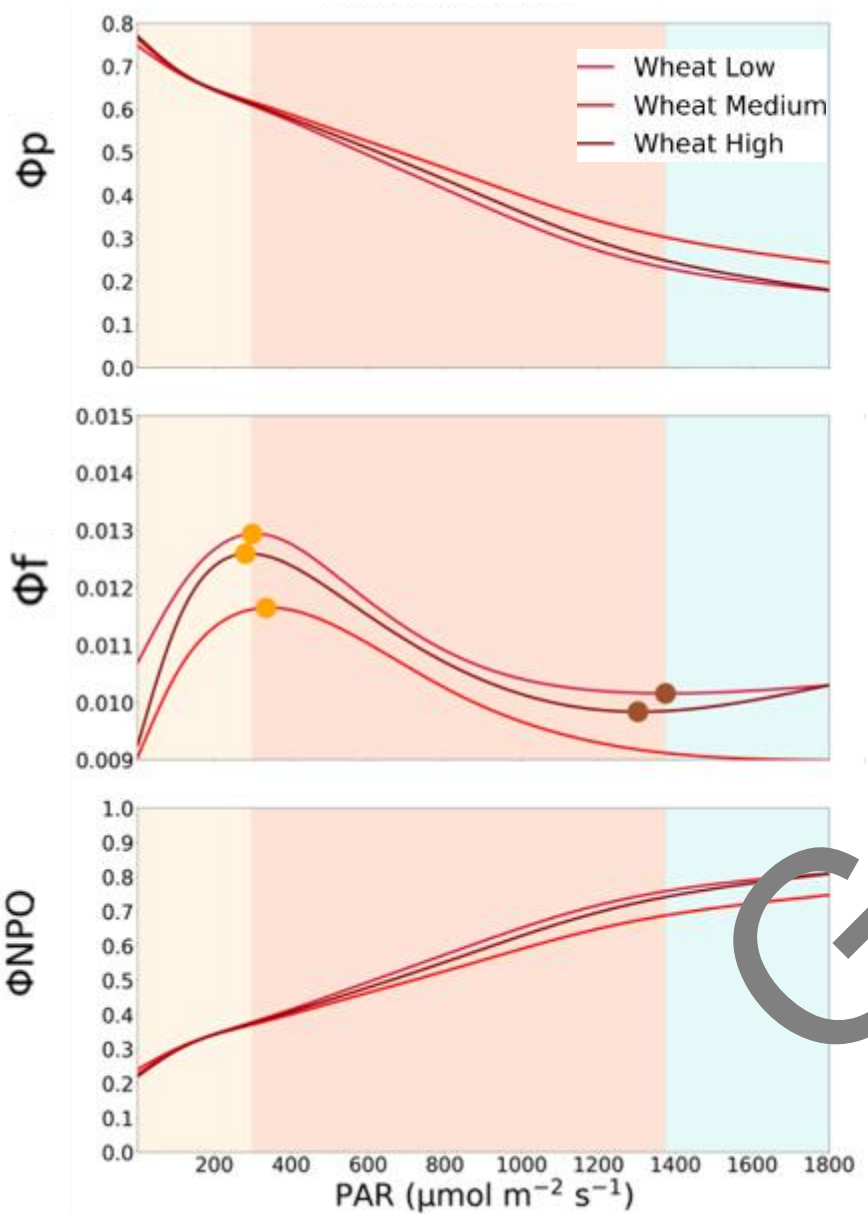
Derived parameters:

- Photosynthetic quantum yield (**ϕp**)
- Fluorescence quantum yield (**ϕf**)
- NPQ quantum yield (ϕ_{NPQ})

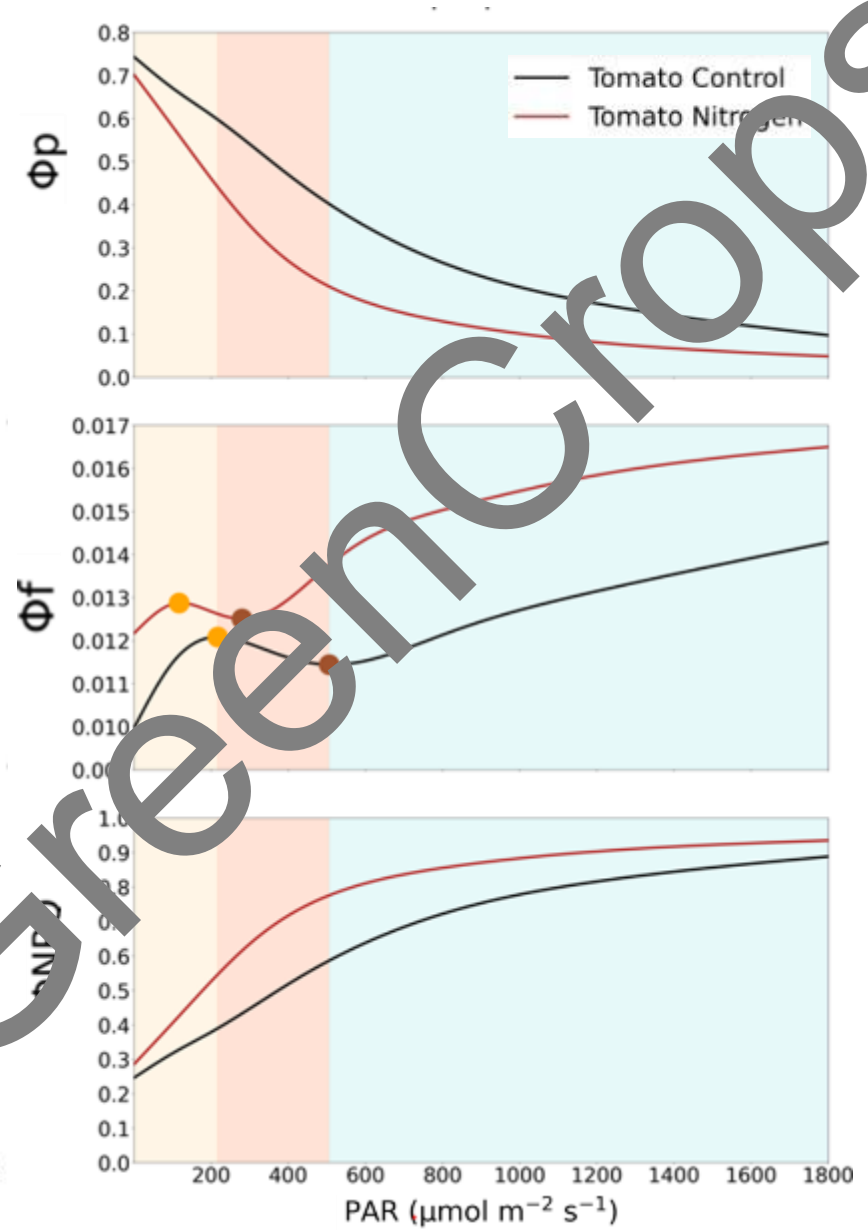
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Results | Nitrogen deficit

Wheat | Nitro | PAR high



Tomate | Nitro | PAR low



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Clear **differences** between treatments and growing light conditions.

- **Treatments**
  - **ϕp**-control > **ϕp-stress**
  - **ϕf**-control < **ϕf-stress**
  - **ϕNPQ**-control < **ϕNPQ-stress**

- **Growing light conditions**
  - **High PAR**

    Phase I and II > Phase III
  - **Low PAR**

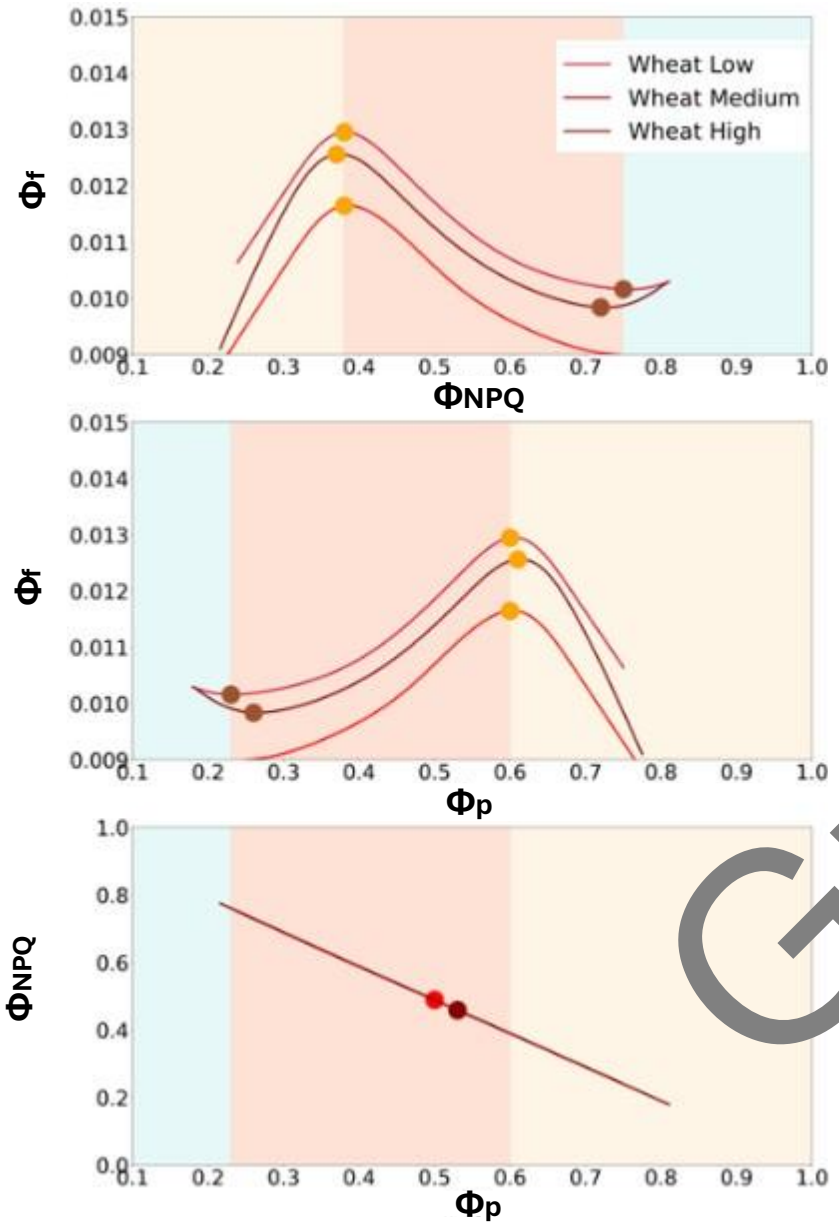
    Phase I and II < Phase III

Phase I
Phase II
Phase III

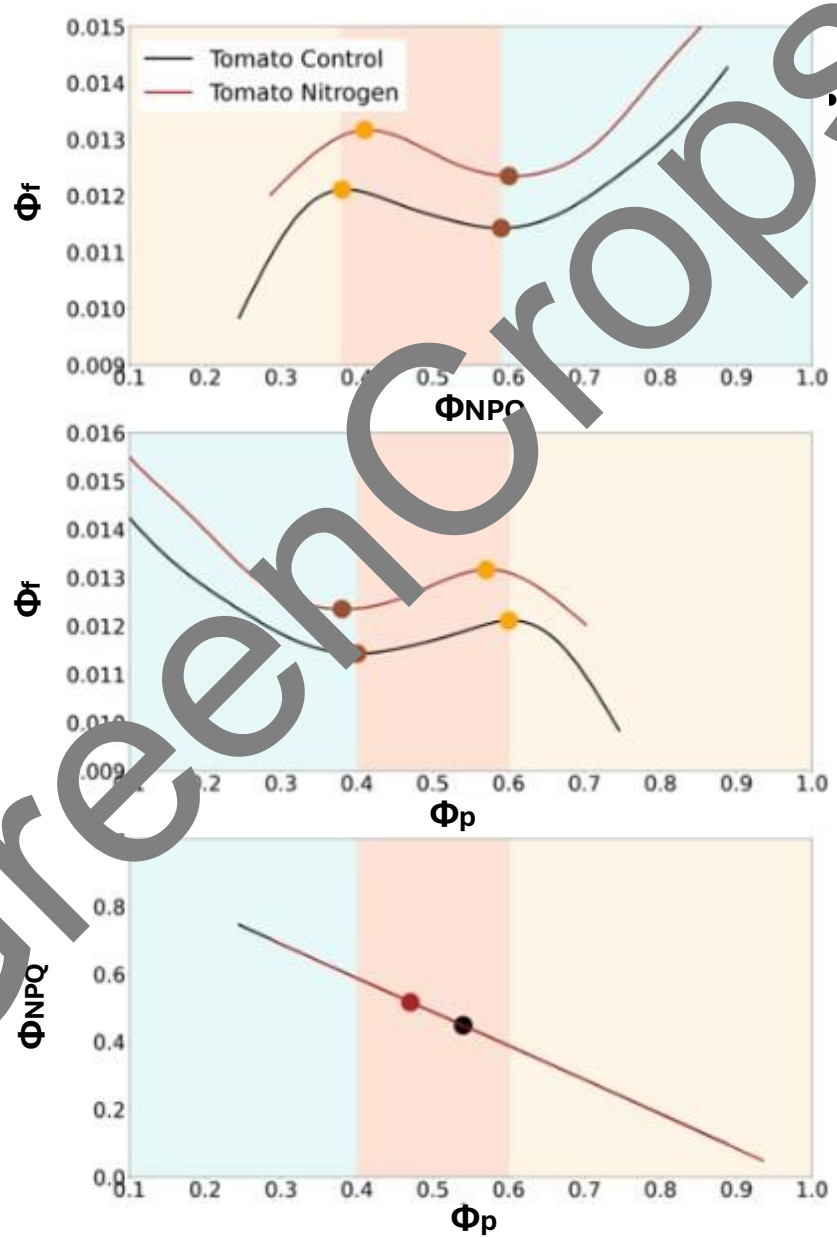
(*) Phases delimited based on light curves first derivative.

Results | Nitrogen deficit

Wheat | Nitro | PAR high



Tomate | Nitro | PAR low



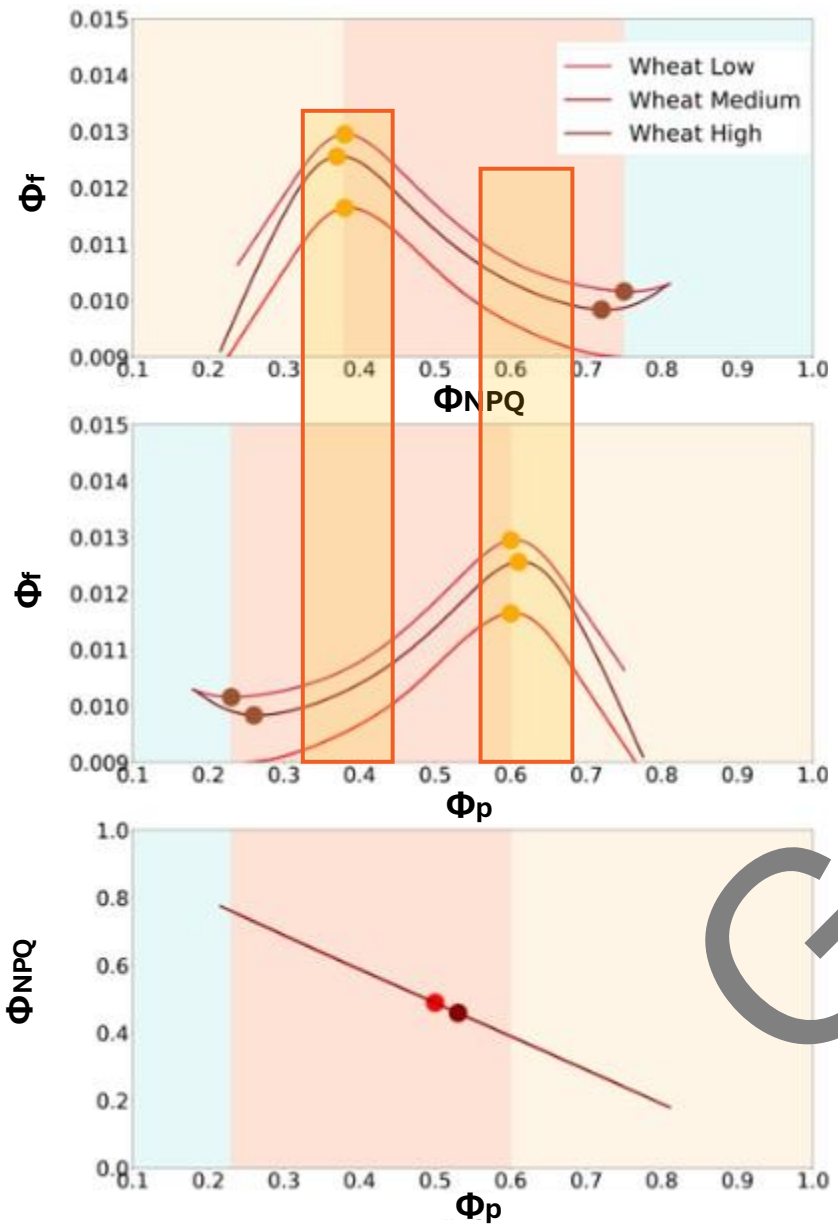
ϕf and ϕp dynamics are **driven** by **ϕNPQ.**

Phase I
Phase II
Phase III

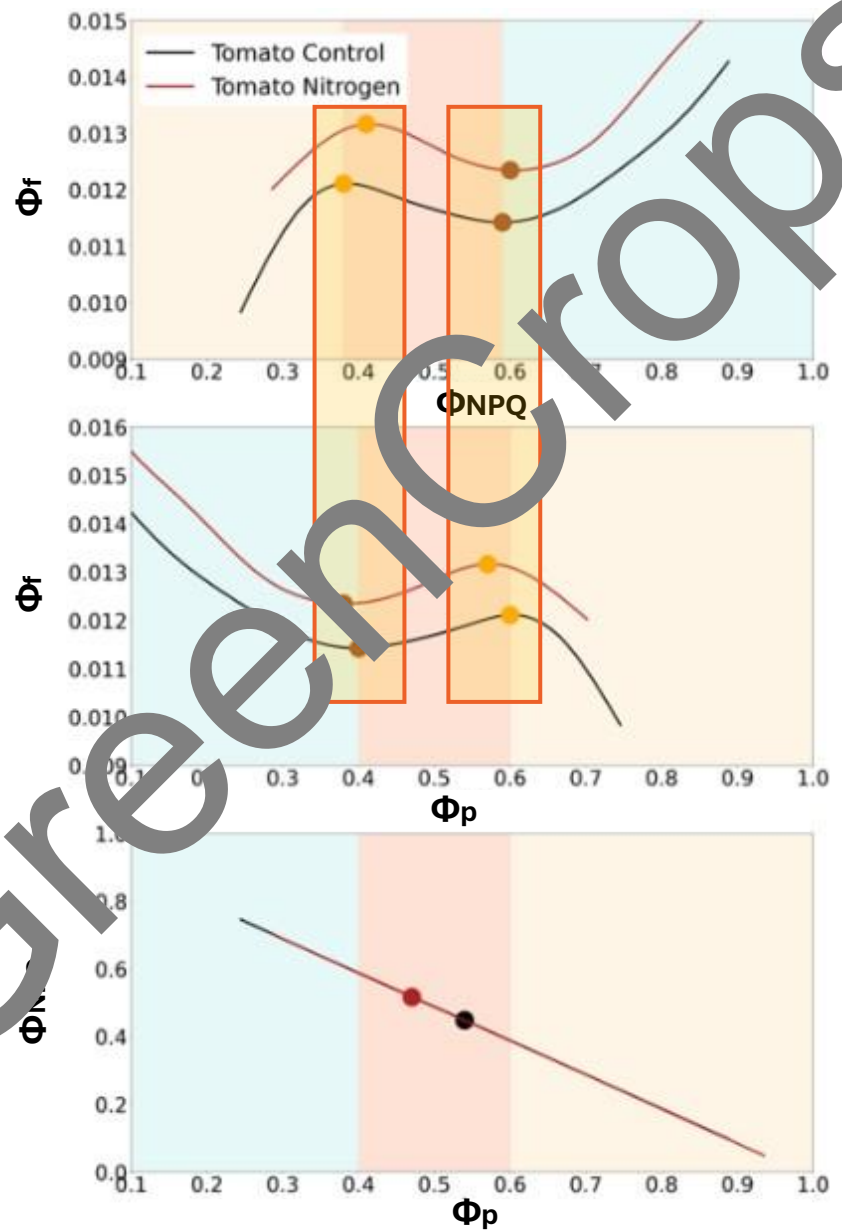
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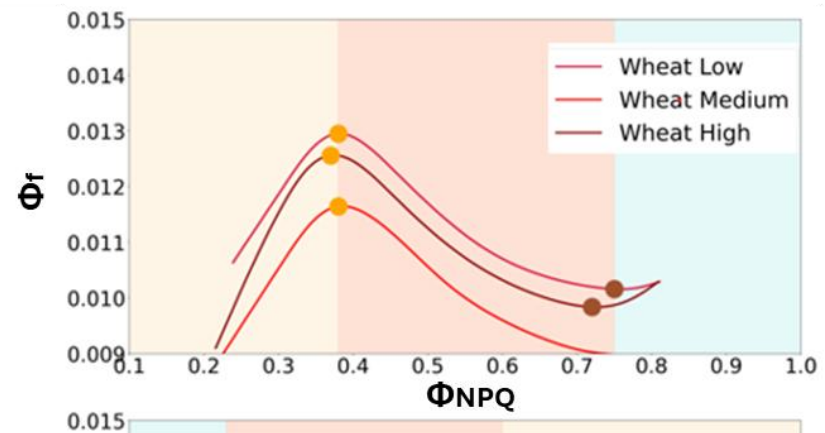
- **ϕf and ϕp** dynamics are **driven** by **ϕNPQ.**
- When **ϕf-ϕp** is at **peak optimal** function **NPQ** has a **low activity** and conversely.

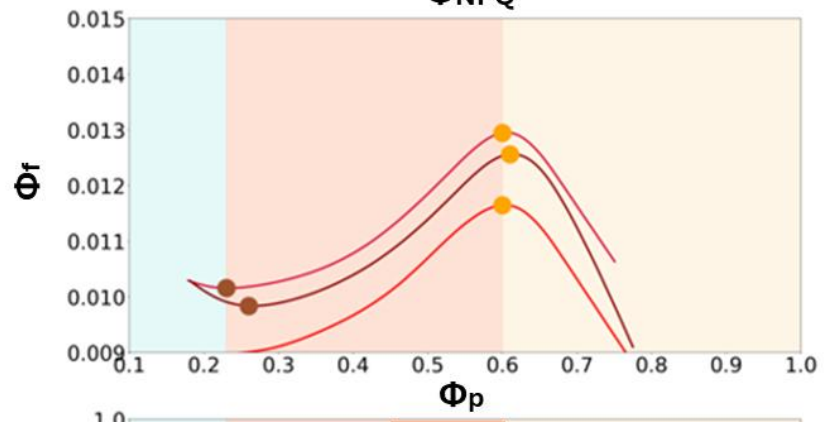
Phase I
Phase II
Phase III

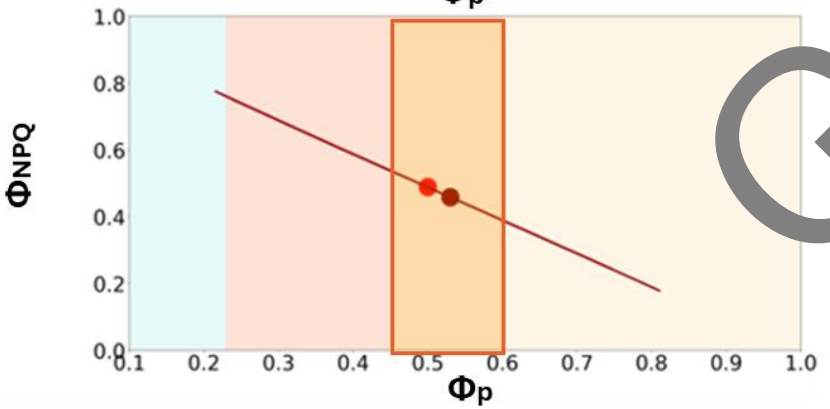
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Results | Nitrogen deficit

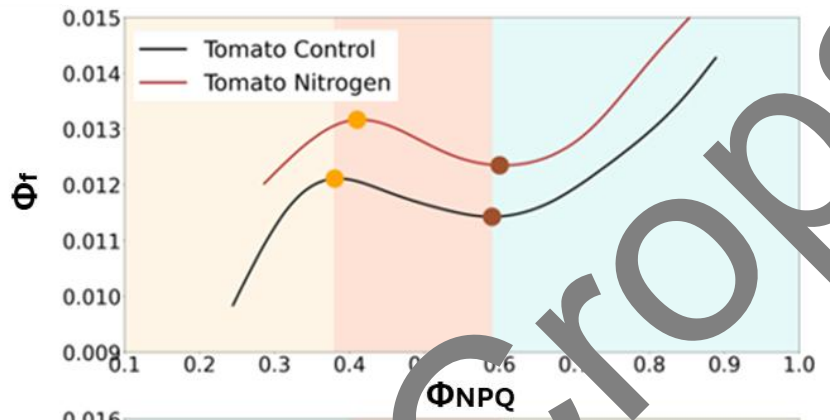
Wheat | Nitro | PAR high

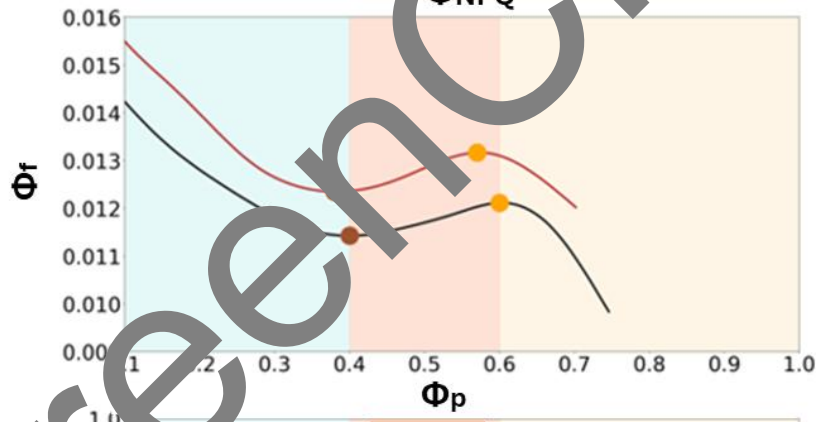


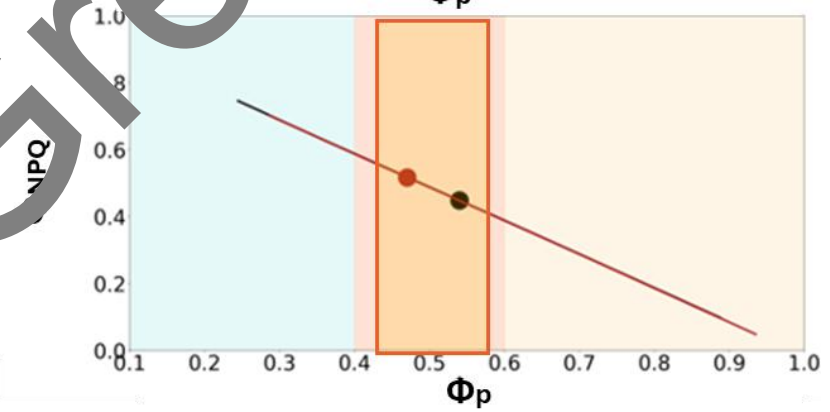




Tomate | Nitro | PAR low





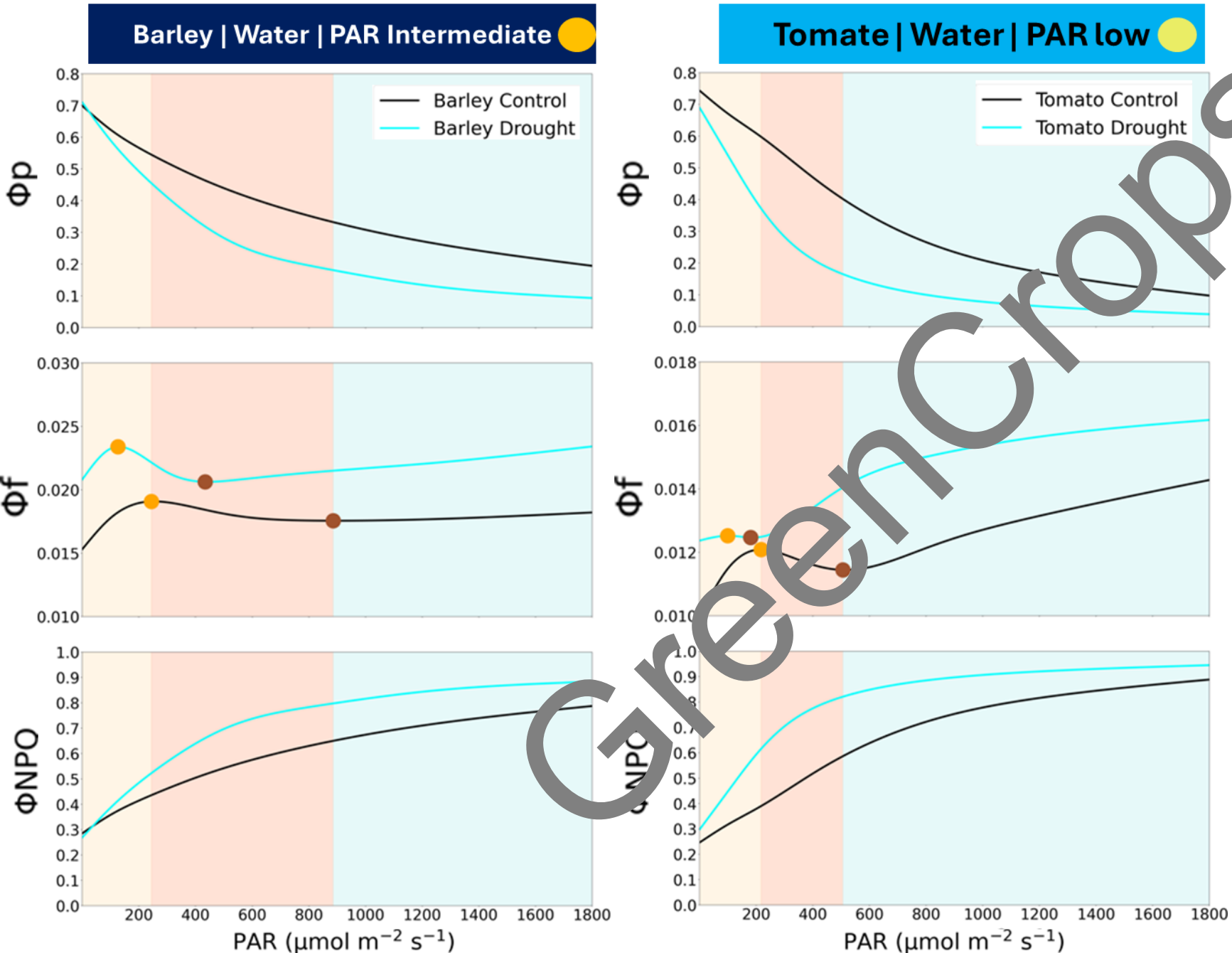


- **ϕf and ϕp** dynamics are **driven** by **ϕNPQ.**
- When **ϕf-ϕp** is at **peak optimal** function **NPQ** has a **low activity** and conversely.
- A **point of change** in the relationship among **Φp** and **ΦNPQ** is detected and is always in the **second phase**.

Phase I
Phase II
Phase III

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Results | water deficit

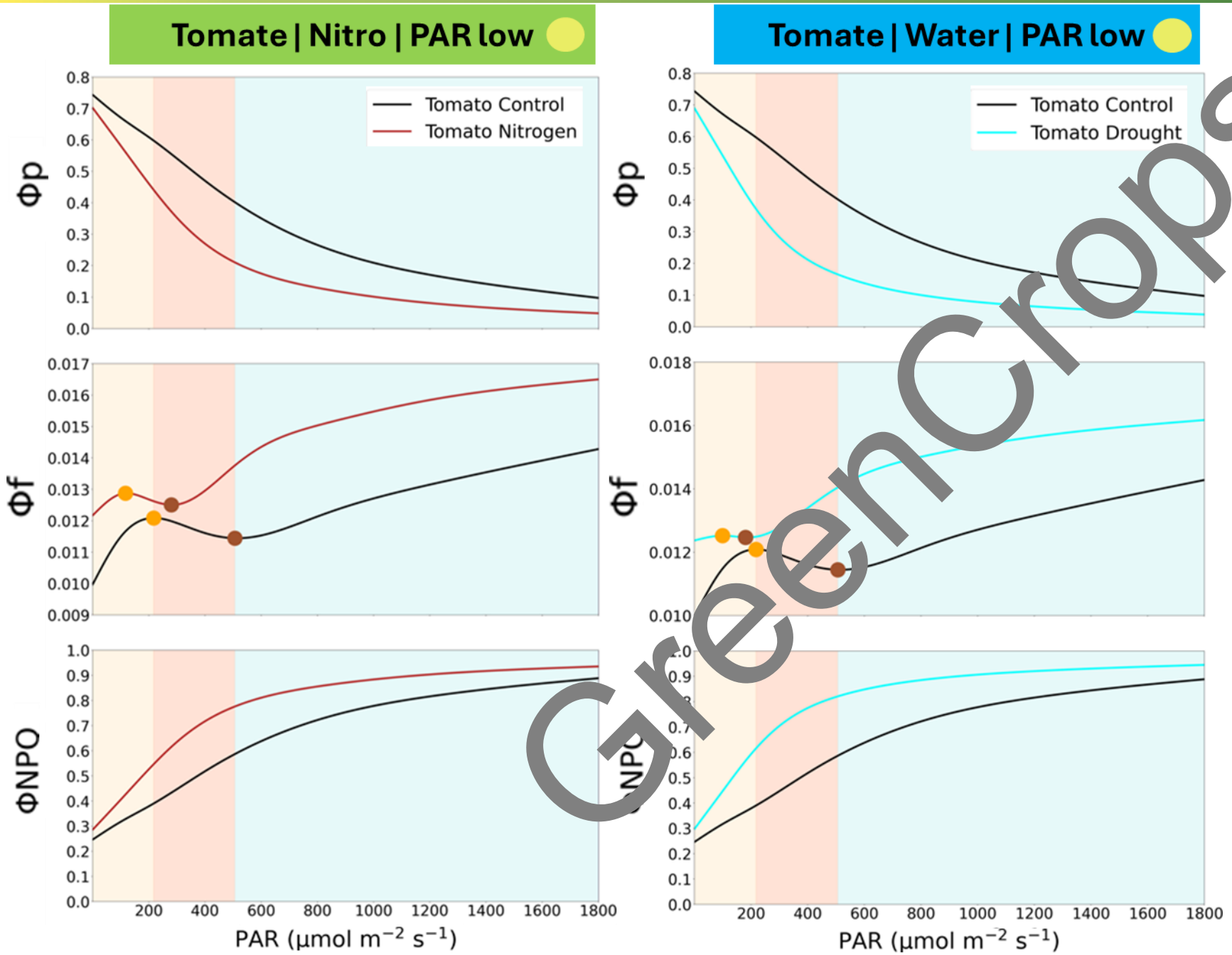


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- **Treatments**
  - Similar results as observed in nitrogen deficit.
- **Growing light conditions**
  - **Phase III:** longer in both **intermediate** and **low PAR**.
  - **Tomate:**
    - Phase I: drought < nitro
    - Phase II: drought < nitro
    - Phase III: drought ~ nitro

Phase I
Phase II
Phase III

Results | water deficit

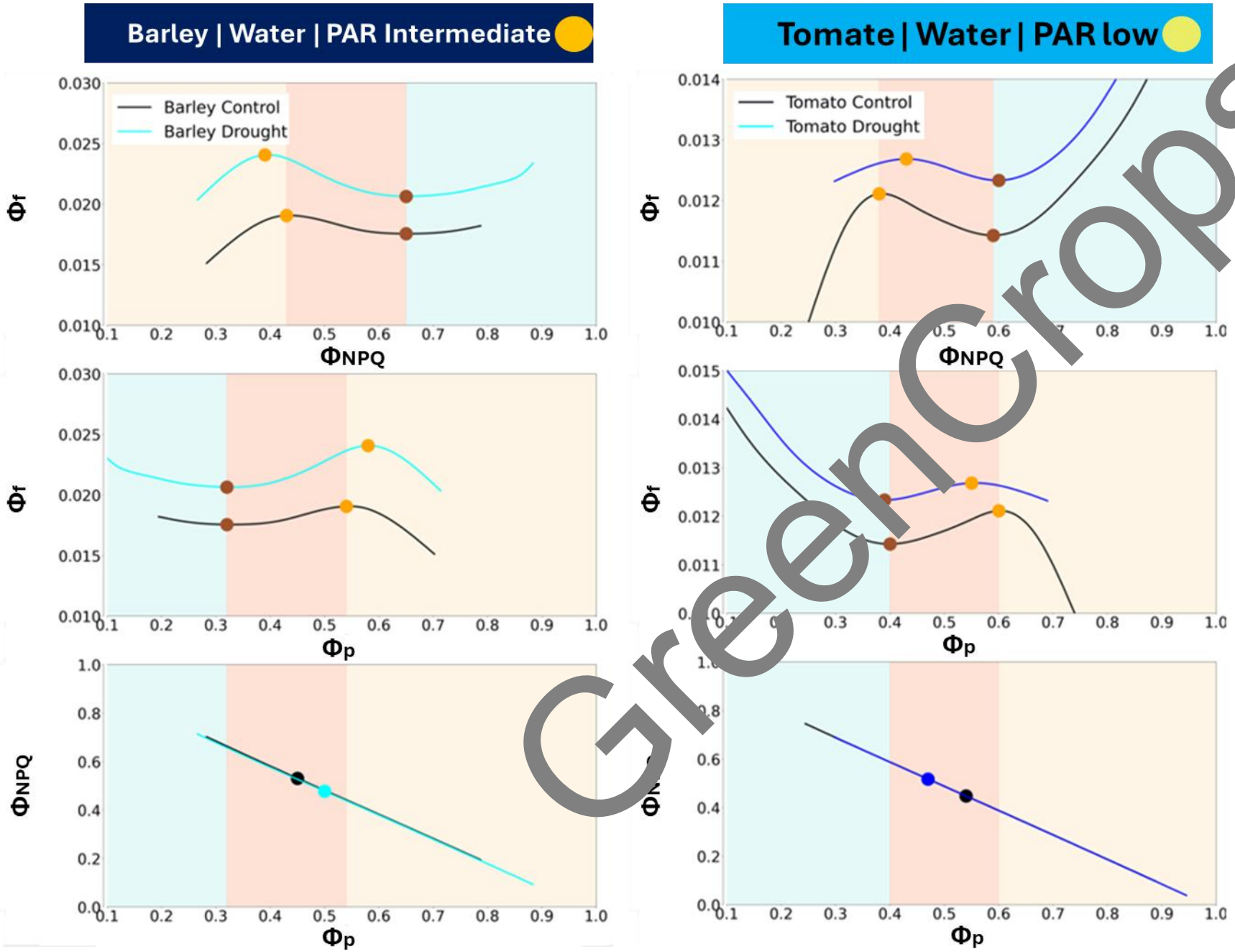


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    - Phase I: drought < nitro
    - Phase II: drought < nitro
    - Phase III: drought ~ nitro

Phase I
Phase II
Phase III

Results | water deficit



- In water deficit the **maximun Φp peak** is reached **earlier** and lasts shorter compared to nitrogen.
- The **duration** of the phases is shorter and **NPQ** acts **earlier** than in nitrogen.

Phase I
Phase II
Phase III

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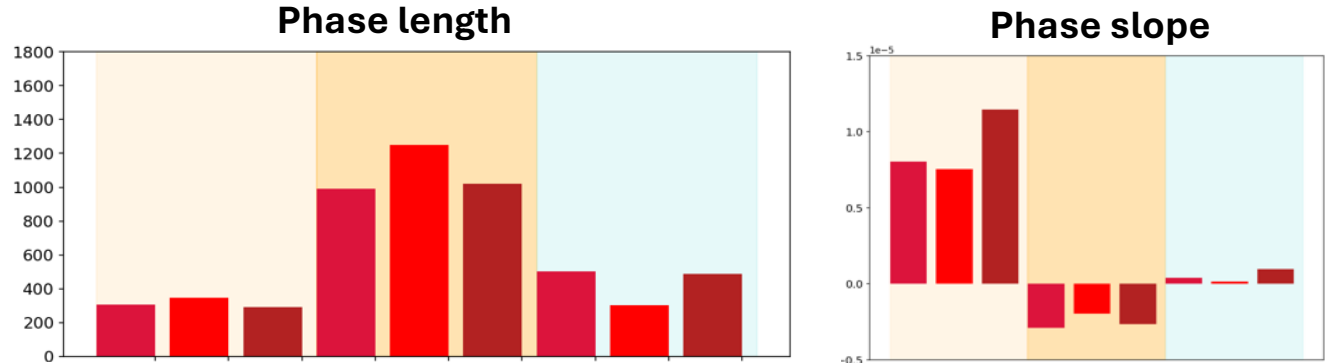
Conclusions and future work

In this study:

- **Changes** (magnitude) in **ϕp, ϕf, and ϕNPQ** are primarily **driven** by **water/nutrient availability**.
- **Growth light conditions** determine the **shape (slope)** and **length** of their dynamic **phases**.
- **Water deficit** resulted in **more pronounced differences** in **phase shape (slope)**, and **length**.
- Ongoing analysis will quantify the length and slope of these observed phases.

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WHEAT | HL | NITRO →

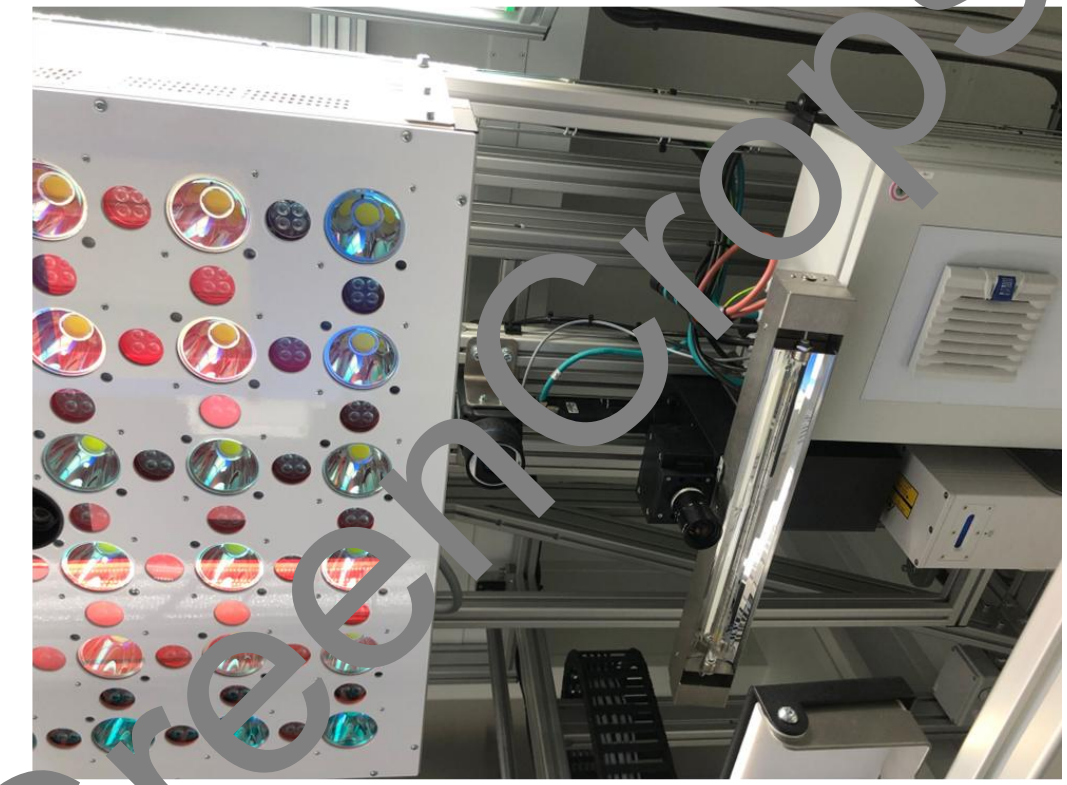


Next experiment



PlantScreen Chamber





- Active fluorescence imaging system.
- Hyperspectral imaging scanning camera.
- Thermal camera.
- 3D reconstruction system.

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- **Simulate diurnal cycle.**
- **Control and drought.**
- **Active and passive fluorescence.**
- **Pigment analysis.**

Thank you for your attention

For further questions or cooperation opportunities, please contact us.

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