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Electrochemical biosensors as an emerging data collection tool for plant phenotyping and agriculture

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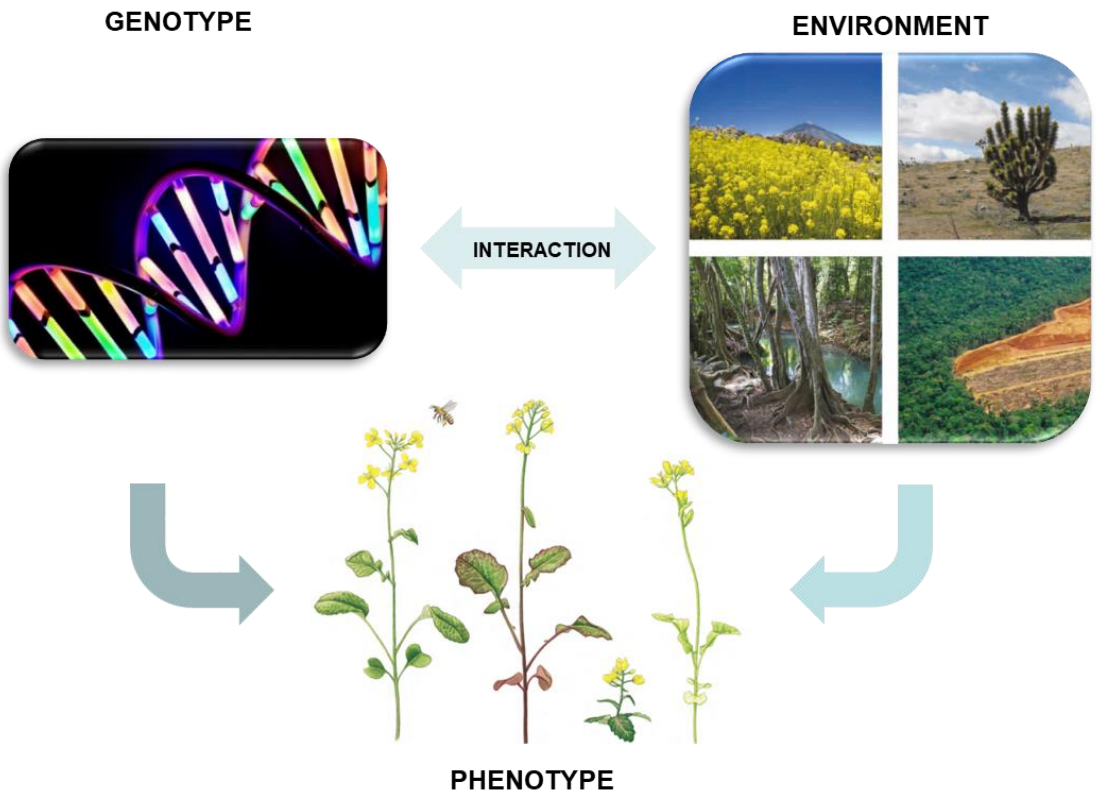
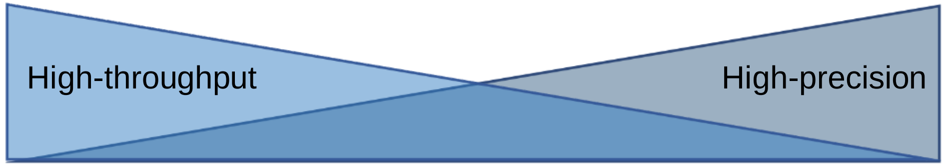
Monitoring of environmental interactions of plants





In vitro bioassaying

Plant-based assays

Whole plant analysis

Key words: Phenotype / Non-invasive / Bioassaying / Automation / High-throughput/precission / controlled conditions

What can we do

olophen

phenotyping technologies & methods

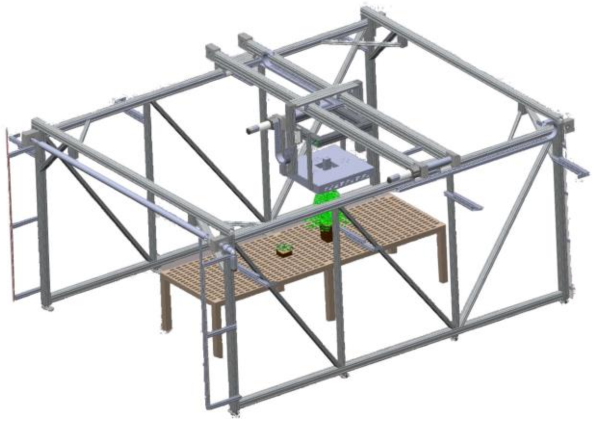
- High-throughput
- High-precision
- Affordable

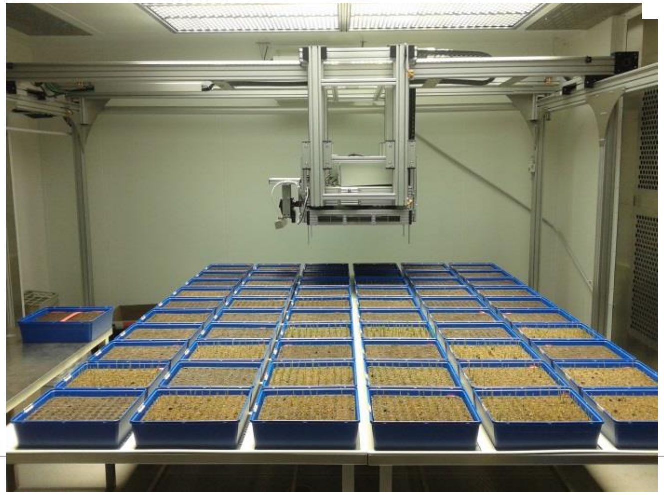
Palacký University
Olomouc

EDUCATION
PARTNER

OloPhen
Top view imaging system XYZ PlantScreen^{TM}

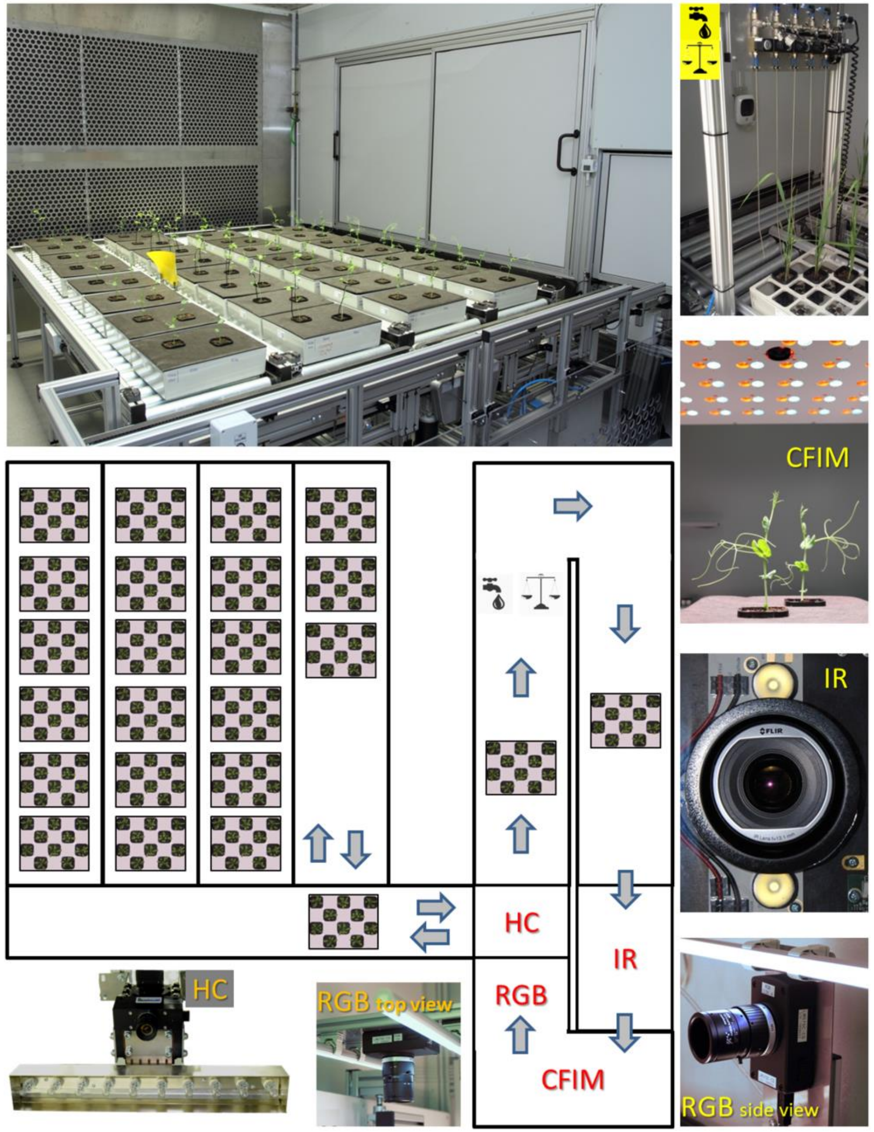
- Controlled conditions
- plant growth sensor (RGB top view high-resolution camera with homogenous LED lightning)
- sensors of physiological responses:
  - FluorCam unit – Chl flurescence kinetic analysis
  - hyperspectral unit (VIS 380-900 nm)
- capacity: 7.5 square metres (528 culture multiwell plates, 64 trays, 1280 standardized Arabidopsis pots)

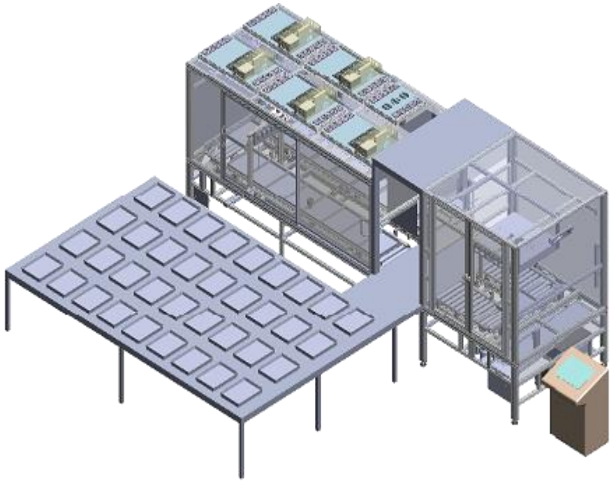


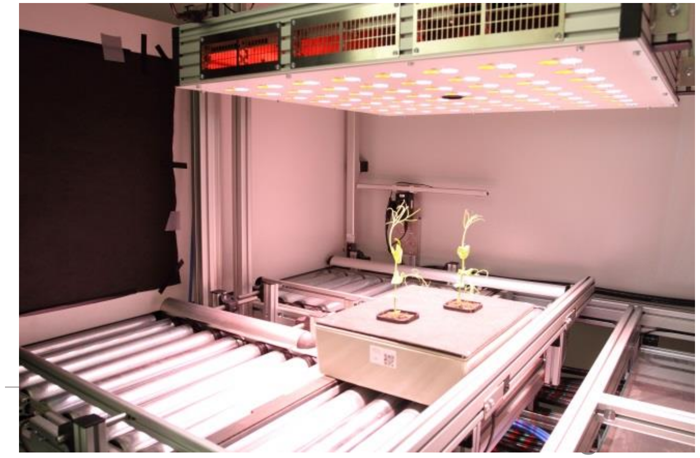


OloPhen
Conveyor PlantScreen^{TM} system

- Controlled conditions
- three RGB cameras, FluorCam, thermoimaging, acclimation cabinet, automatized pot weighing and watering
- capacity: 640 plants for top-view experiments, 64-32 plants for three-views experiments



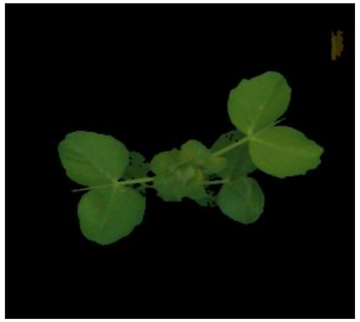




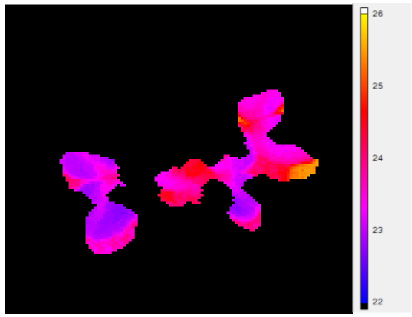
Humplík JF, Lazar D, Husičková A, Spíchal L (2015) Automated phenotyping of plant shoots using imaging methods for analysis of plant stress responses – a review. *Plant Methods,* 11:29.

High-precision phenotyping
In planta assays – stress response

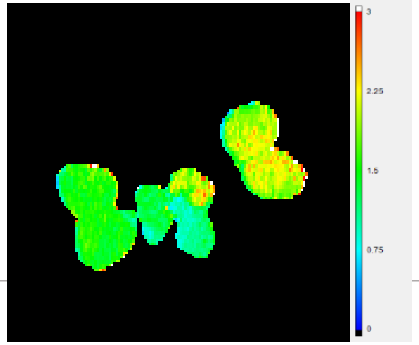
RGB

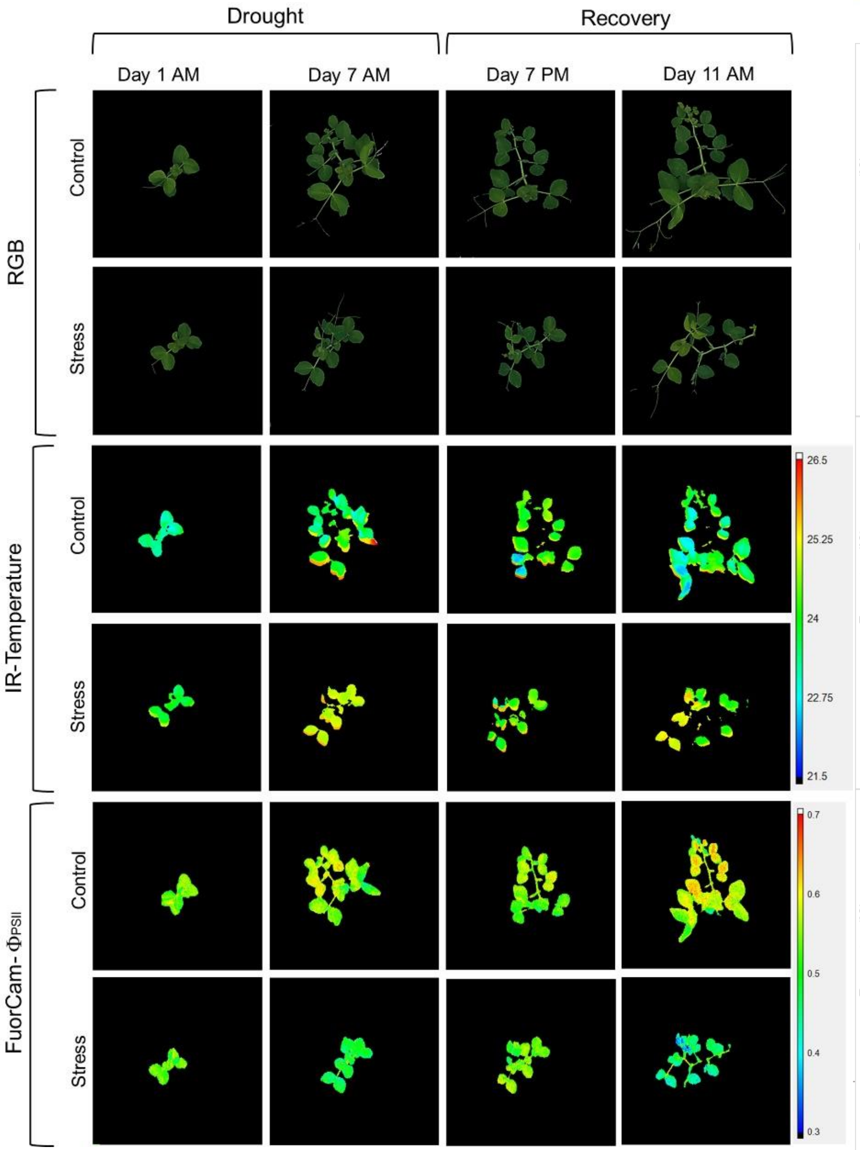


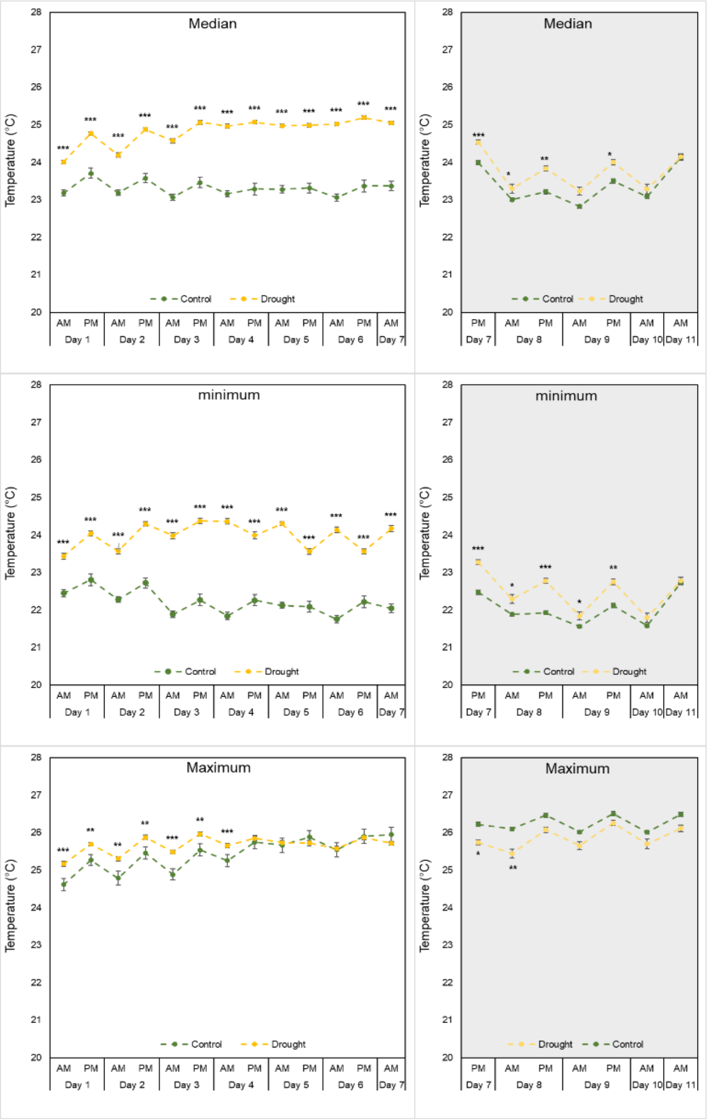
IR



FluorCam







Blicharz et al. (2021). Phloem exudate metabolic content reflects the response to water-deficit stress in pea plants (Pisum sativum L.). Plant J.

What if you want?

1 G x 1 E x 10 R = 10 plants

1 G x 2 E x 10 R = 50 plants

5 G x 2 E x 10 R = 100 plants

1 C x 5 G x 2 E x 10 R = 100 plants

5 C x 5 G x 2 E x 10 R = 500 plants

3 c x 5 C x 5 G x 2 E x 10 R = 1500 plants

3 c x 5 C x 5 G x 2 E x 3 e x 10 R = 4500 plants

3 c x 5 C x 5 G x 2 E x 3 e x 50 R = 22500 plants

T1 → T2 → T3 → T4 → T…

G genotype

E environmental condition

C compound

c compound concentration

e environmental condition level

R repetition

T timepoint

What if you want do it in 2 weeks?

OloPhen
In vitro bioassays – Shoot growth response

- Analyses of effect on shoot area of Arabidopsis
  - Stimulation/Inhibition of shoot growth
  - normal conditions / Interaction with stress conditions
  - Salt, temperature, nutrition, drought, chemicals, pathogen response

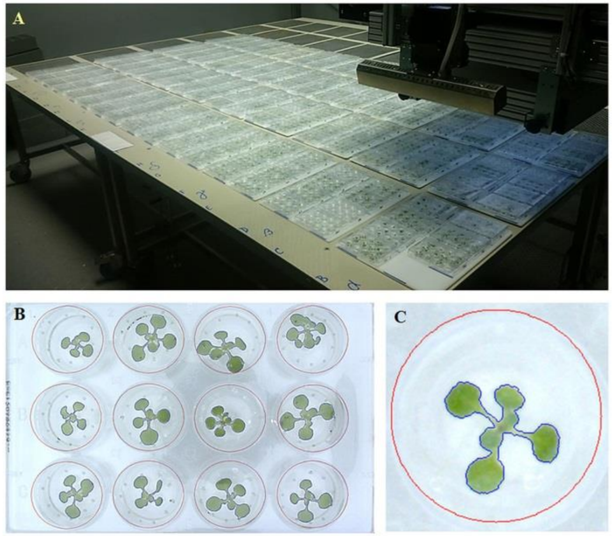
METHODS ARTICLE
Front. Plant Sci., 04 October 2017 | https://doi.org/10.3389/fpls.2017.01702

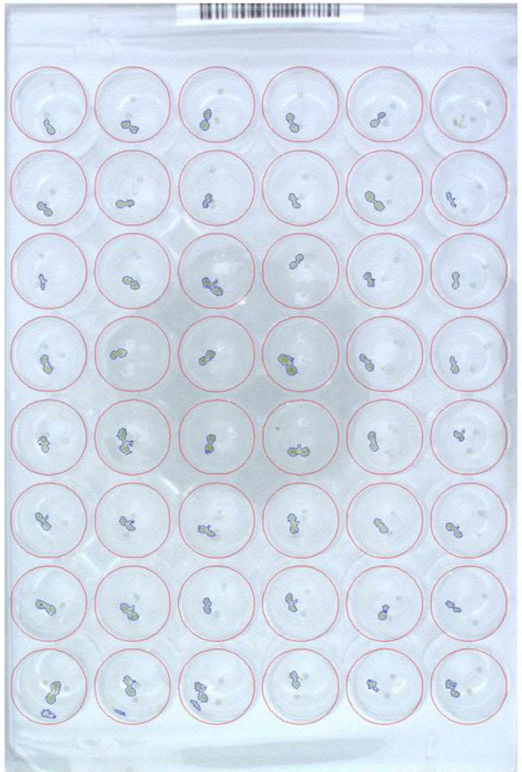
Check for updates

An Automated Method for High-Throughput Screening of *Arabidopsis* Rosette Growth in Multi-Well Plates and Its Validation in Stress Conditions

Nuria De Diego[1], Tomáš Fürst[1], Jan F. Humplík[1,2], Lydia Ugena[1], Kateřina Podlešáková[1] and Lukáš Spíchal[1*]

[1]Department of Chemical Biology and Genetics, Centre of the Region Haná for Biotechnological and Agricultural Research, Faculty of Science, Palacký University, Olomouc, Czechia
[2]Laboratory of Growth Regulators, Centre of the Region Haná for Biotechnological and Agricultural Research, Institute of Experimental Botany, Czech Academy of Sciences, Olomouc, Czechia

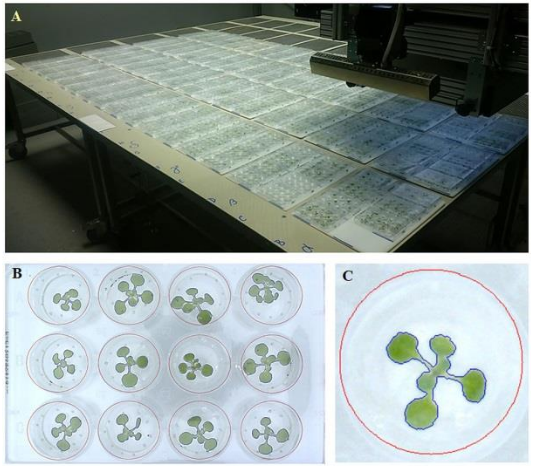




„This approach will allow simultaneous testing of a large number of potentially bioactive compounds in a wide range of concentrations and/or genotypes, under various growth conditions.“ (De Diego et al., 2017)

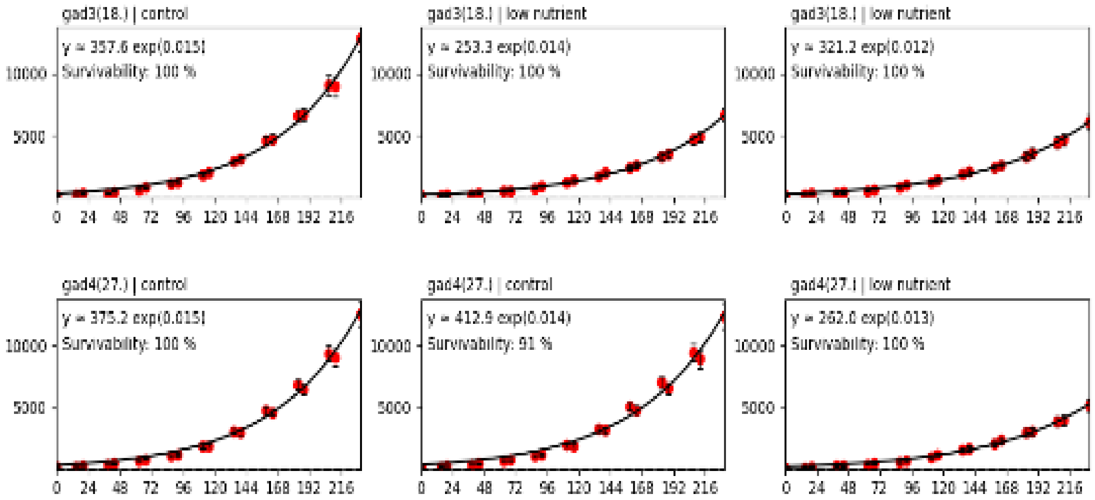
In vitro bioassays – Shoot growth response

6-, 12-, 24-well plates



De Diego et al., 2017

48-well plates



Ugena et al., 2018

Type of well plate	No. plants	Replicates	Platform capacity	Total plants	No. variants	Assay duration
6-Well Plates	6	3		2880	160	14 days
12-Well Plates	12	2	480 Plates	5760	240	9 days
24-Well plates	24	1		11520	480	9 days

48-well plates 528 plates 25344 plants 7 days

48-well plates | 528 plates | 25344 plants | 7 days

1 day / 1 plate

a.m.

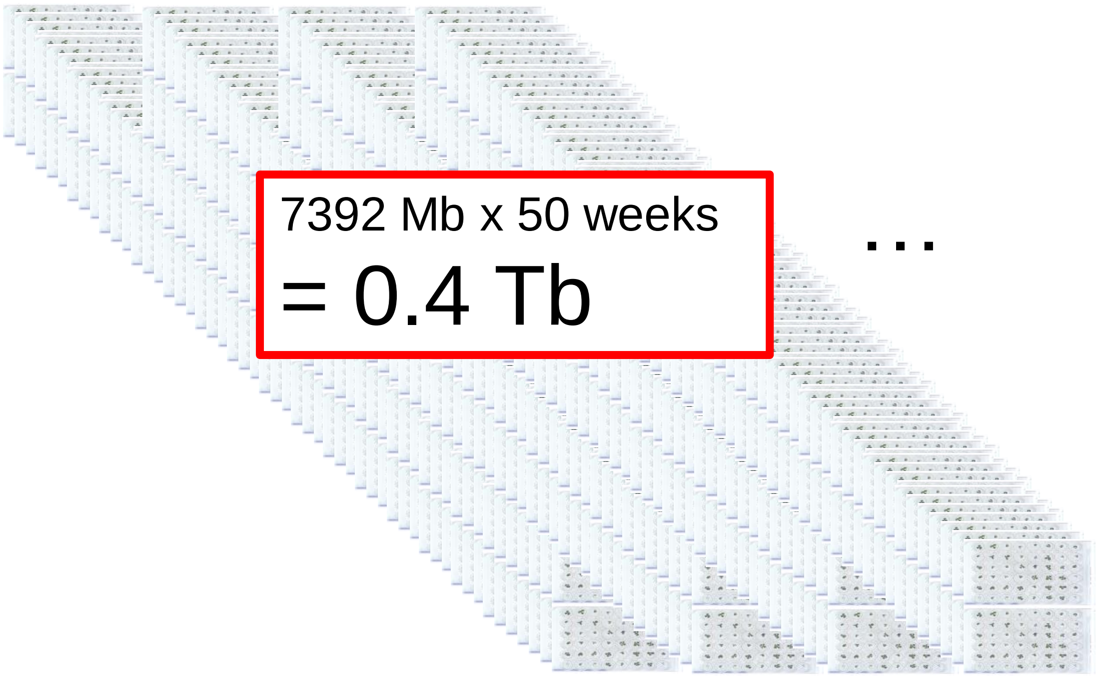
p.m.

2 x 10 Mb = 20 Mb

1 week / 1 plate

2 x 7 x 10 Mb = 140 Mb

1 week / 528 plates



7392 Mb x 50 weeks
= 0.4 Tb

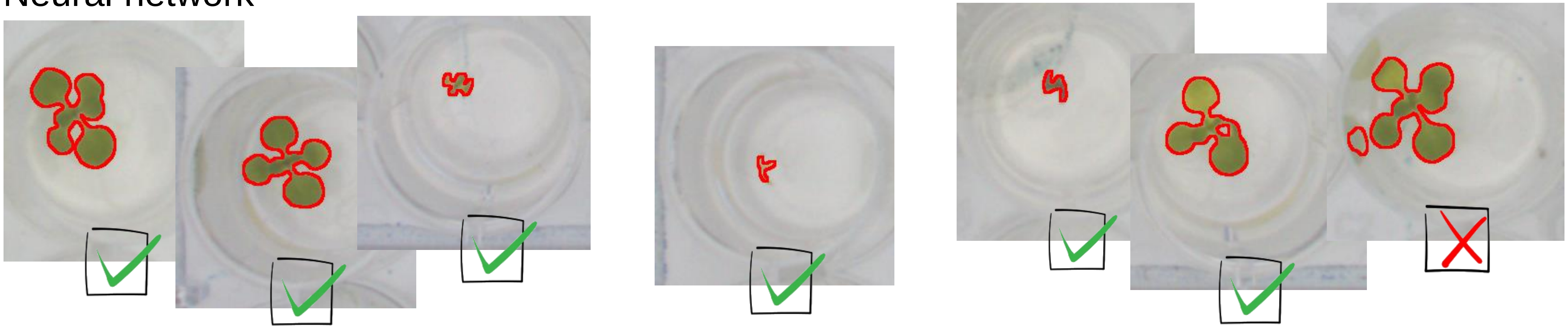
…

2 x 7 x 528 x 10 Mb = 7392 Mb

Software development – Image analysis

- Color based analysis

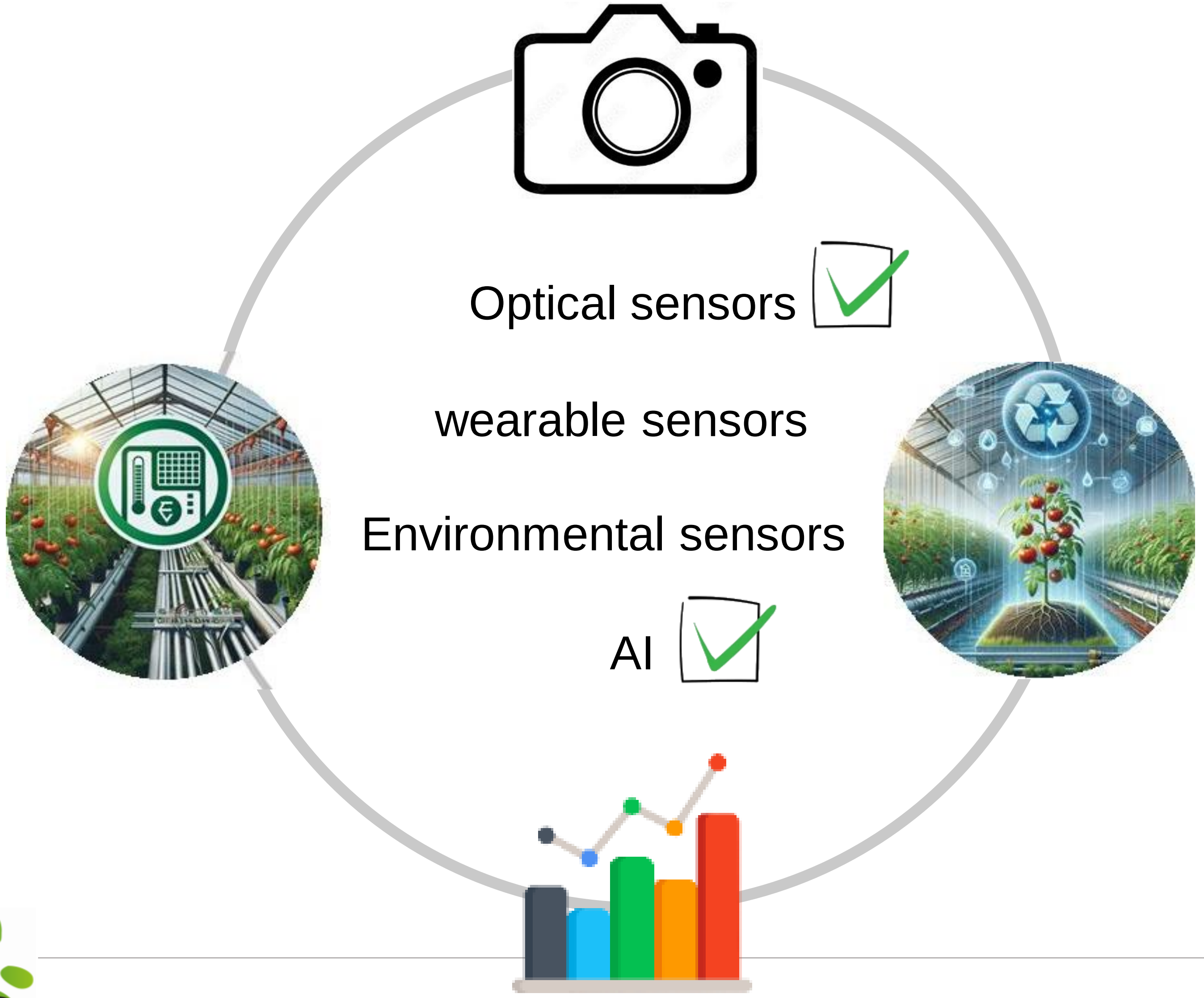
- Neural network

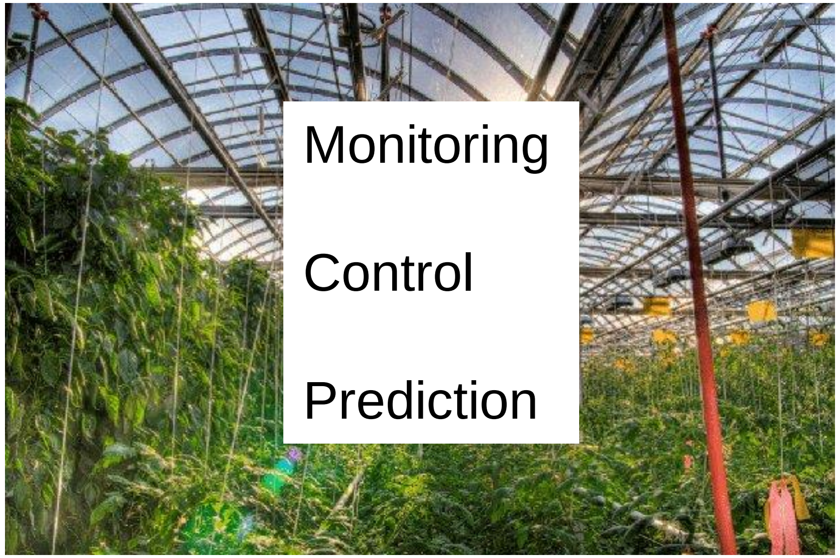


Because the model is only as good as you train it

What we want to do

Integration of data in greenhouses / plant factories





Wearable sensors in plants – state of the art

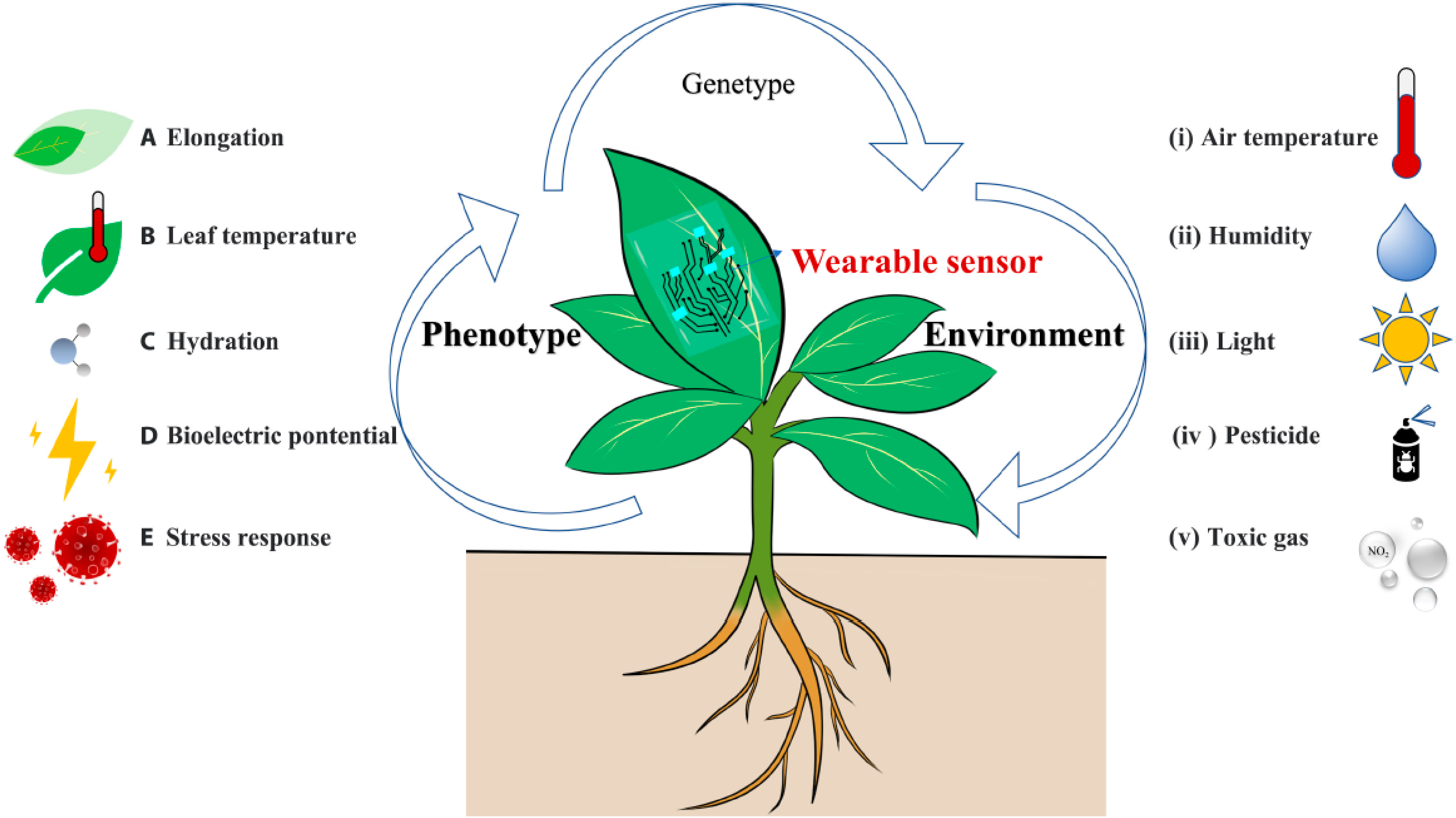


Fig. 1. Wearable sensors for monitoring plant phenotypes and environment.

Zhang et al. 2023 | https://doi.org/10.34133/plantphenomics.0051

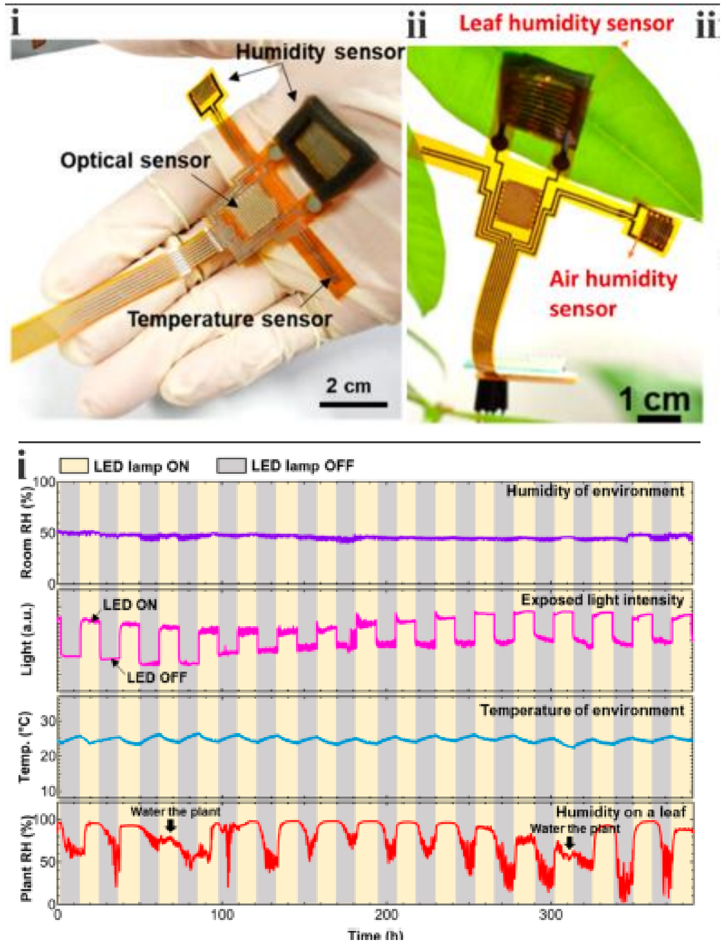
2

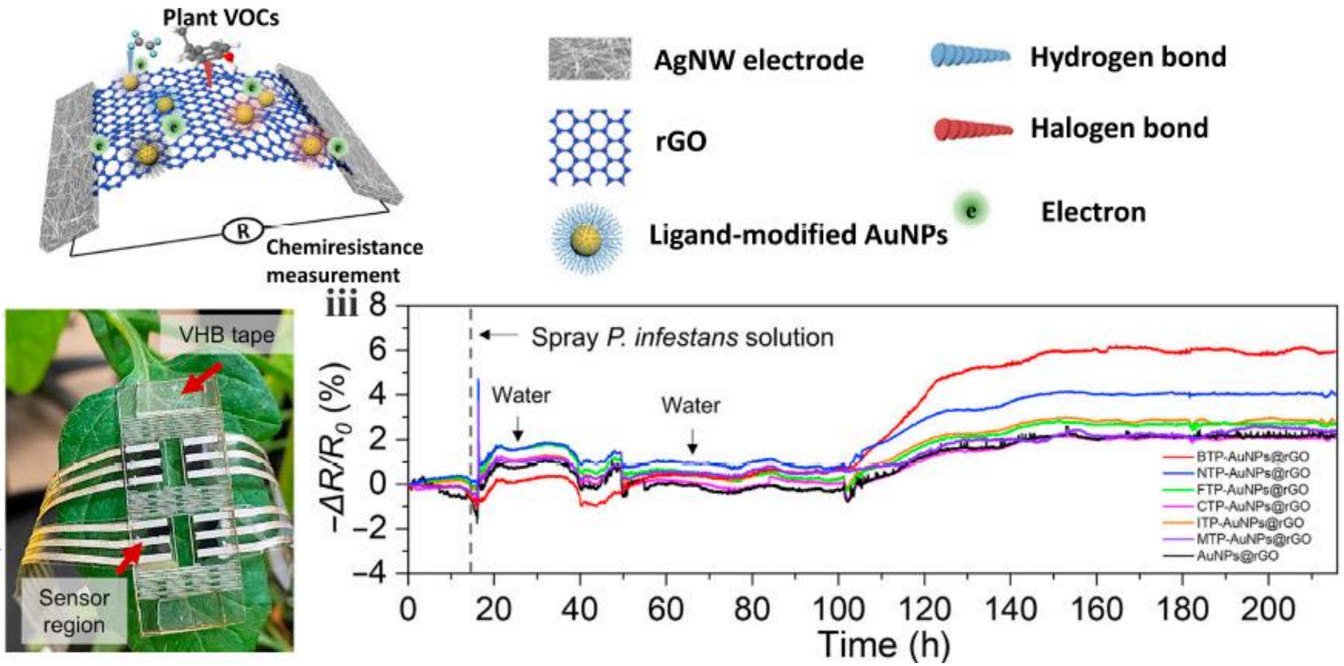
Wearable sensors in plants – state of the art

Phenotypes	Sensor	Plant	Ref.
Elongation	A Ti/Au-based strain sensor	Barley and lucky bamboo	[50]
	A chitosan-based sensor	Cucumber	[54]
	A carbon nanotube/graphite-based strain sensor	*Cucurbita pepo*, *Solanum melongena* L.	[39]
	A liquid-alloy-based sensor	Sprout	[55]
Temperature	A tag sensor	/	[56]
	A "dust" network of wireless sensors	Melon	[40]
	An RFID-based system	Pumpkin	[58]
Hydration	A PI-based sensor	Tobacco	[64]
	A GO-based humidity sensor	*Epipremnum aureum*	[41]
	A graphene-based sensor	Maize	[69]
	A Cu-based flexible electronic sensor	Watermelon	[70]
Bioelectric potential	BDD electrodes	*Opuntia*	[73]
	BDD /Nafion and BDD/ Vylon electrodes	*Aloe* and *Opuntia*	[42]
	Thermogel-based morphable ionic electrodes	Sunflower and tobacco	[48]
	Self-adhering electrodes	*Dionaea muscipula*, *Arabidopsis thaliana*, and *Codariocalyx motorius*	[74]
Stress response	A graphene-based sensor array	Tomato leaf	[80]
	Conductive polymer electrodes	*Hosta* and pothos seedling	[82]
	Conductive polymer electrodes	Grape leaf	[44]

Zhang et al. 2023 | https://doi.org/10.34133/plantphenomics.0051

Wearable sensors in plants – state of the art





Zhang et al. 2023 | https://doi.org/10.34133/plantphenomics.0051

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- Adéla Hýlová
- Cintia Marchetti

olophen

CZPPN
CZECH PLANT PHENOTYPING NETWORK

ČZU

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