MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

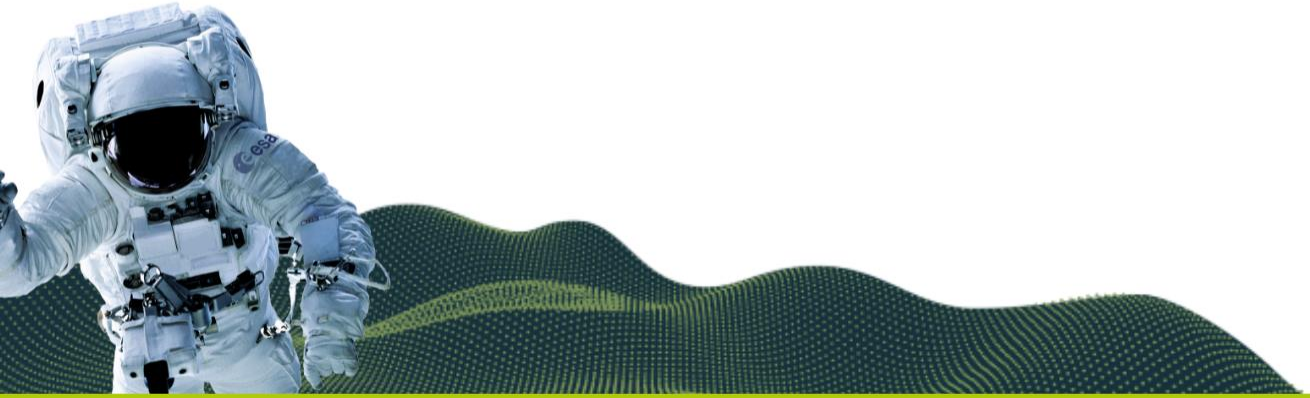
2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR FUTURE

PaCMan UNIT UPGRADE

New subsystems for a deeper investigation of the root zone

Claudia Quadri, Lorenzo Bucchieri, Øyvind Jakobsen



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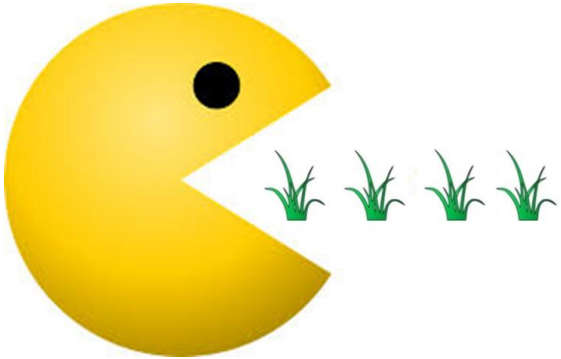


PaCMan 2 Project

PlAnt Characterization unit for closed life support system MaiNtenance, subsystem integration, review and scientific deployment

Outline

The PCU

Hydroponic system upgrade

- Root sampling
- Root monitoring

Conclusions

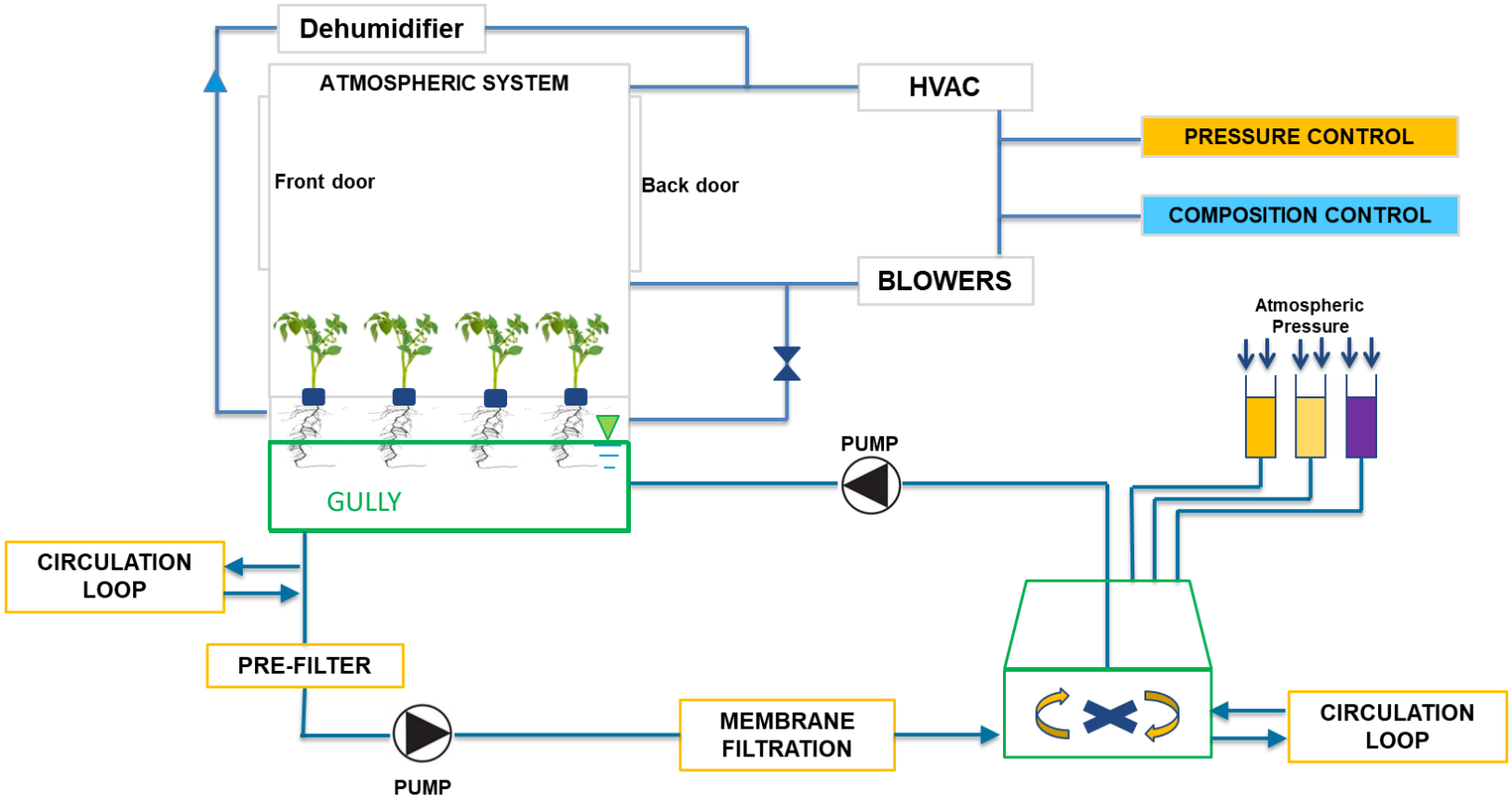
THE PCU

Plant Characterization Unit

Plant Characterization Unit

The PCU is a research facility with closed atmospheric and liquid compartments. It offers scientific studies of various crops under different conditions to characterize crop growth parameters, both in the root zone and aerial zone, as input to the MELiSSA mechanistic model for plant growth.

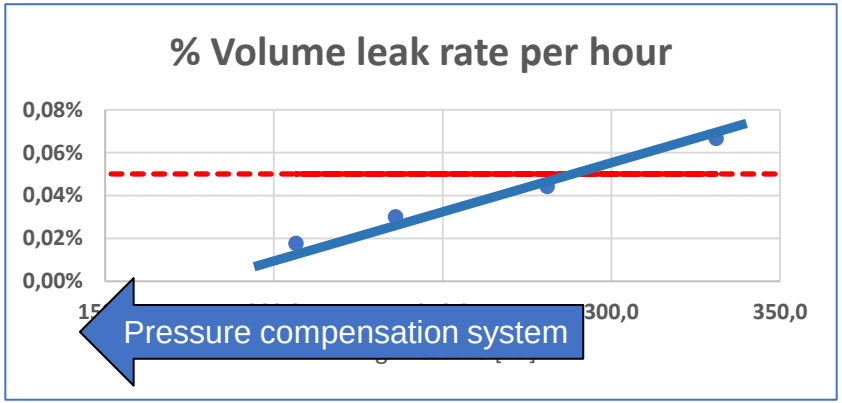
Modular System Architecture



Anti-leakage strategy

Automated Pressure compensation system

Control system ensures to keep gradients from external environment below 50Pa



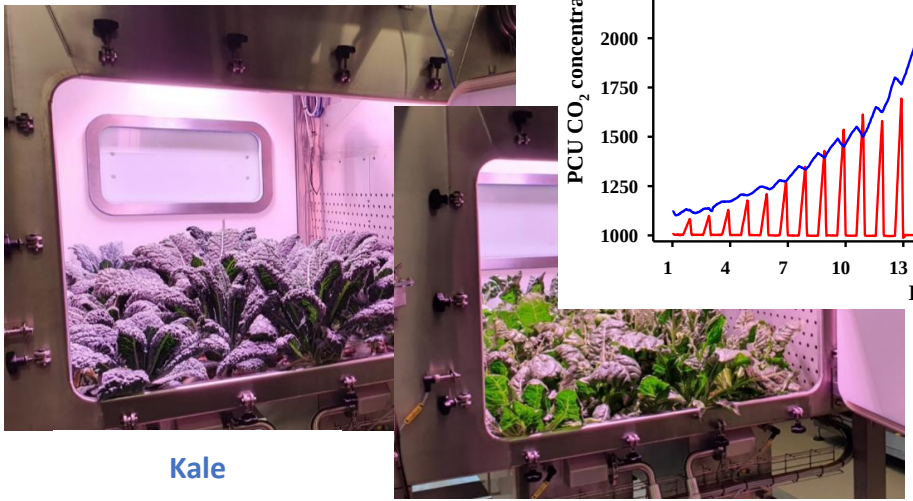
Results achieved comparable with the nuclear industry standard

The anti-leakage property of the PCU gives the possibility to compute mass balances and allows reliable measurements for scientific testing.

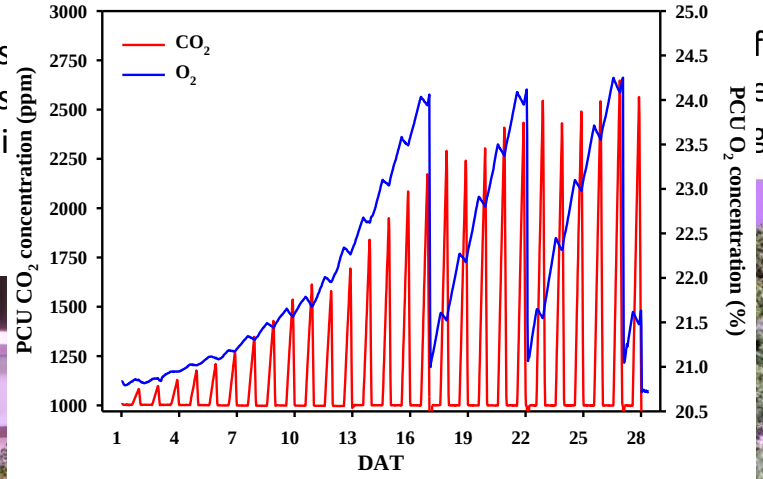
System Validation

Comparison of three leafy vegetable species belonging to three different botanical families:
Asteraceae, Brassicaceae and *Chenopodiaceae*

One of the objectives of the test was
ability to sustain complete crop tests
belonging to different botanical fami



Kale



Lettuce cultivation in a urine recycling scenario: Effects of different NH4:NO3 ratios and NaCl

f the test was to verify the PCU
ete crop tests with different
gies.

Low NH4:N ratio

High NH4:N ratio

HYDROPONIC SYSTEM UPGRADE

Root sampling

REQUIREMENTS

7 requirements were set for the root sampling sub-system:

- Root samples taken once a week during the ongoing life tests
- Root samples to be cut and not torn, gently pinched and not squished.

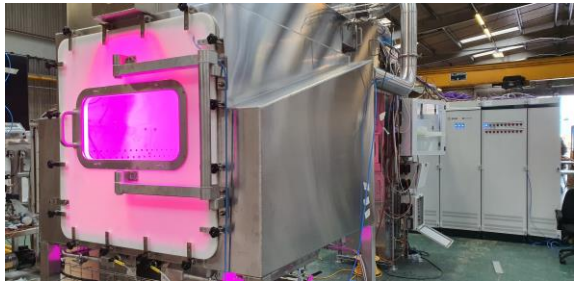
System constraints and layout

Additional Challenges

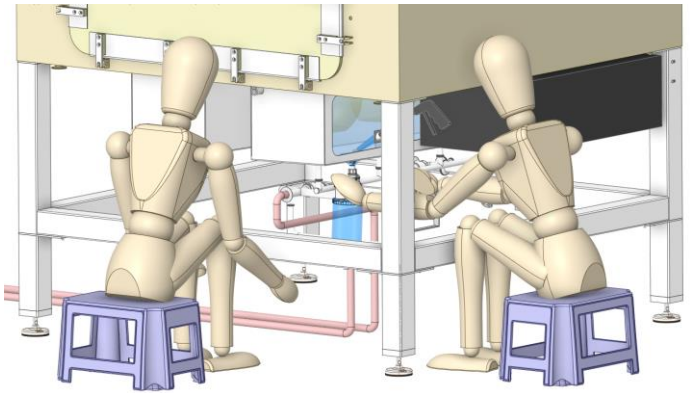
Tangled roots

Lettuce roots – 28 day old

Tightness



Ergonomics

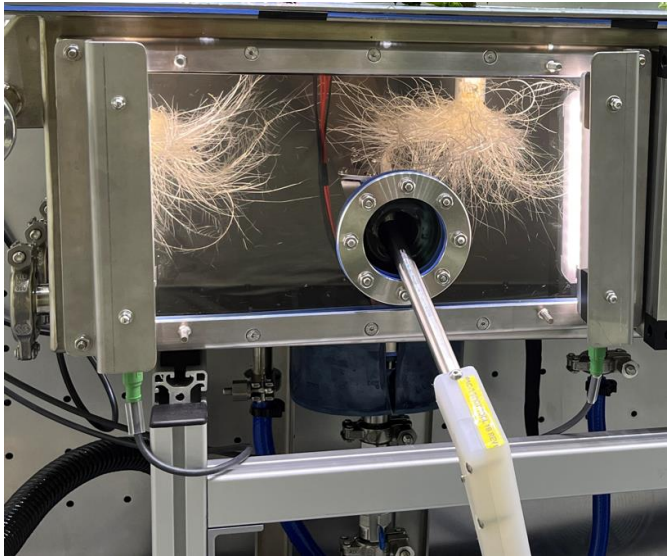


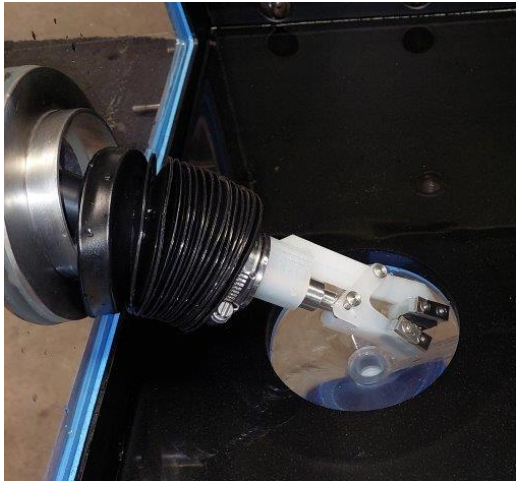
Root sampling

SAMPLING TOOL

The tool has translational and rotational degrees of freedom

The cutting tool has a horizontal blade on the head which facilitates the cutting of vertical roots. Additionally, a rubber gasket has been foreseen to gently pinch the root and at the same time have part of the sample not squeezed by the tool.



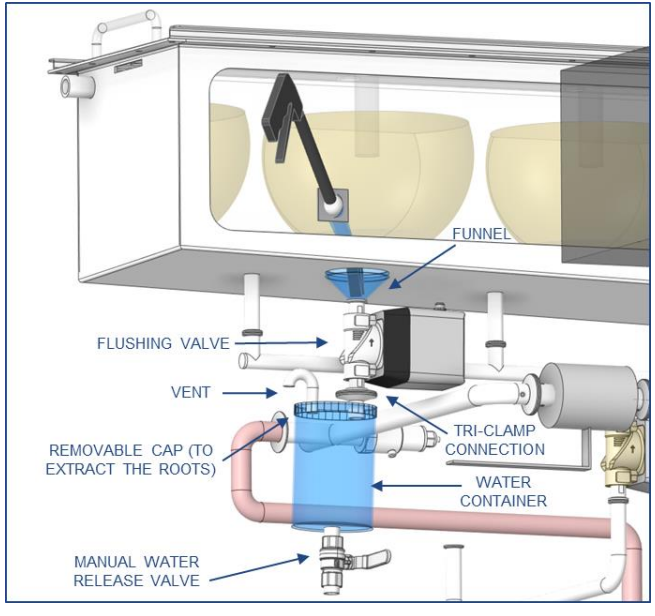


Root sampling

EXTRACTION SYSTEM

By opening the flushing valve just before the sampling tool, a suction pressure will let the sample come out.

The jar allows to collect the samples in a clean way and limits the amount of nutrient solution outflowing together with the roots

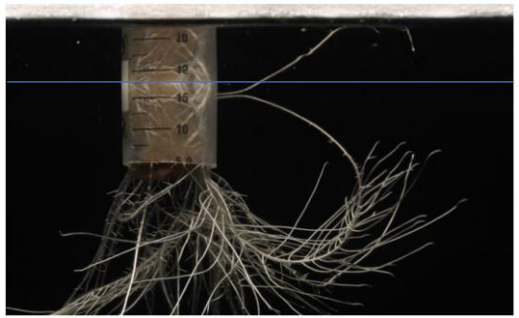


Root monitoring

REQUIREMENTS

Automated, non-destructive, in situ monitoring of roots

Liquid surface acts as a mirror



Walls and front glass reflections

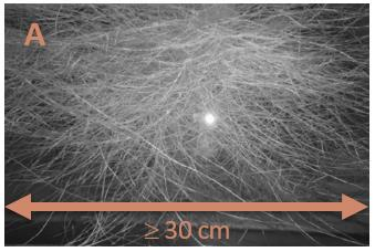
Homogeneous Illumination

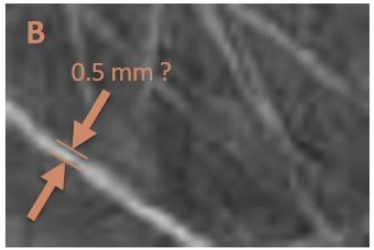
System constraints and layout

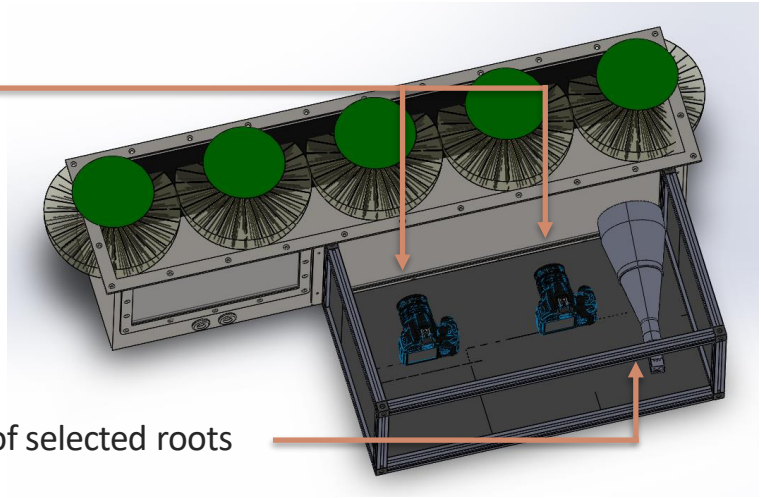
Additional Challenges

Imaging strategies and testing

A. Capture the full root system of two individual plants

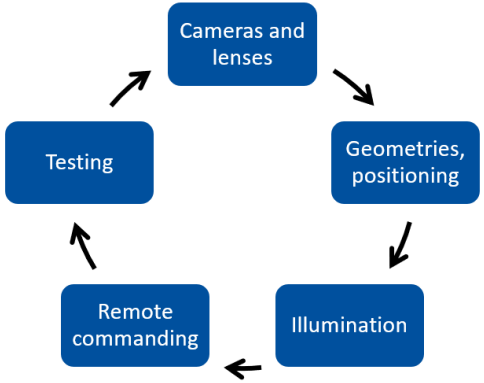






B. Estimate the diameter of selected roots

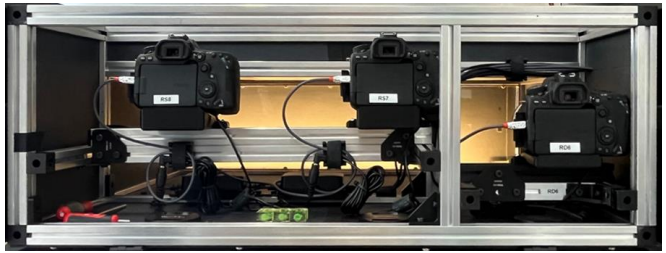
Imaging technologies reviewed, wide range of cameras and lenses identified, theoretically evaluated and a subset tested in breadboard



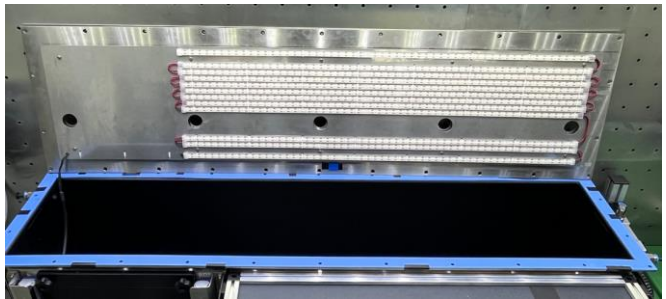
Hardware selection and installation

Final Hardware:

Canon EOS 90D (33 Mpx)
Tamron SP 35mm f/1.4 DI USD
Canon EF 100mm f/2.8L Macro IS USM



Cameras installed in box for mechanical and light protection, alongside gully



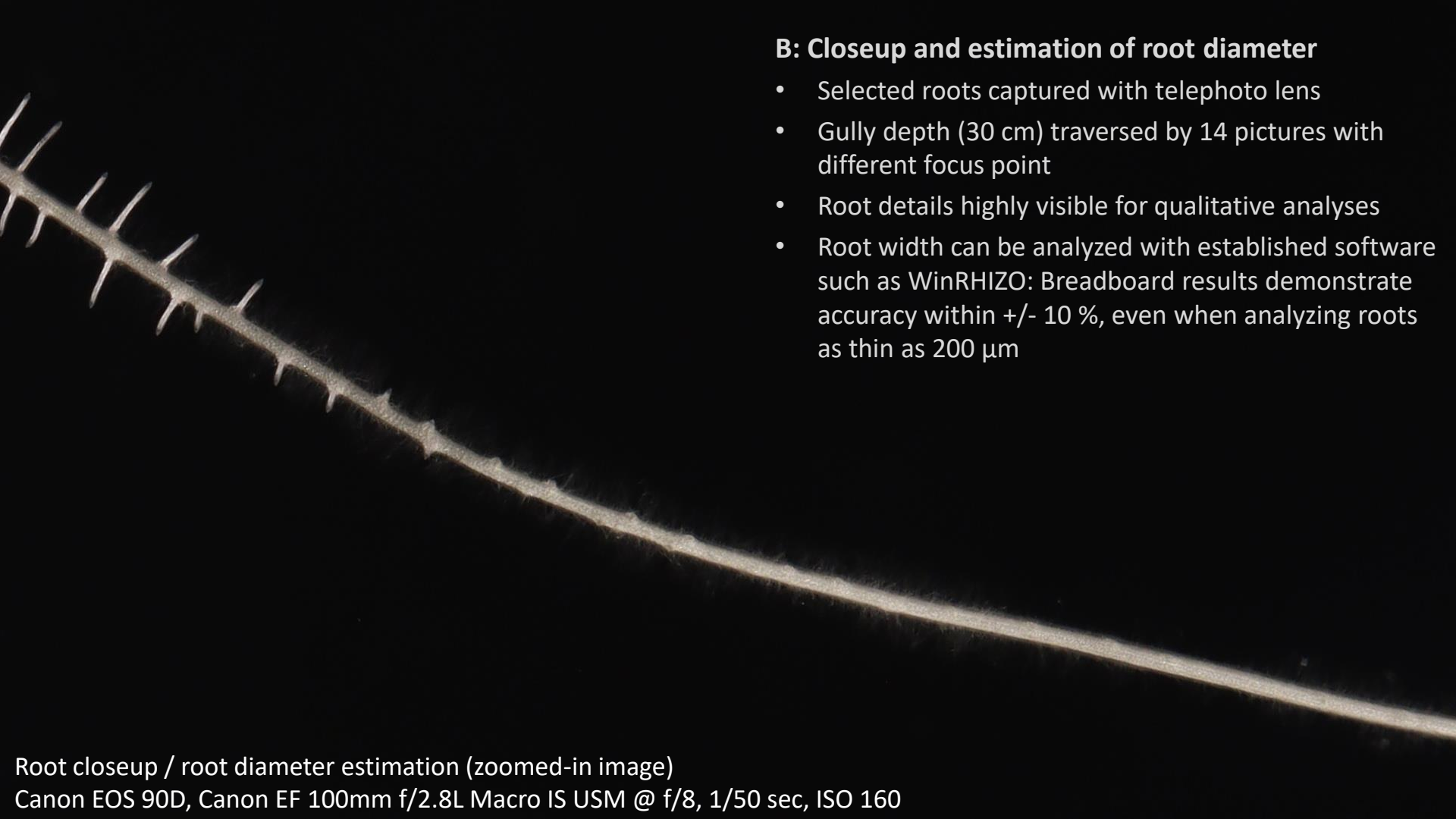
LED strips for illumination installed under the gully lid and inside gully (submerged)

A: Imaging of full root system

- The full root system of one plant (>30 cm width) captured as one image by one camera (deep depth of field)
- System duplicated to monitor two plants
- White roots on black background, minimal overlap with neighbor plants allows easy image segmentation for future post-processing

Full root system of one plant,
Canon EOS 90D, Tamron SP 35mm f/1.4 DI USD @ f/16, 1/40 sec, ISO 400

Root closeup / root diameter estimation (zoomed-in image)
Canon EOS 90D, Canon EF 100mm f/2.8L Macro IS USM @ f/8, 1/50 sec, ISO 200



B: Closeup and estimation of root diameter

- Selected roots captured with telephoto lens
- Gully depth (30 cm) traversed by 14 pictures with different focus point
- Root details highly visible for qualitative analyses
- Root width can be analyzed with established software such as WinRHIZO: Breadboard results demonstrate accuracy within +/- 10 %, even when analyzing roots as thin as 200 µm

Root closeup / root diameter estimation (zoomed-in image)
Canon EOS 90D, Canon EF 100mm f/2.8L Macro IS USM @ f/8, 1/50 sec, ISO 160

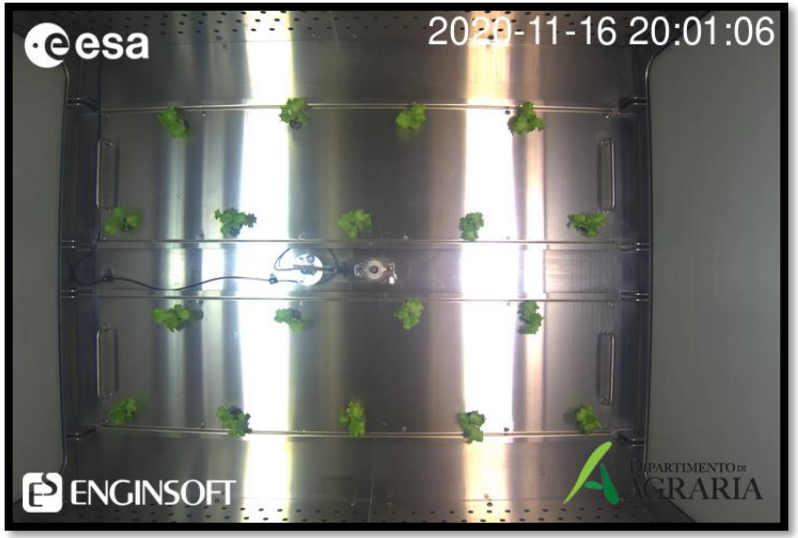
CONCLUSIONS

Conclusions

The PCU is a state of the art research infrastructure, to study and characterize crop development and production.

- The performed life tests demonstrated:
  - Leak performance
  - Reliability in collecting scientific data
  - Reliability in sustain crop tests with different species
  - Nutrient solution flexibility

- The implementation of the new root sub-systems demonstrate the benefit of a **Modular Architecture**
  - Fast replacement of gully (*3 days*)
  - Evaluation of a new lighting system



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Claudia Quadri
EnginSoft

c.quadri@enginsoft.com

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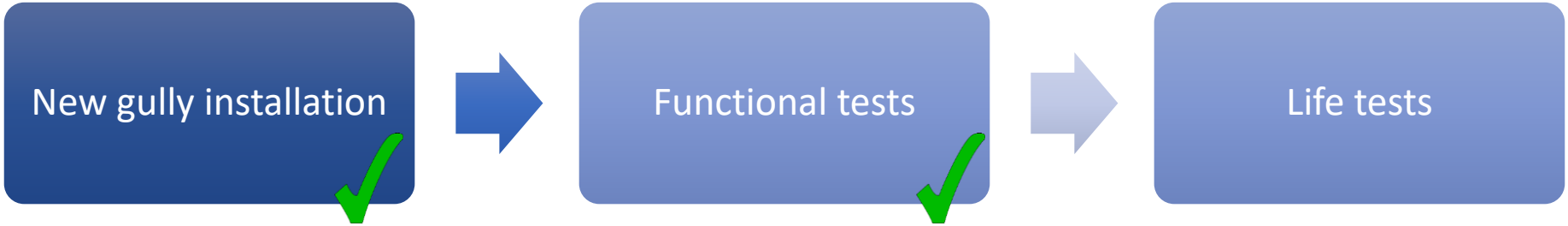
PARTNERS

Ongoing Activity

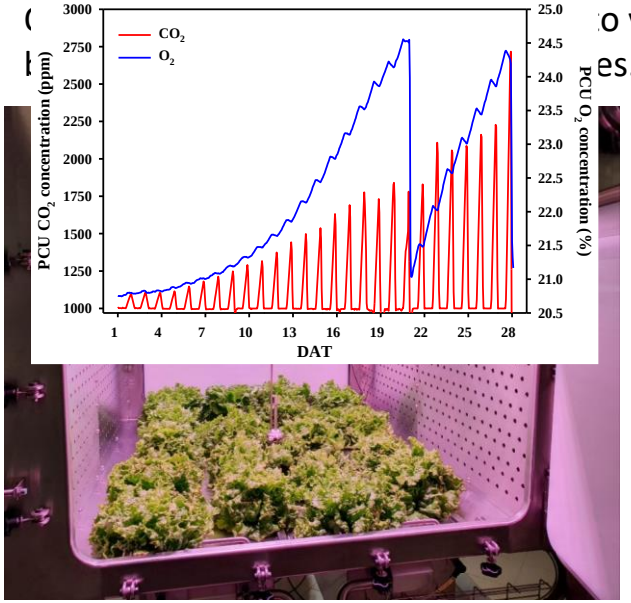


Four test will be conducted using different nutrient solution compositions with the following objective:

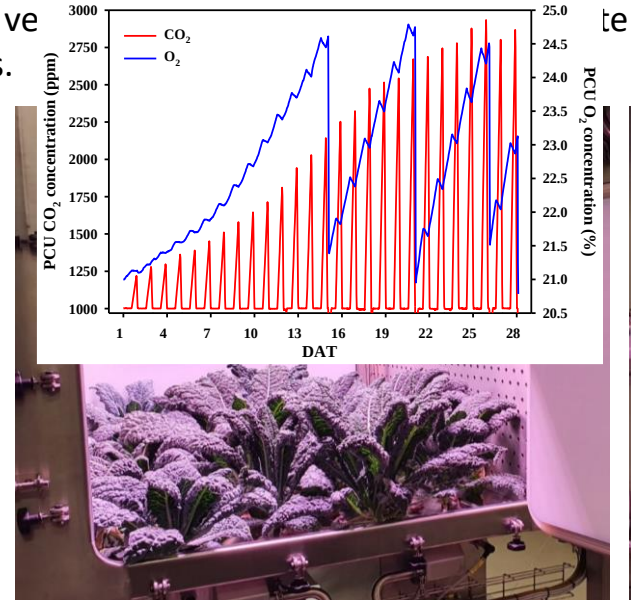
- Validate the two new sub-systems
- Evaluate the PCU performance with the modified gully
- Compare the performance of the two gullies within the same experiments
- Gain scientific knowledge about the impact of sub-optimal mineral nutrition conditions on plant performance (high Na+ concentration and decreased K- concentration)

System Validation

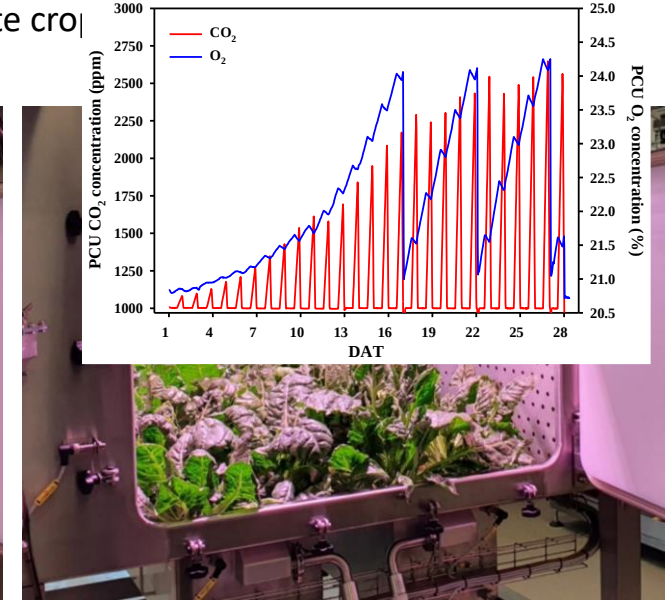
Comparison of three leafy vegetable species belonging to three different botanical families:
Asteraceae, Brassicaceae and *Chenopodiaceae*



Lettuce



Kale



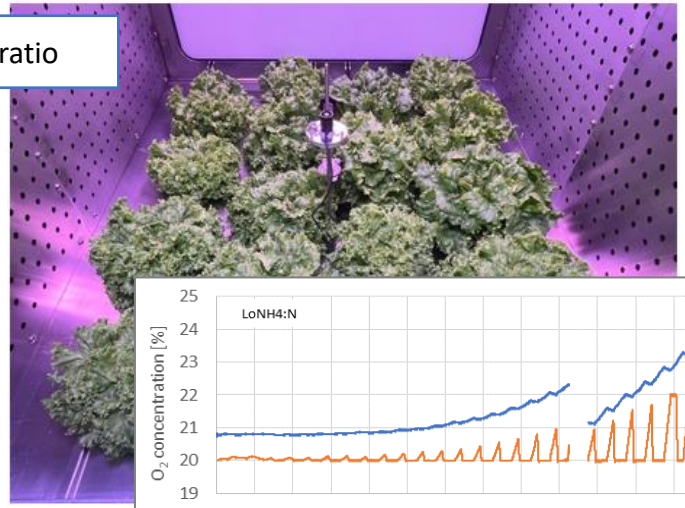
Swiss Chard

System Validation

Lettuce cultivation in a urine recycling scenario: Effects of different NH4:NO3 ratios and NaCl

One of the objectives of the test was to verify the PCU ability to sustain complete crop tests with different nutrient delivery strategies.

Low NH4:N ratio



High NH4:N ratio