Plant Bioelectronics & Biohybrid Systems

Eleni Stavrinidou
Associate Professor
eleni.stavrinidou@liu.se

@EleniStavrin

LINKÖPING UNIVERSITY

LINKÖPING UNIVERSITY

LABORATORY OF ORGANIC ELECTRONICS

Campus Norrköping

www.liu.se/loe

Electronic Plants

@ePlants_at_LiU

Daniela Parker

Dr. Gwennael Dufil

Prof. Eleni Stavrinidou

Dr. Iwona Bernacka Wojcik

Dr. Johannes Gladisch

Alexandra Sandhén

Abdul Manan Dar

Erica Colaprico

Vasileios Oikonomou

Cyril Routier

Vetenskapsrådet

Swedish Foundation for Strategic Research

WWSC Wallenberg Wood Science Center

European Research Council
Established by the European Commission

Image by andreas160578 from Pixabay

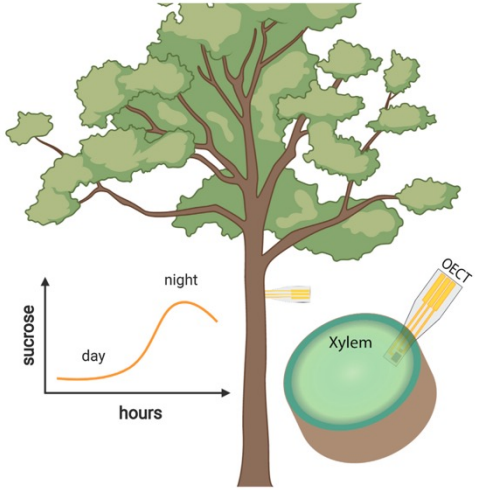
Climate crisis

- Climate change brings droughts, floods, heat and cold waves affecting harvest
- Arable land is decreasing: pollution, erosion, urbanization
- World population and food demands are increasing – UN: 60% more food by 2050
- Intensification of agriculture: increase of greenhouse gas emissions, pollution, and loss of ecosystems

Bioelectronics & Biohybrid Technologies

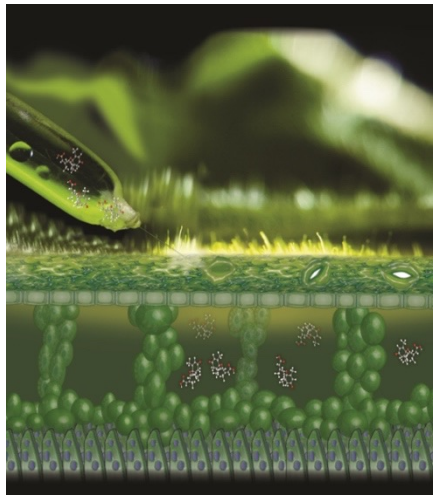
- Tools for fundamental understanding of plant biology
- Application in agriculture and forestry

Monitoring biological processes



Diacci, Stavrinidou et al., iScience 24, 101966

Dynamic control of plant physiology



I. Bernacka-Wojcik, Stavrinidou et al, Advanced Science 2023, 2206409

Monitoring of microclimate

Nassar, Hussain et al, npj Flexible Electronics (2018) 24

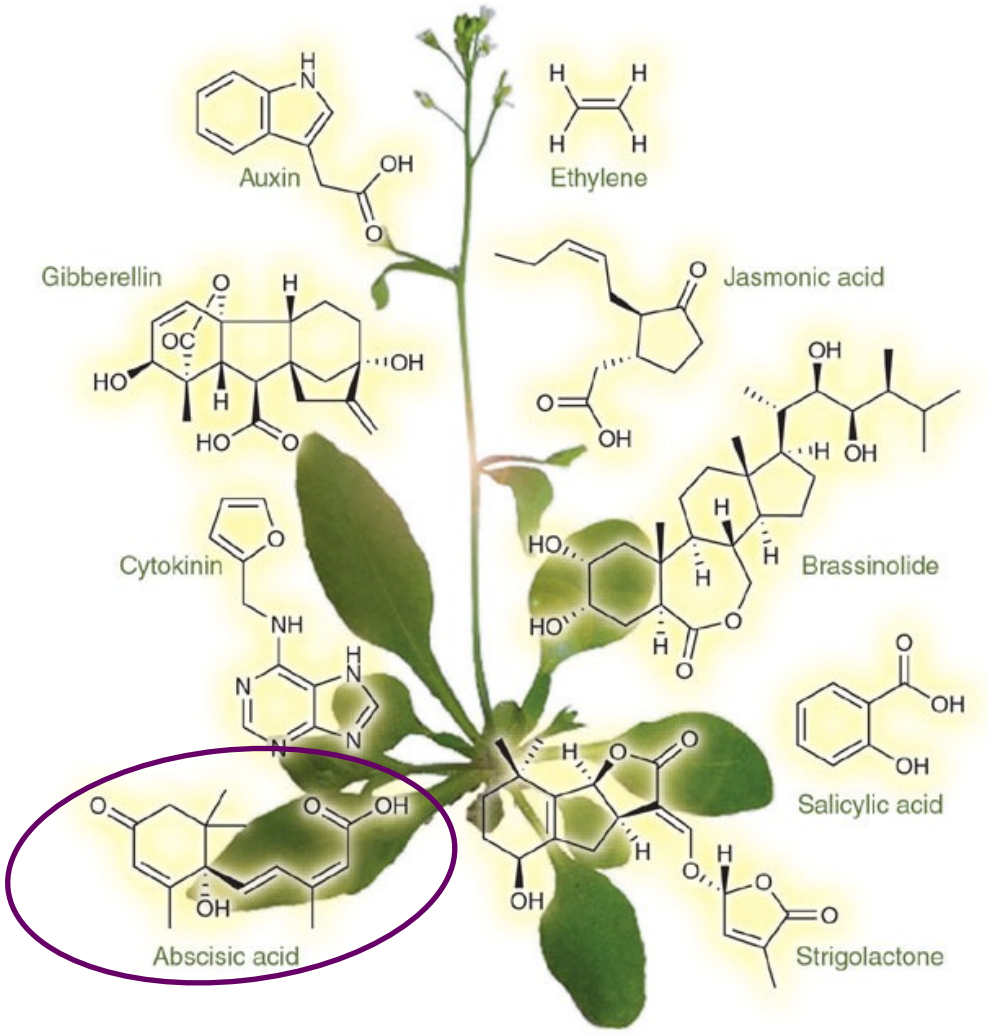
Focus Areas:

- *Abiotic and biotic stress: elucidating mechanisms, early detection*
- *Growth and yield: monitoring and enhancing*
- *Optimizing resources use*

Dufil, Stavrinidou et al. Chem. Rev. 2022, 122

Bioelectronic devices for modulating plant physiology

Phytohormones regulate plant responses to stress



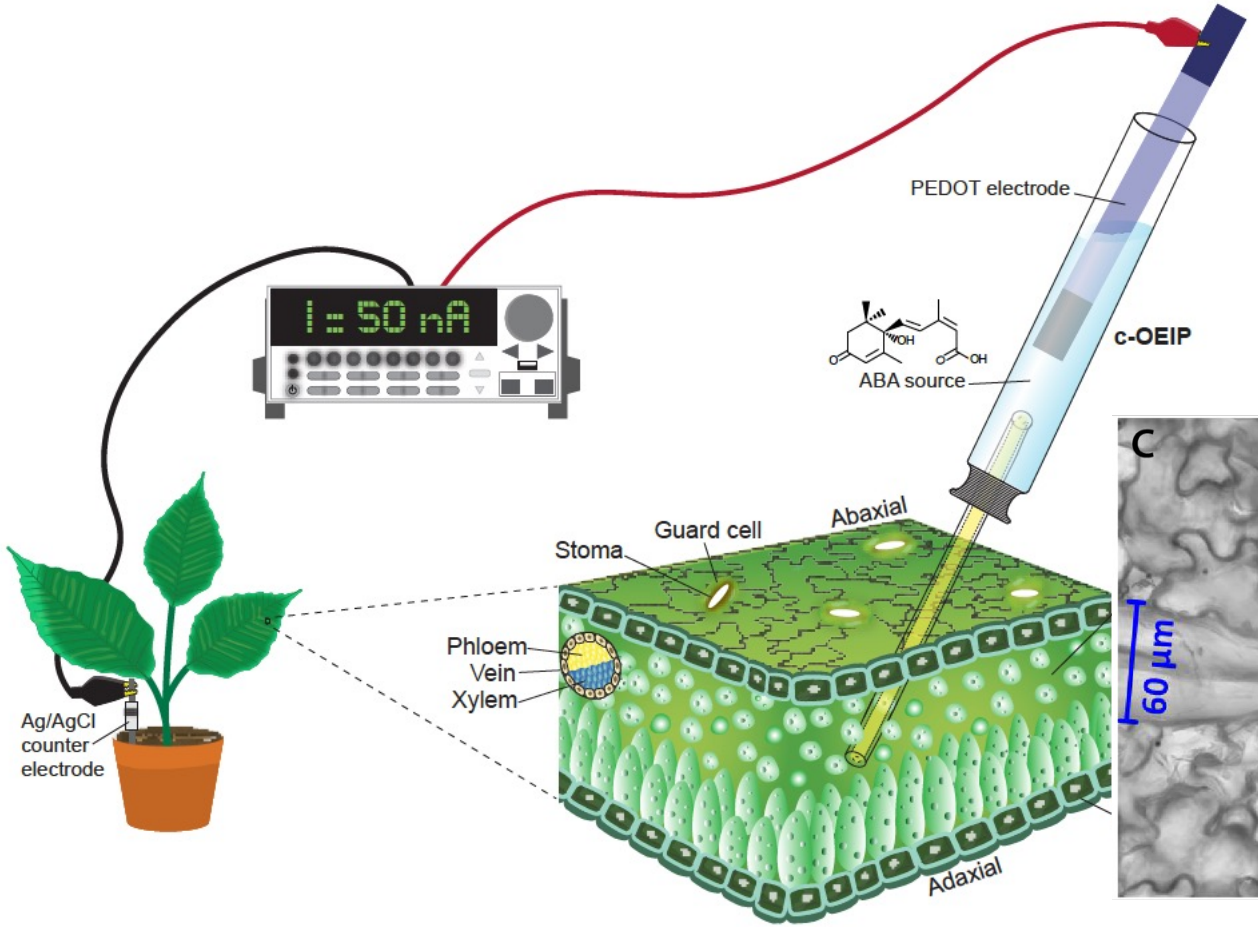
- Regulators of plant growth and development
- Mediators of responses to biotic and abiotic stress

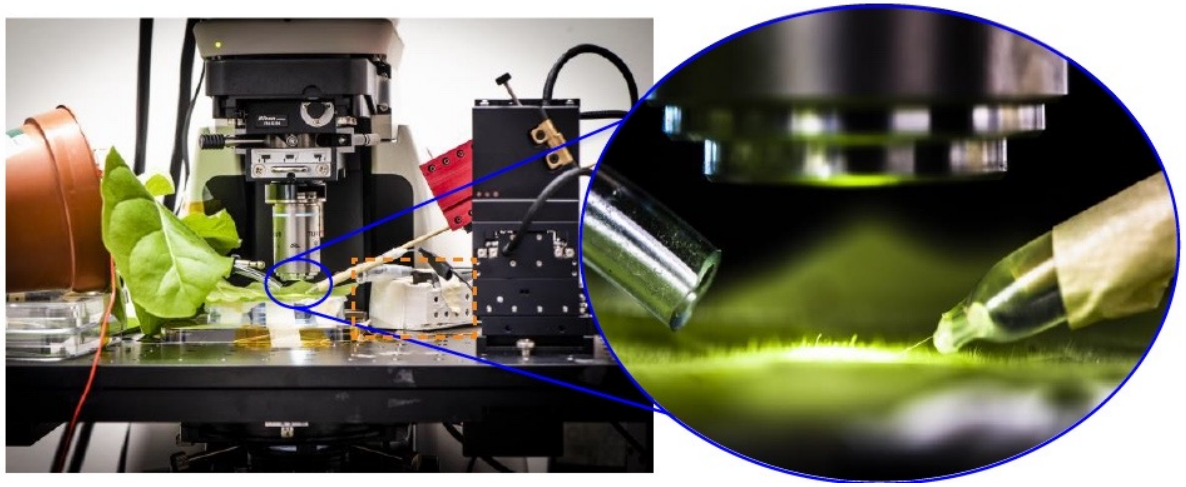
Abscisic acid:

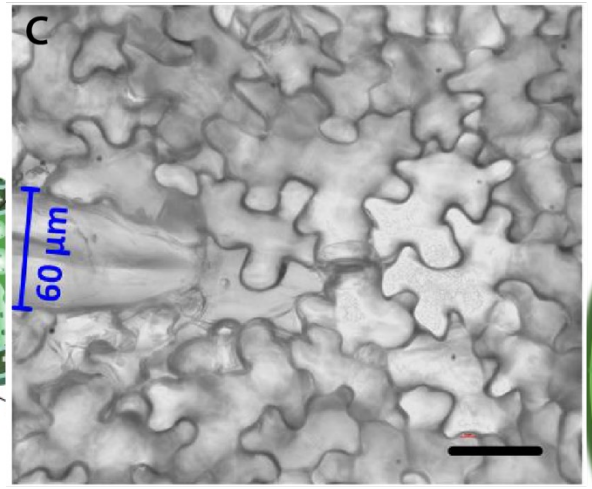
- **Various growth processes**
- **Seed dormancy**
- ***The stress hormone***
- **Drought response**

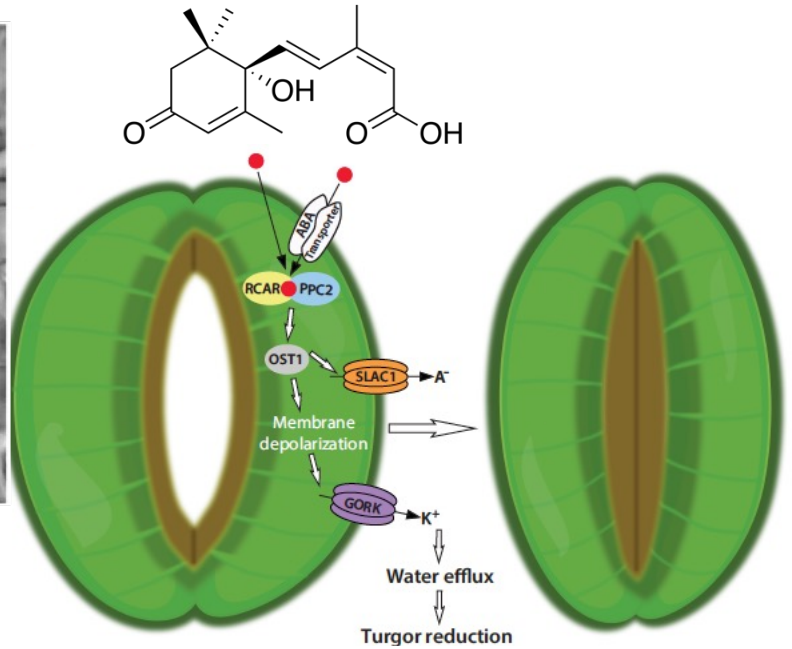
Santner et al., Nature Chem. Bio., 2009

Organic Electronic Ion Pump for electronic control of stomata









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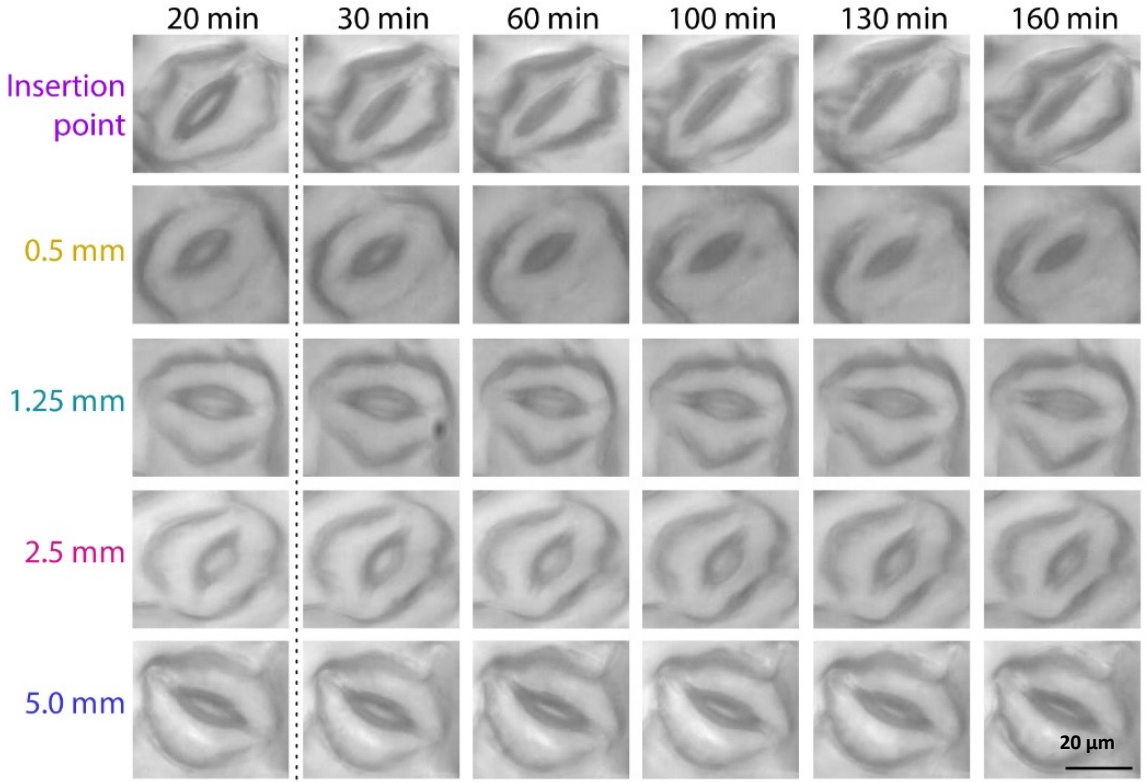
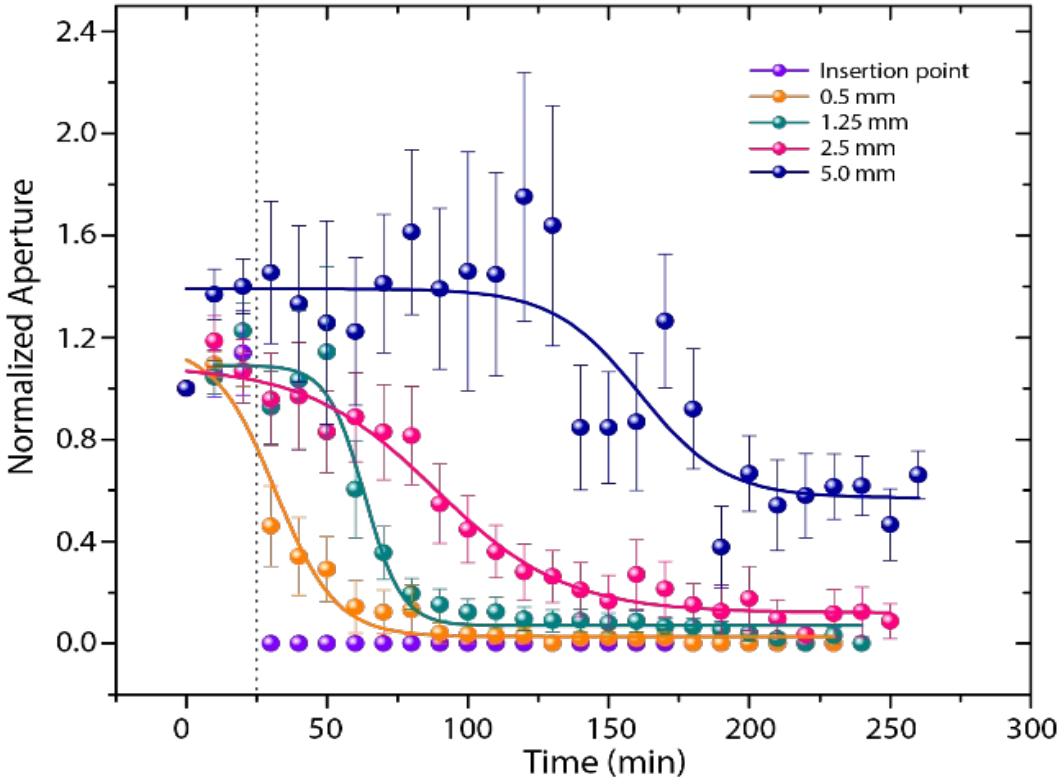
Bernacka-Wojcik, Huerta, Stavrinidou et al, Small 2019, 1902189

OEIP mediated ABA delivery to intact leaf with minimal invasiveness





Delivered ABA induces stomata closure revealing signal propagation kinetics

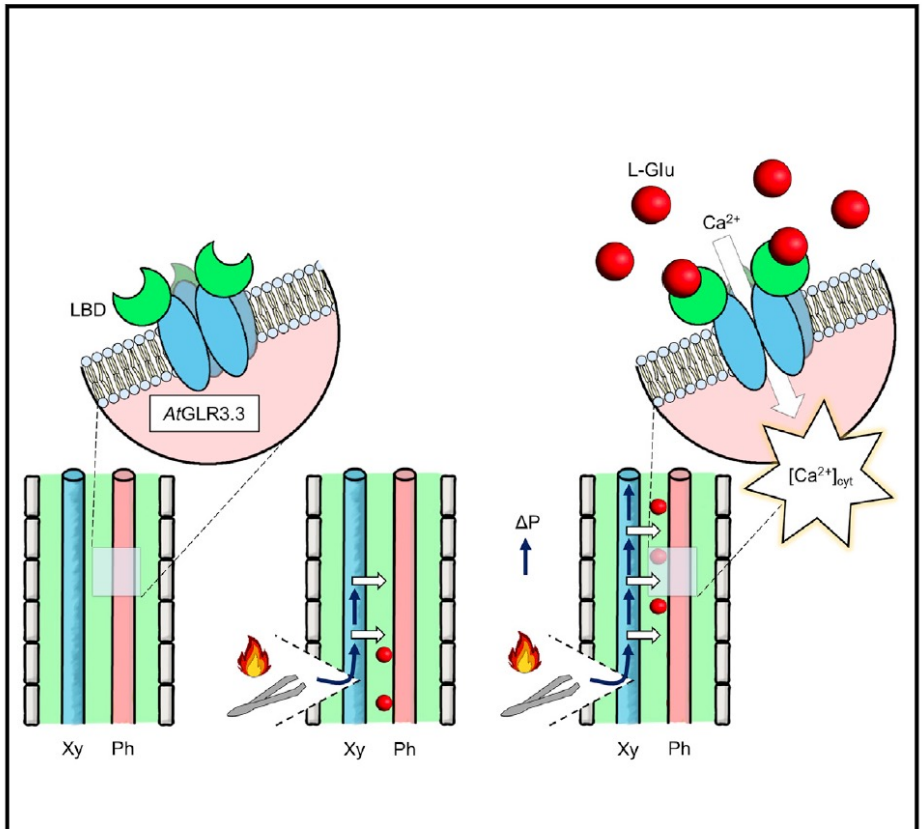
Bernacka-Wojcik, Huerta, Stavrinidou et al, Small 2019, 1902189

Article

Current Biology

Long-distance turgor pressure changes induce local activation of plant glutamate receptor-like channels

Graphical abstract



Authors

Matteo Grenzi, Stefano Buratti,
Ambra Selene Parmagnani, ...,
Maria Cristina Bonza,
Eleni Stavrinidou, Alex Costa

Correspondence

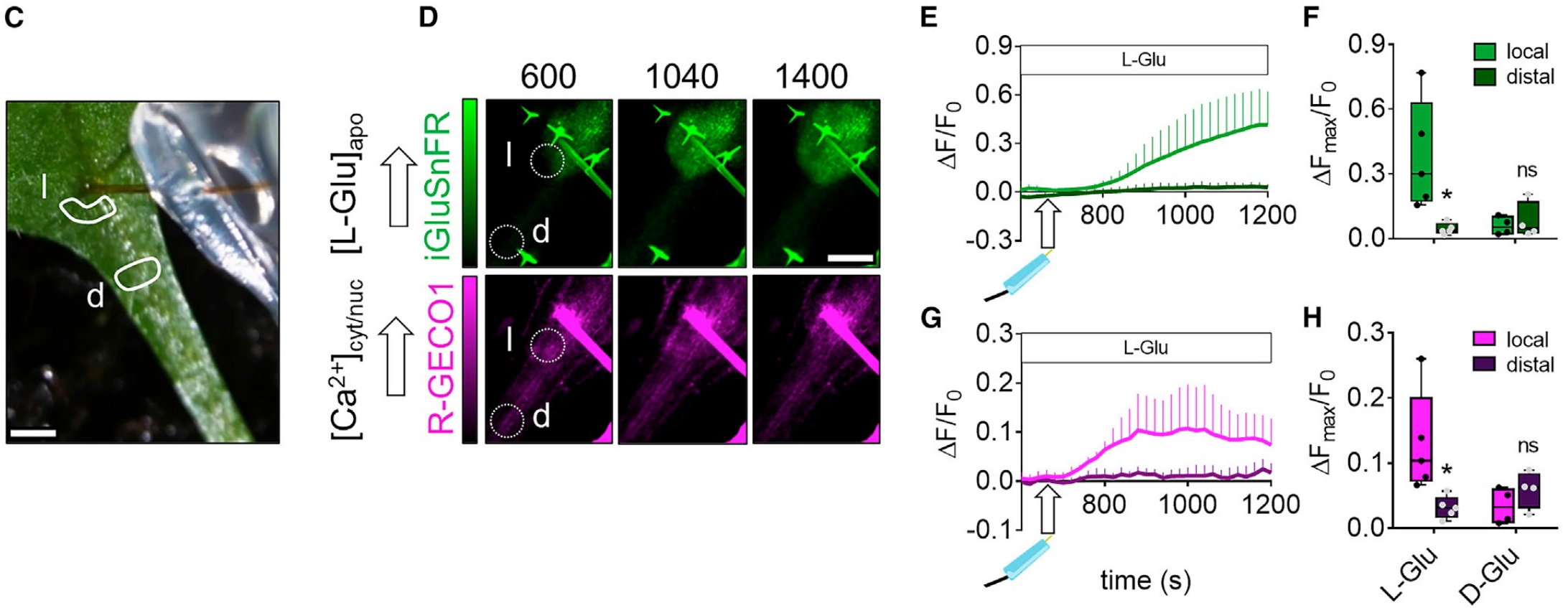
alex.costa@unimi.it

In brief

In *Arabidopsis thaliana*, mechanical stresses induce long-distance Ca^{2+} signals mediated by the glutamate receptor-like 3.3 channel. Grenzi et al. show that the stress-induced systemic increase of apoplastic L-glutamate, in a submillimolar range of concentrations, gates the *At*GLR3.3 through its ligand-binding domain.

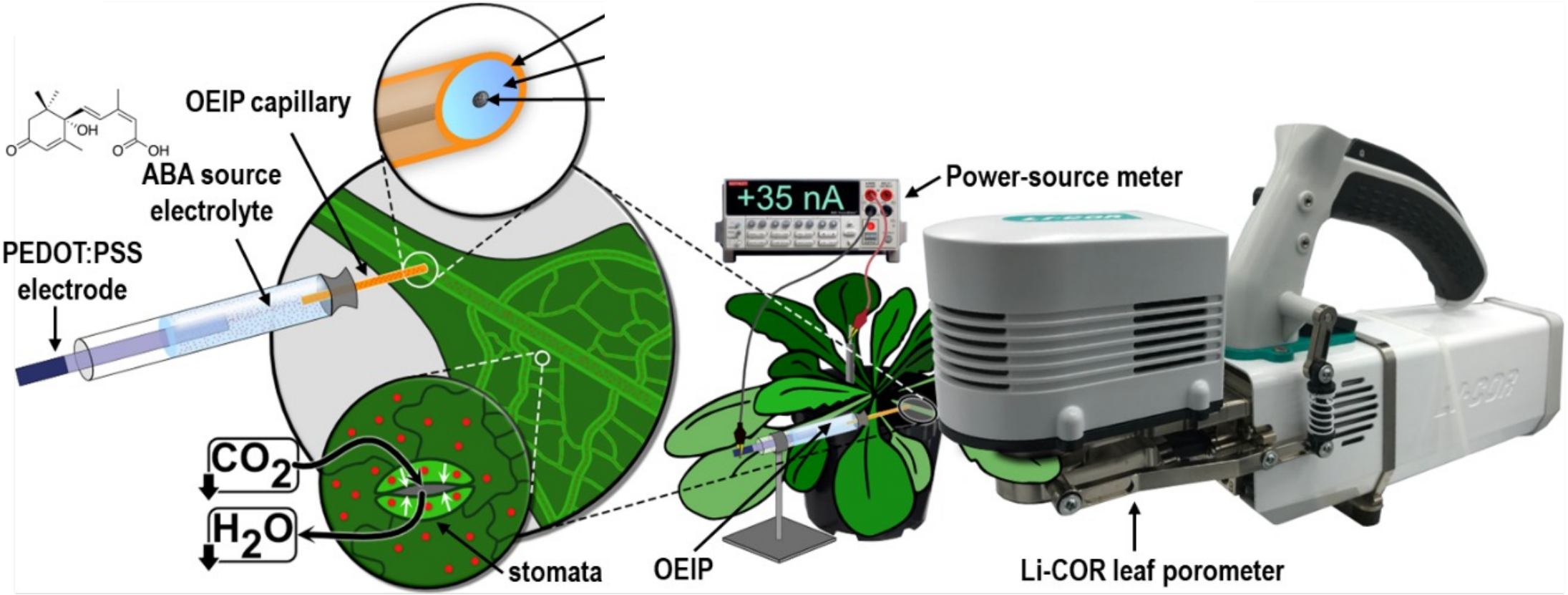
In collaboration with Alex Costa, University of Milano

C-OEIP helps elucidating role of glutamate in wounding responses



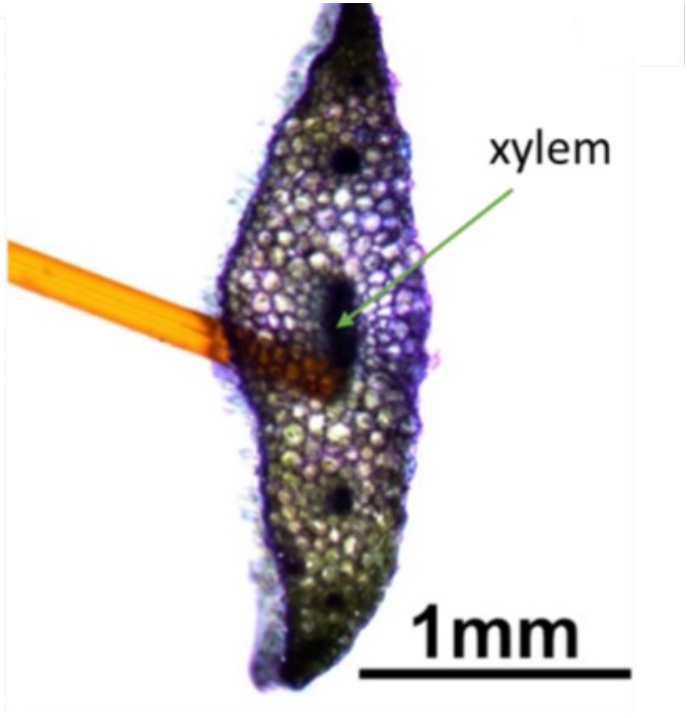
Grenzi,… Abdel-Azis, …, Stavrinidou, Costa, Current Biology 33, 1–17, 2023

Flexible c-OEIP for inducing long distance responses



In collaboration with Totte Niittylä, UPSC

OEIP-ABA delivery in vascular tissue of petiole

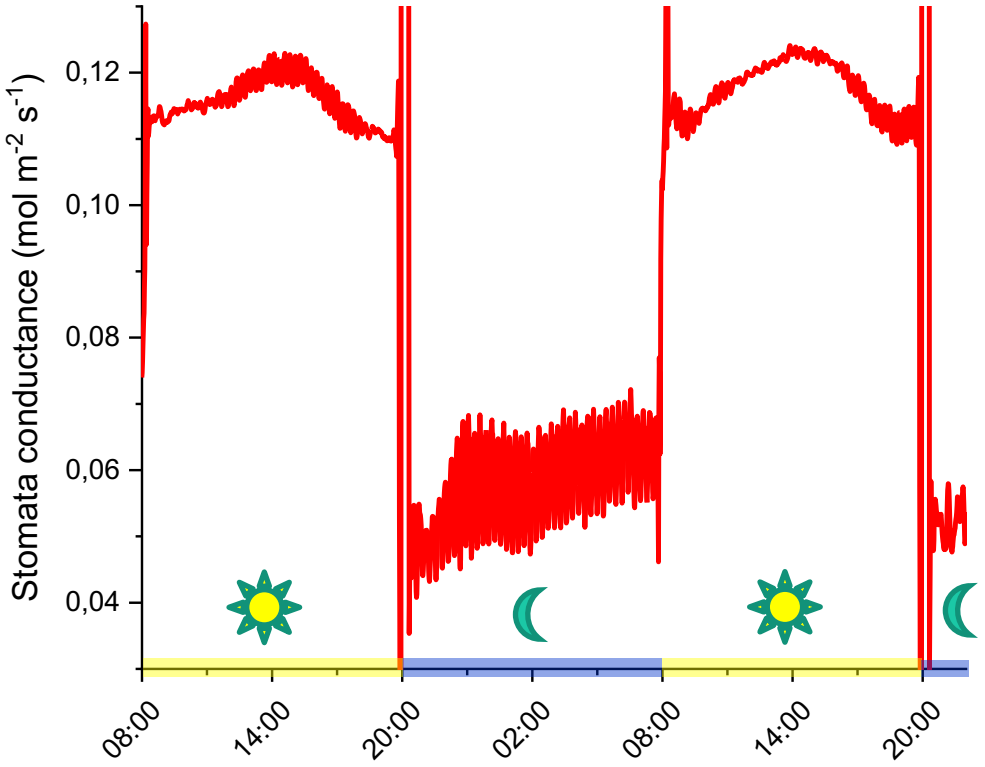


- Exogenous delivery directly to plants vasculature
- ABA will enter the transpiration stream
- Stomata response in the leaf far from OEIP is monitored with Licor

Bernacka-Wojcik, Stavrinidou et al,
Advanced Science 2023, 2206409

Monitoring stomatal conductance with LICOR Porometer

Licor



Stomatal conductance:

- degree of stomatal opening
- rate of water vapor

- Licor enables monitoring 5cm^2 leaf area
- Can be combined with photosynthesis measurements

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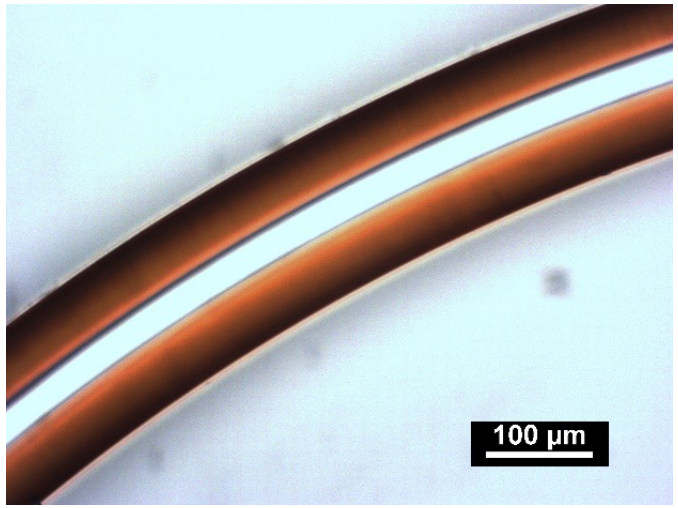
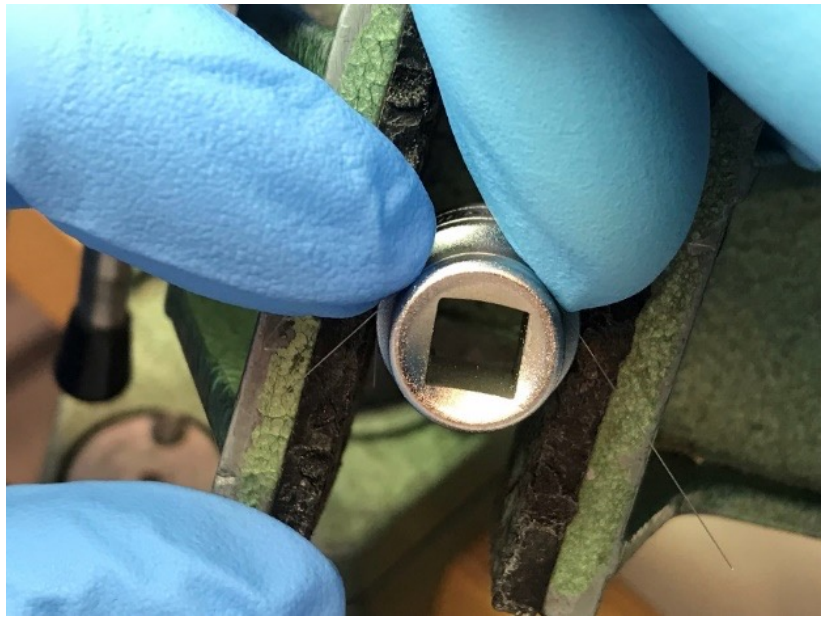
Enhancing c-OEIP mechanical properties



Polyimide coating

- ✓ highest strength per unit
- ✓ high fracture toughness

UV-curing via PI coating is challenging

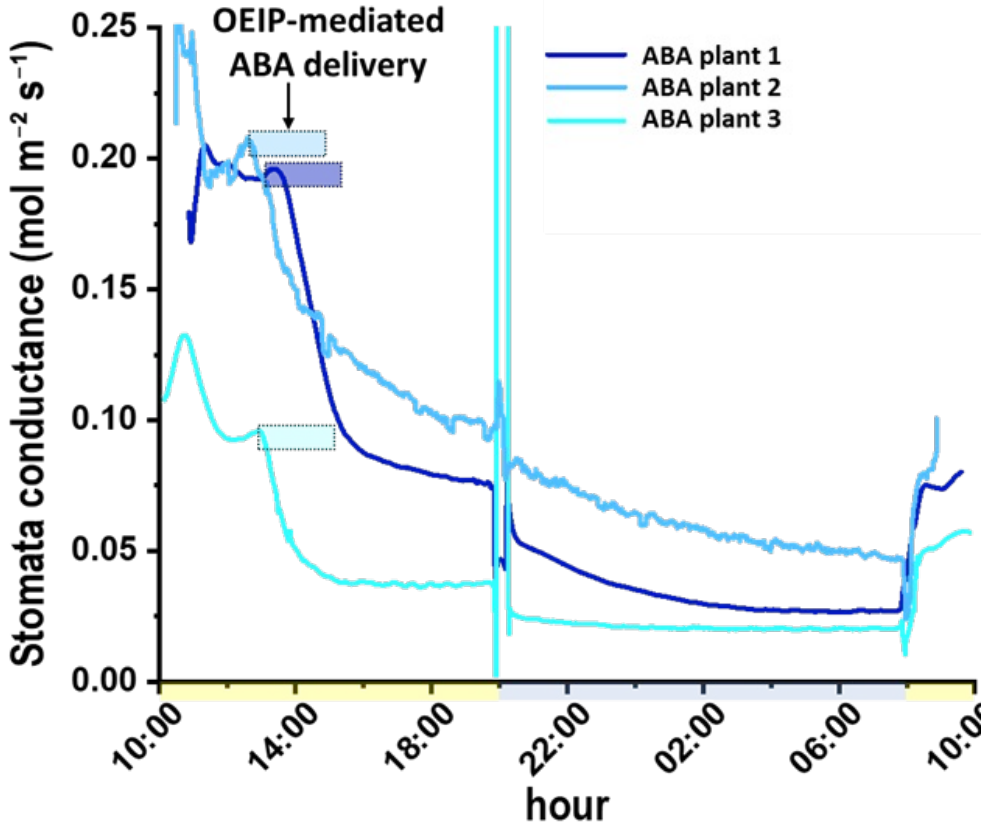


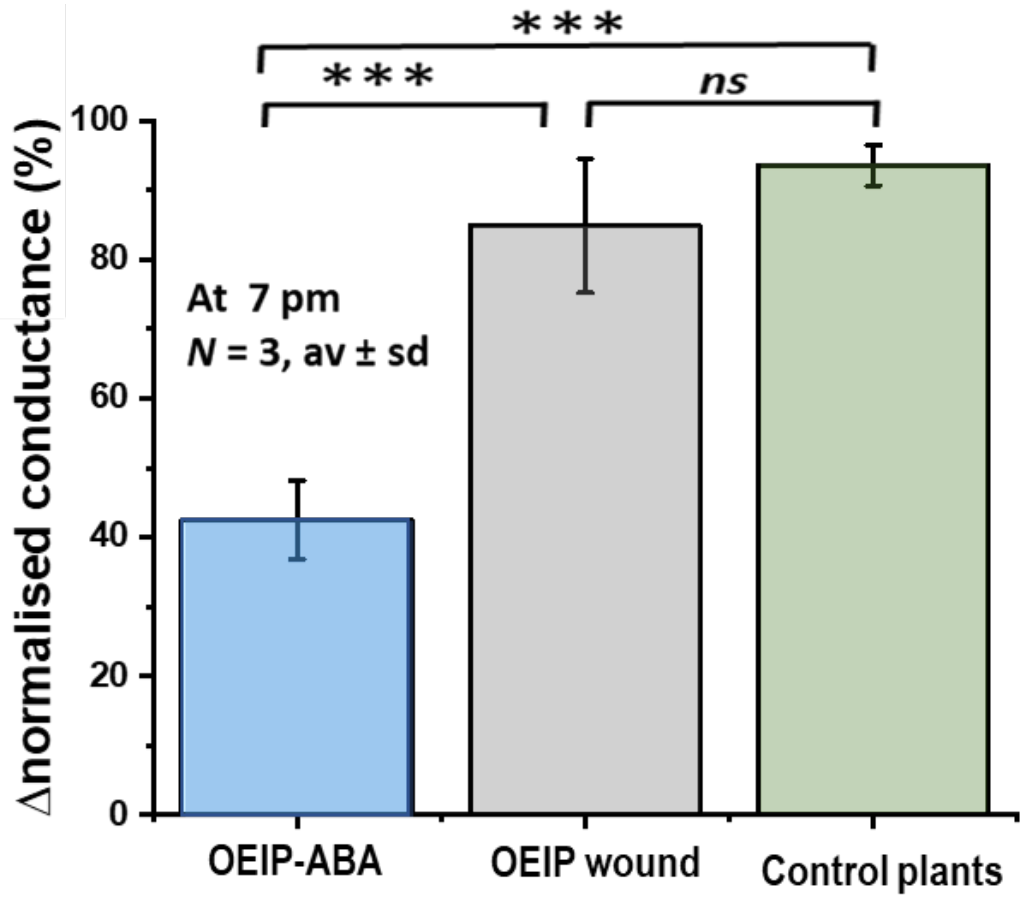
Sustained bending radius

- Glass 5.5 mm
- W/ Polyimide: 0.7 mm

Bernacka-Wojcik, Stavrinidou et al, Advanced Science 2023, 2206409

Controlling distant leaf's transpiration





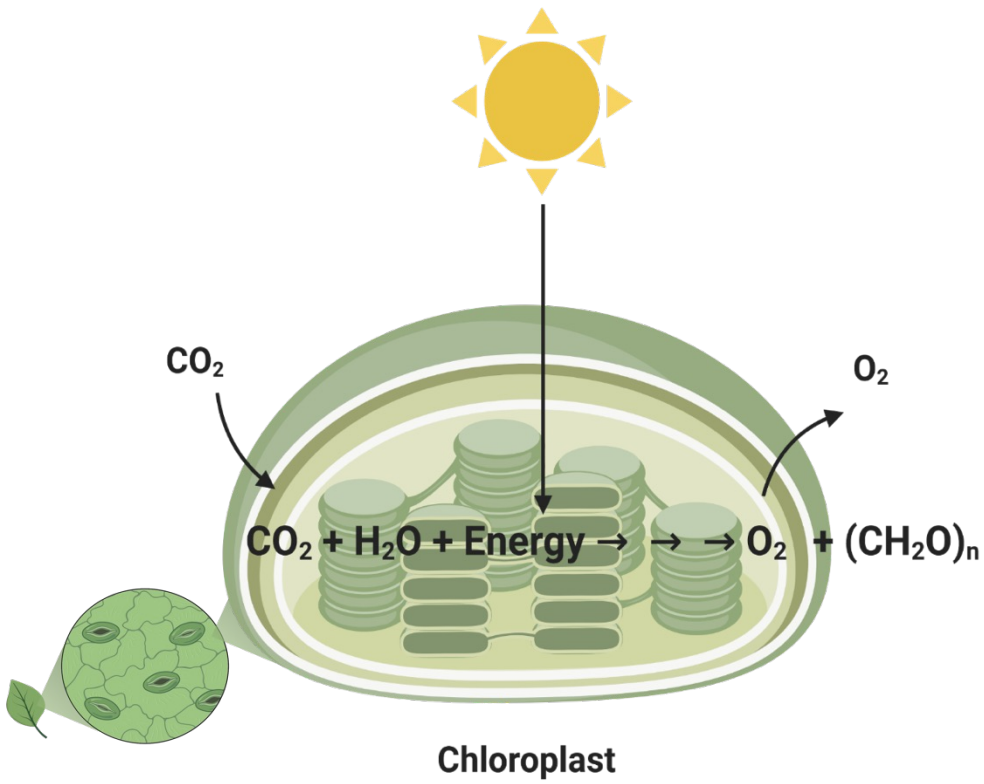
Stomata conductance decreases and remains low for long time (>20h)

Bernacka-Wojcik, Stavrinidou et al,
Advanced Science 2023, 2206409

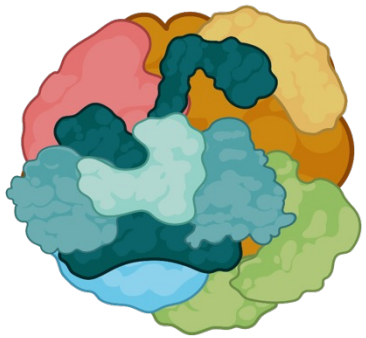
Plant based biohybrid systems

Nanoparticles for enhancing plants CO_2 uptake and carboxylation reaction

Photosynthesis



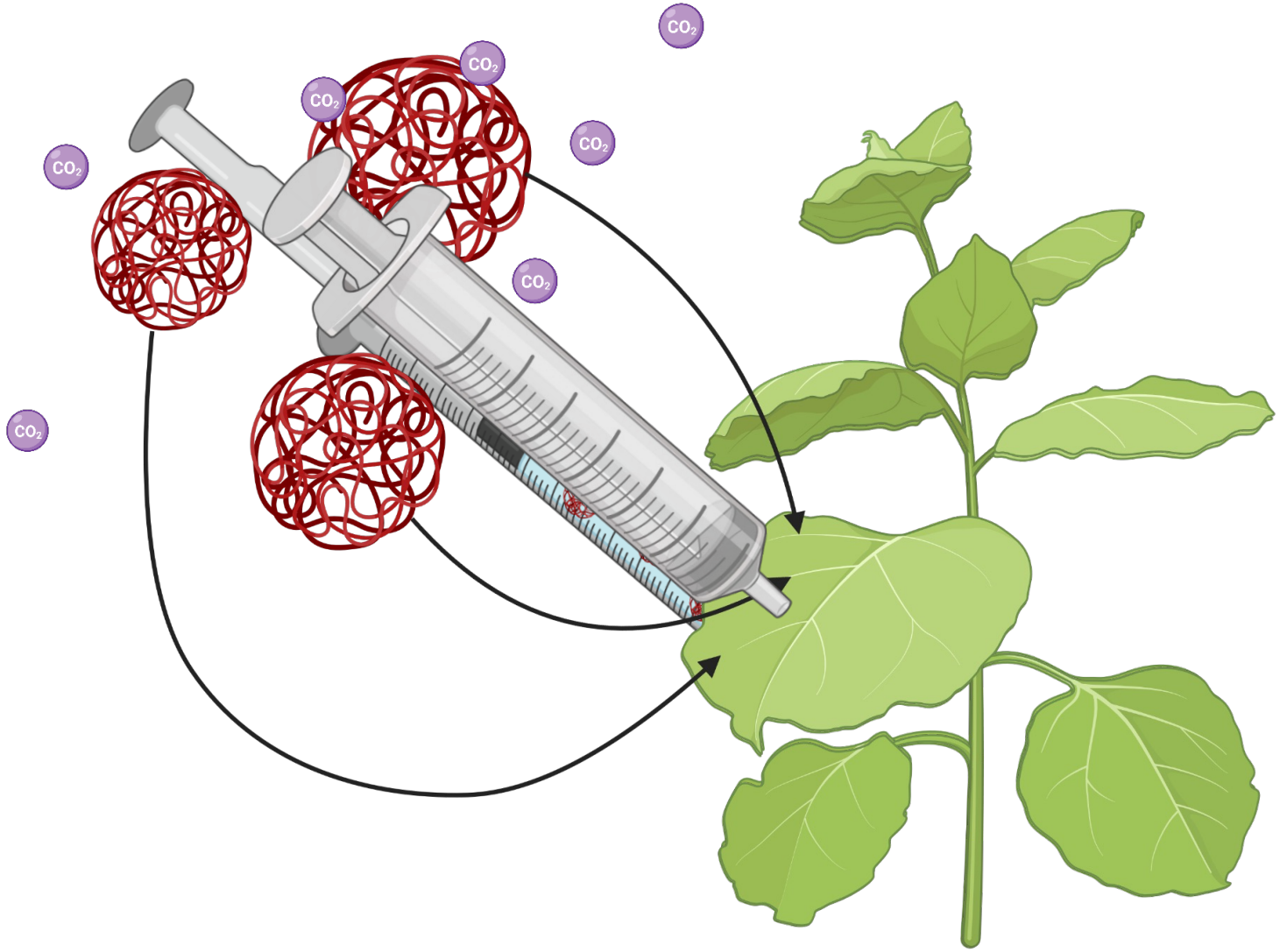
Key enzyme: **RuBisCO**



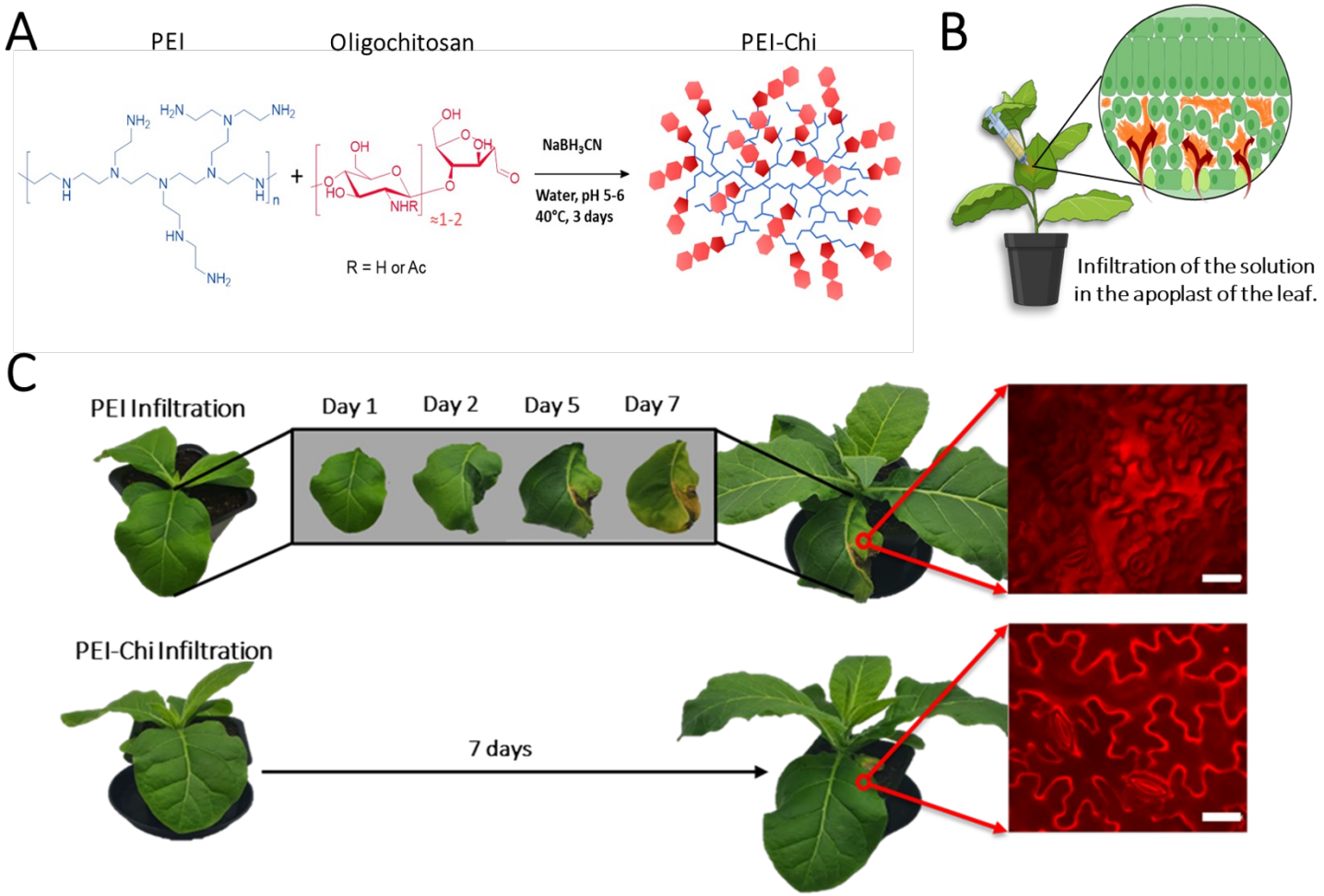
Responsible for the carbon fixation in plant metabolism

Inefficient
Activity highly limited by the diffusion of atmospheric CO_2 in the leaf.

Nanoparticles for increasing CO_2 uptake and fixation



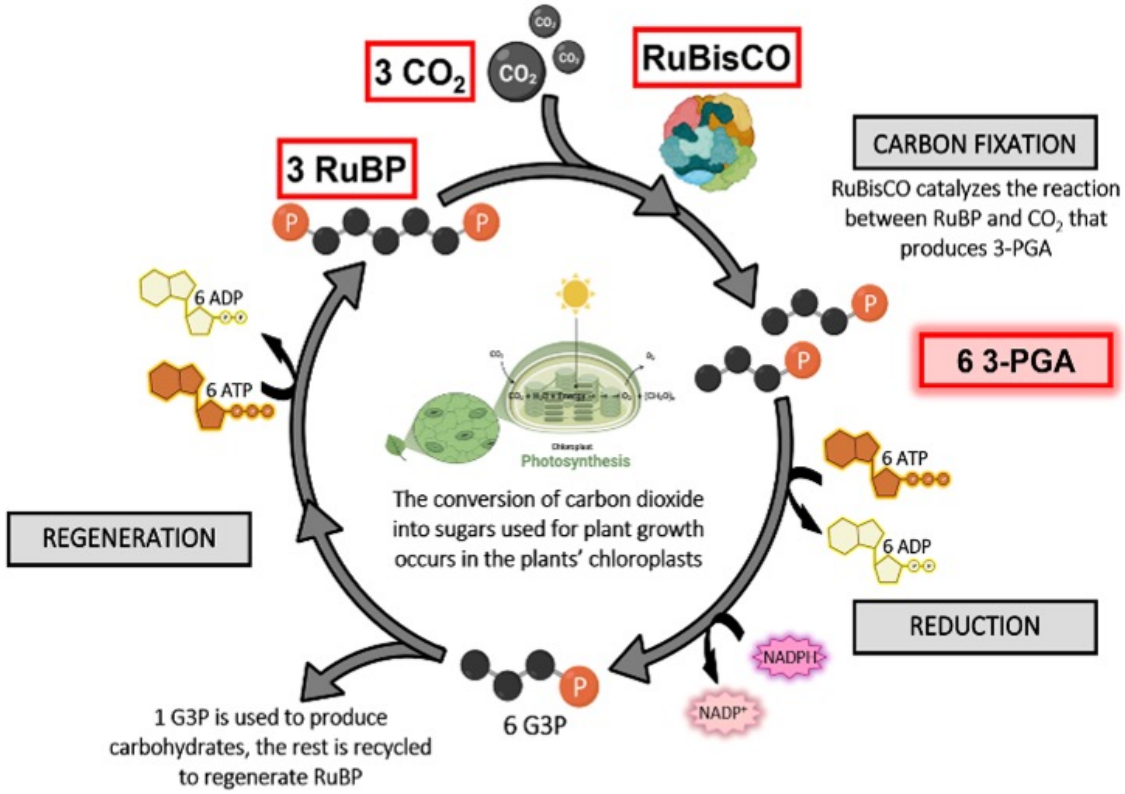
Phytocompatible Chitosan - PEI nanoparticles

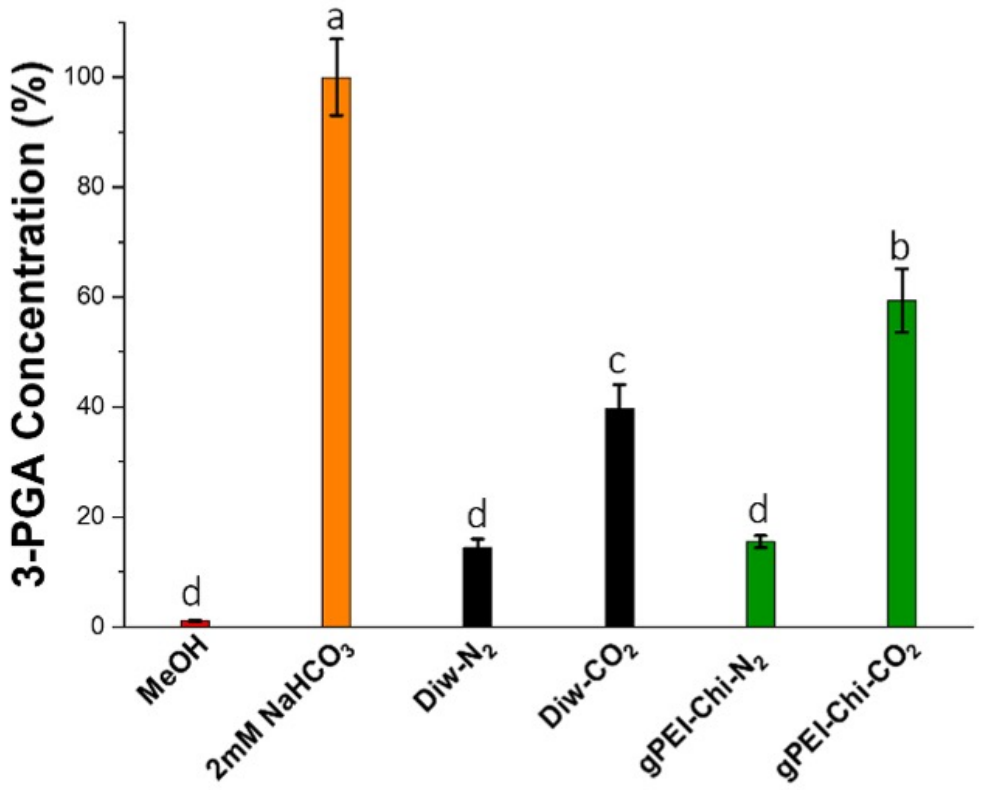


Chitosan functionalization inhibits PEI toxicity

Routier, Vallan, Stavrinidou et al. ACS Nano,
https://doi.org/10.1021/acsnano.2c09255

PEI-Chi nanoparticles enhance 3-PGA production in vitro





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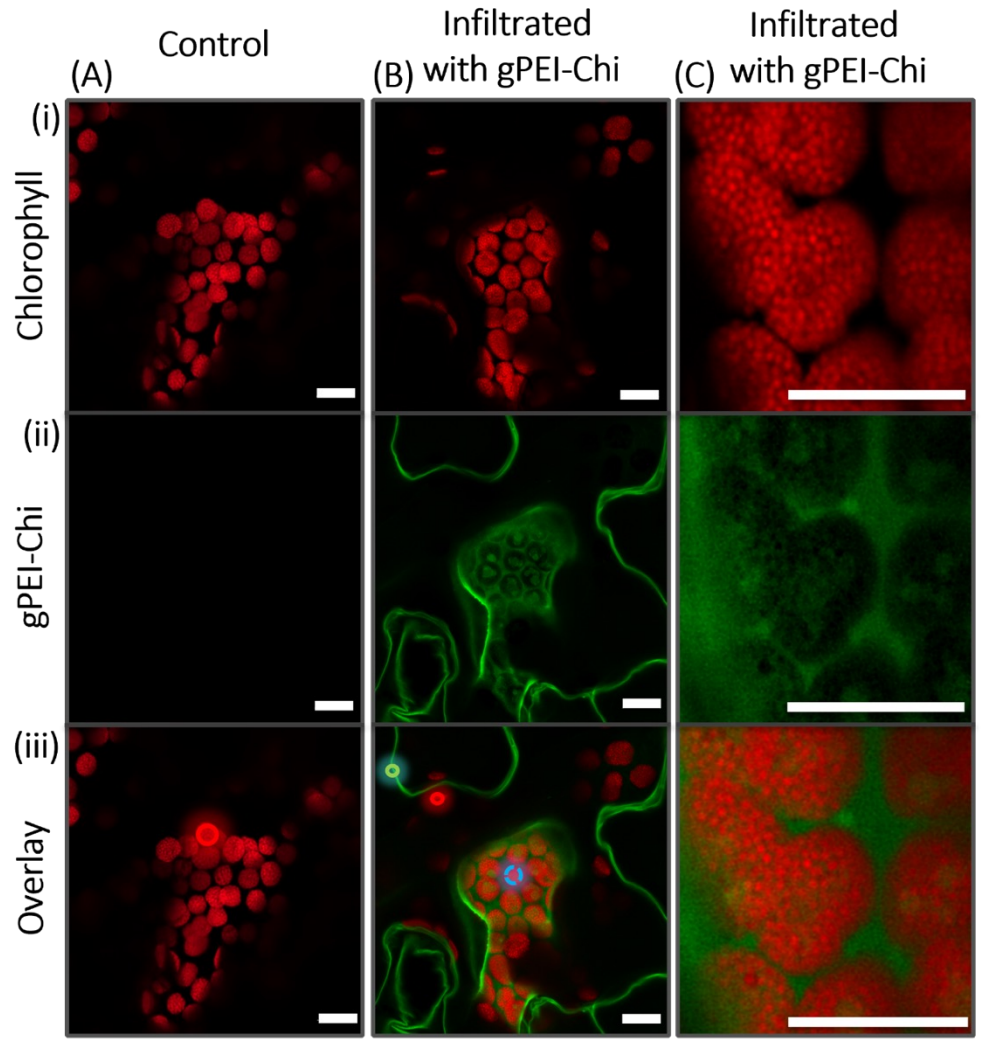
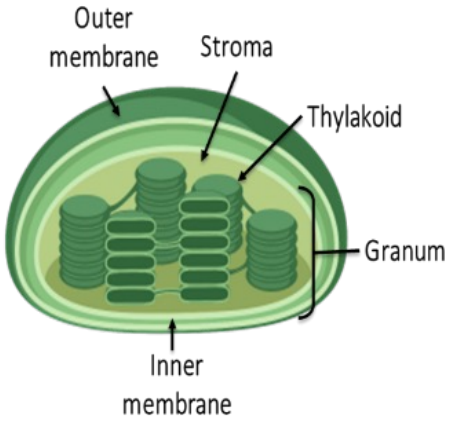
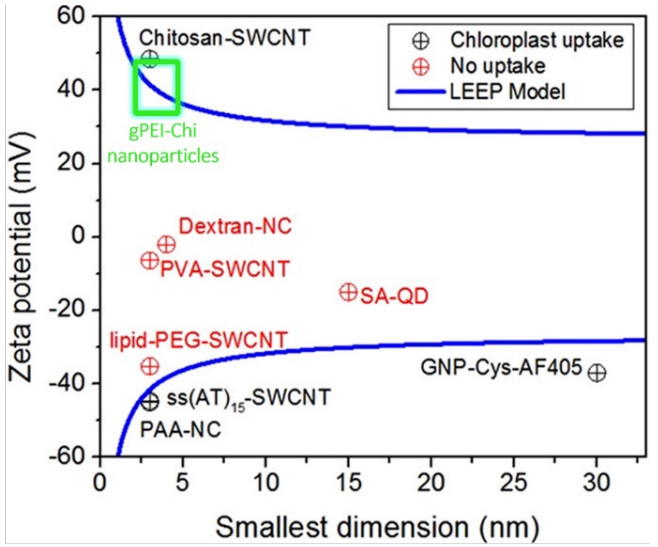
Routier, Vallan, Stavrinidou et al. ACS Nano, https://doi.org/10.1021/acsnano.2c09255

PEI-Chi nanoparticles localize in the chloroplasts







LEEP model developed by Strano group MIT

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Routier, Vallan, Stavrinidou et al. ACS Nano, https://doi.org/10.1021/acsnano.2c09255

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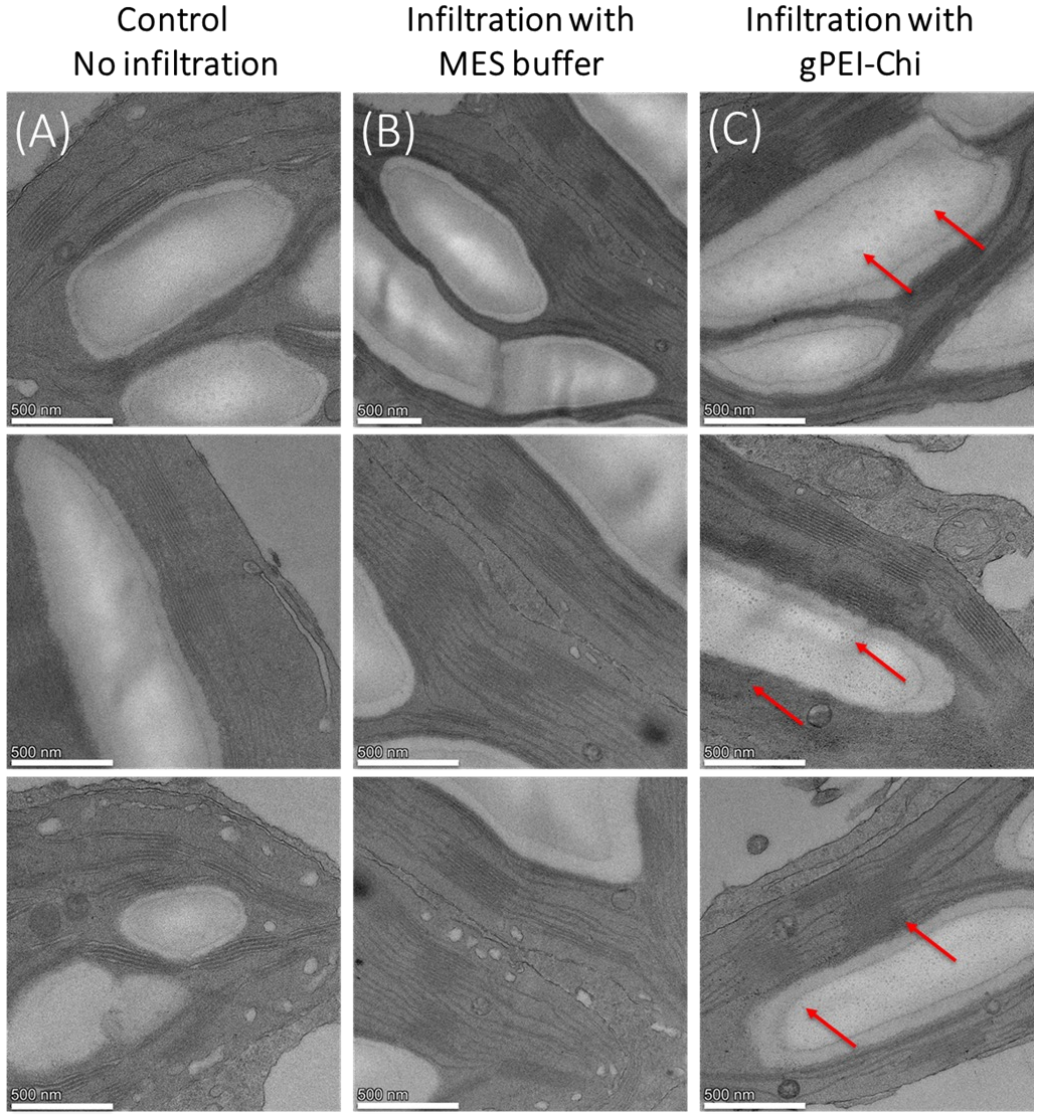

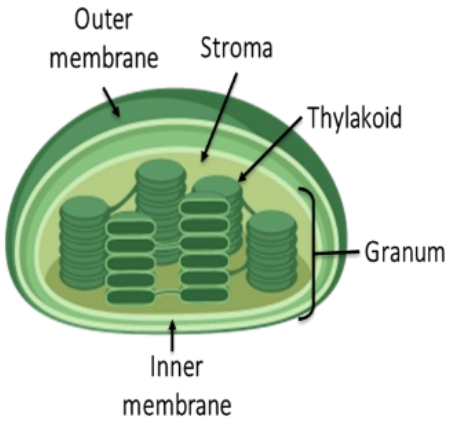

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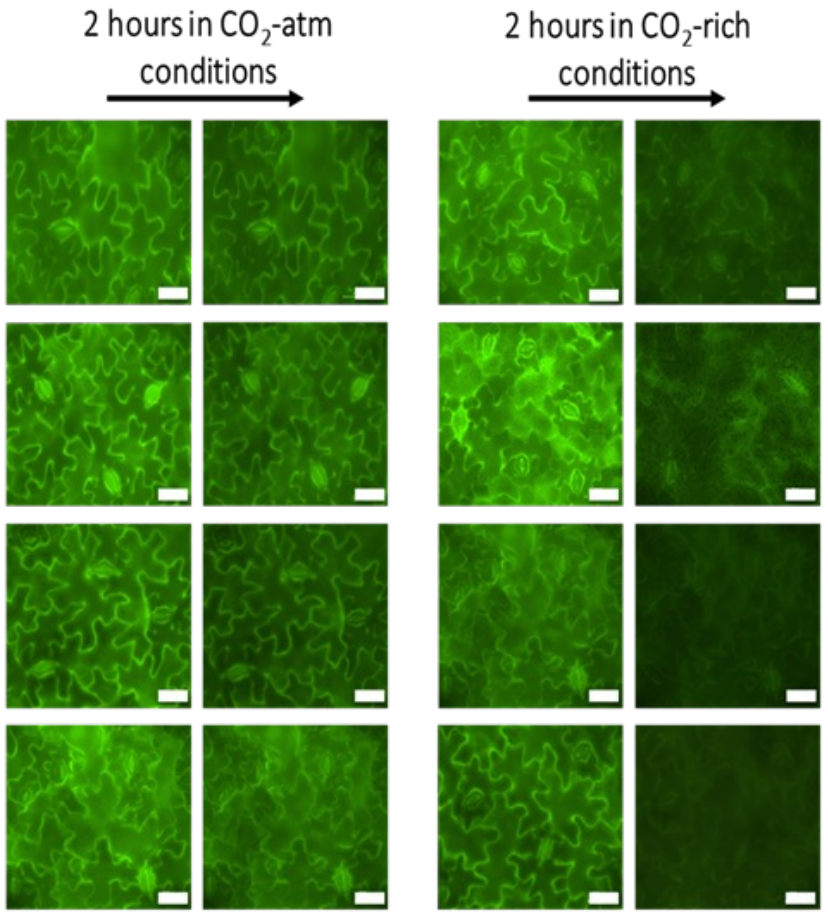
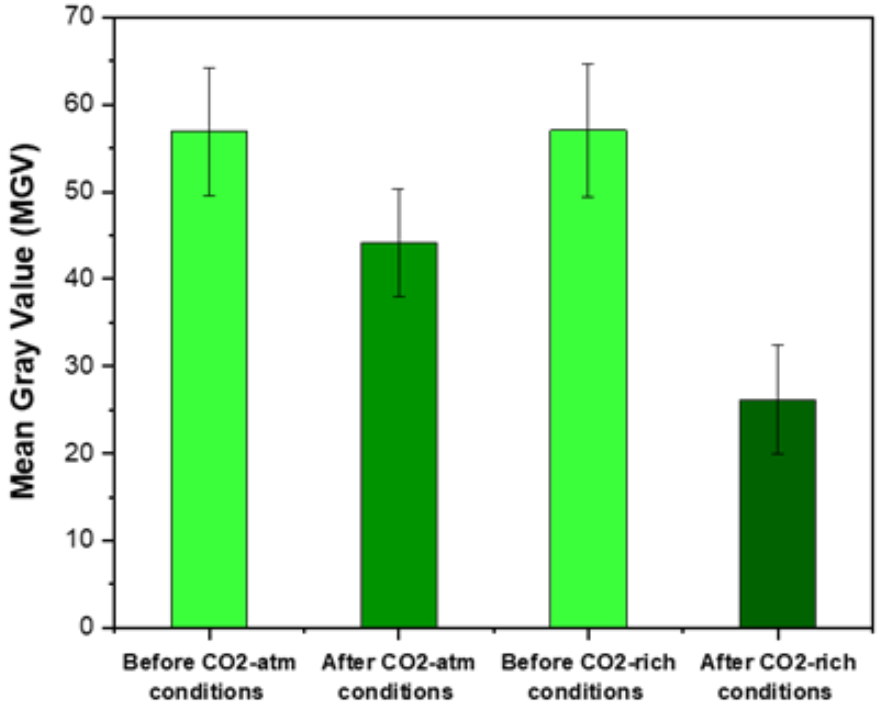
PEI-Chi nanoparticles can capture CO_2 in-vivo

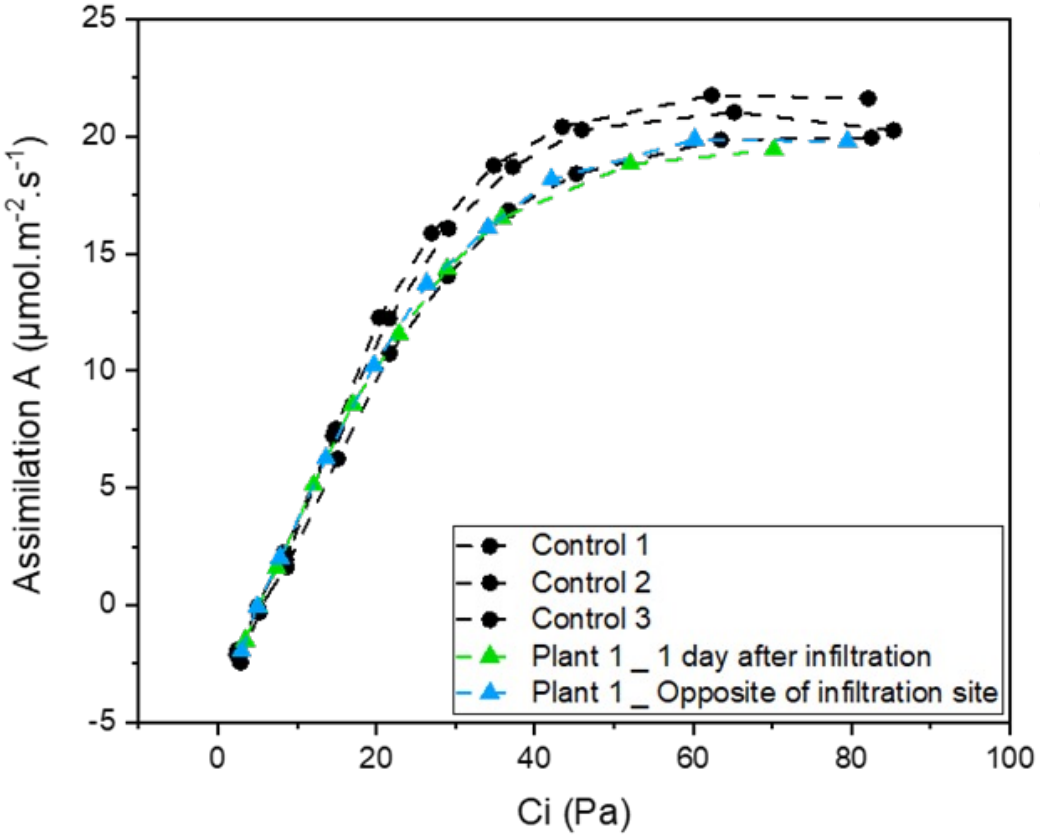




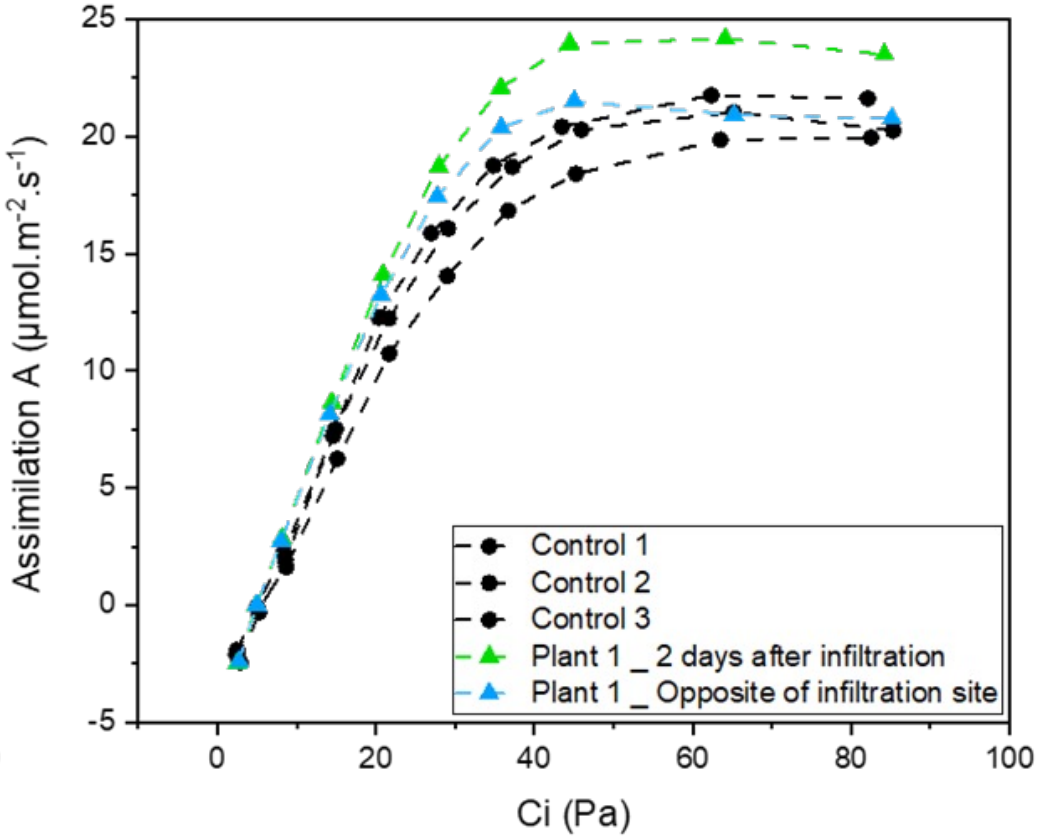
Routier, Vallan, Stavrinidou et al. ACS Nano, https://doi.org/10.1021/acsnano.2c09255

PEI-Chi nanoparticles may impact C assimilation of plants

1 day after infiltration



2 days after infiltration



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Acknowledgments

e-Plants group

eleni.stavrinidou@liu.se

Prof. Eleni Stavrinidou | Dr. Gwennael Dufil | Daniela Parker | Dr. Iwona Bernacka-Wojcik | Vasileios Oikonomou | Alexandra Sandhén | Cyril Routier | Dr. Johannes Gladisch | Erica Colaprico | Abdul Manan Dar

@ePlants_at_LiU

Laboratory of Organic Electronics

Collaborators:

- Prof. Totte Niittylå (UPSC)
- Dr. Loic Talide (UPSC)
- Prof. Torgny Näsholm (UPSC)
- Dr. Yohann Daguerre (UPSC)
- Dr. Daniele Mantione (POLYMAT)
- Dr. Eleni Pavlopoulou (FORTH)
- Dr. Lorenzo Vallan (LCPO)
- Prof. Magnus Berggren (LiU-LOE)
- Prof. Daniel Simon (LiU-LOE)

Alumni:

- Dr. Ilaria Abdel Azis
- Dr. Adam Moreira
- Dr. Chiara Diacci
- Dr. Jee Woong Lee

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