MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR **FUTURE**

Characterization of three leafy vegetables in a sealed-off environmentally controlled growth chamber for life support systems

<u>Antonio Pannico</u>, Youssef Rouphael, Luigi Giuseppe Duri, Roberta Paradiso, Stefania De Pascale

Department of Agricultural Sciences

University of Naples Federico II, Portici, Italy

DIPARTIMENTO DI AGRARIA

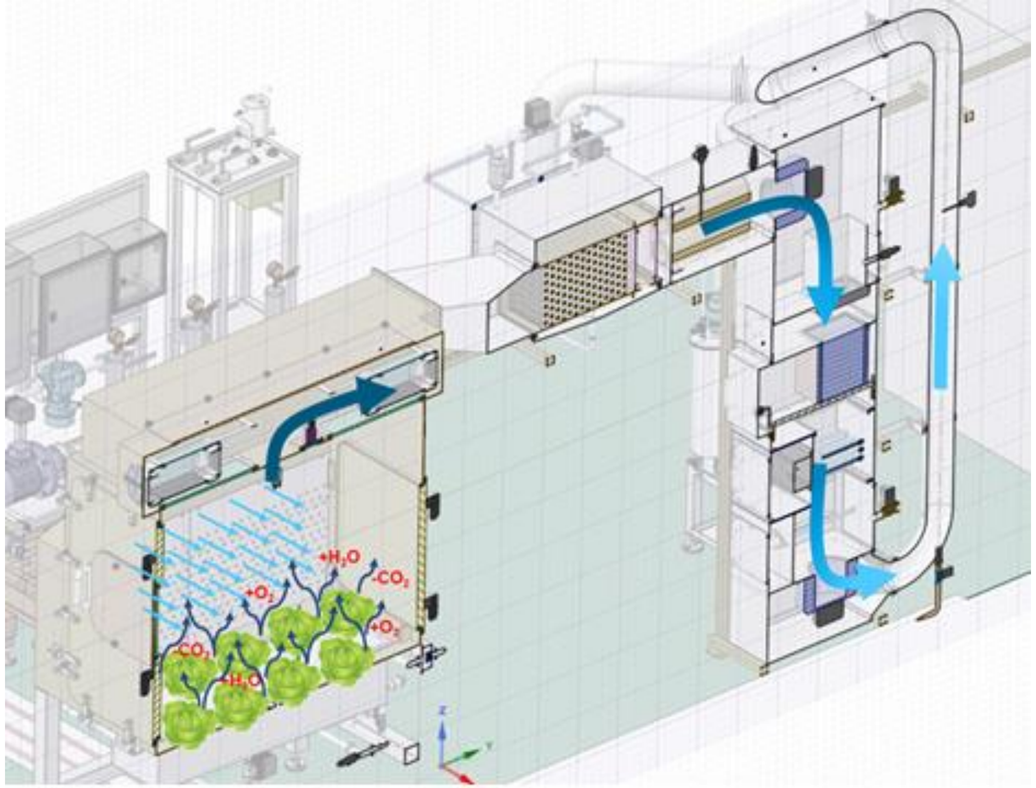
Laboratory of Crop Research for Space

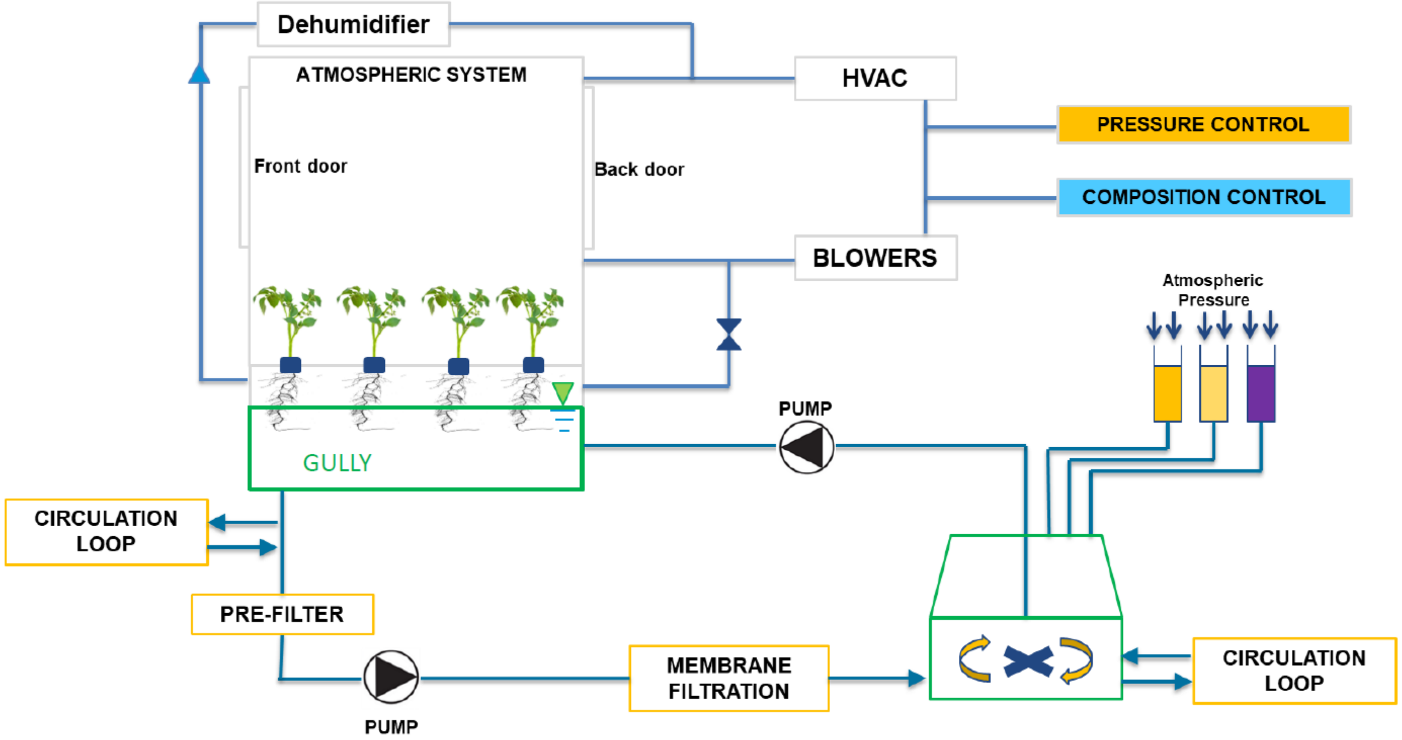
PaCMan - Plant Characterization Unit (PCU)

Laboratory of Crop Research for Space

PaCMan - Plant Characterization Unit (PCU)

Research facility to perform a fine-tuned crop characterization in which is possible to monitor and control independently the root and the aerial zone.



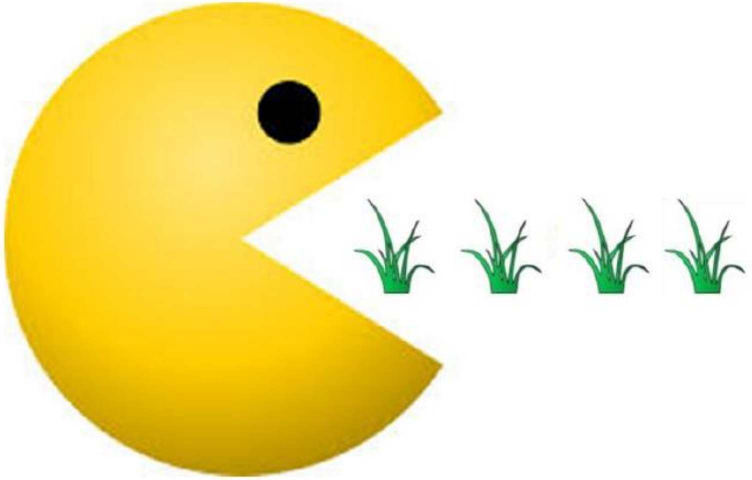


“PaCMan’’ ESA Project

Aims

1) To compare 3 leafy vegetables belonging to different botanical families (*Asteraceae*, *Brassicaceae* and *Chenopodiaceae*) in terms of:

- Growth
- Yield
- Nutrient uptake
- Gas exchanges
- Water purification
- Air regeneration



"PaCMan" ESA Project

Aims

2) To test the reliability of the PCU in terms of:

- Environmental control:
  - Aerial zone: temperature, relative humidity, CO_2 concentration, atmospheric composition (gas analyzer), atmospheric pressure (pressure compensation system)
  - Root zone (nutrient solution): temperature, pH, electrical conductivity, dissolved O_2 and CO_2, mineral contents
- Gas tightness (leakproofness)
- VIS imaging and thermal imaging
- Control system and data acquisition (including GUI software)

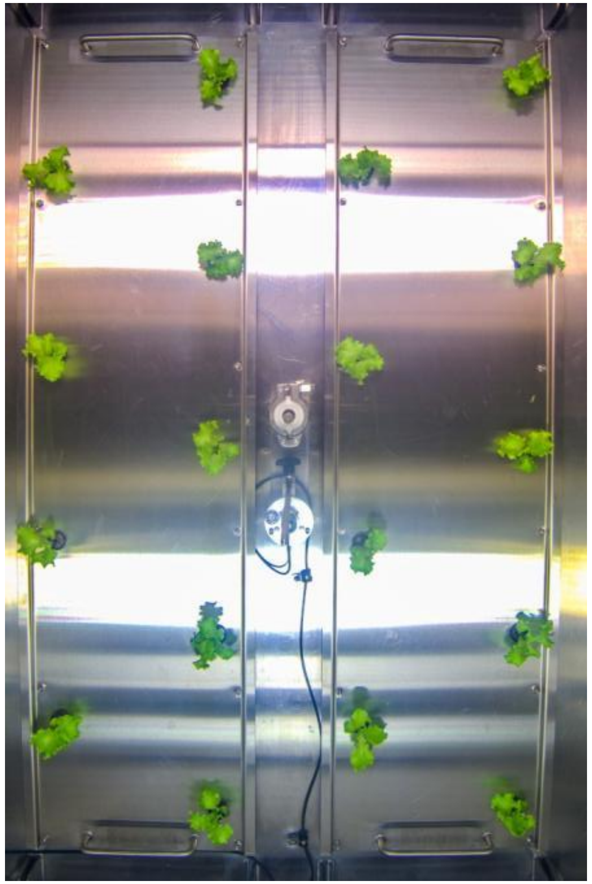
Material and methods

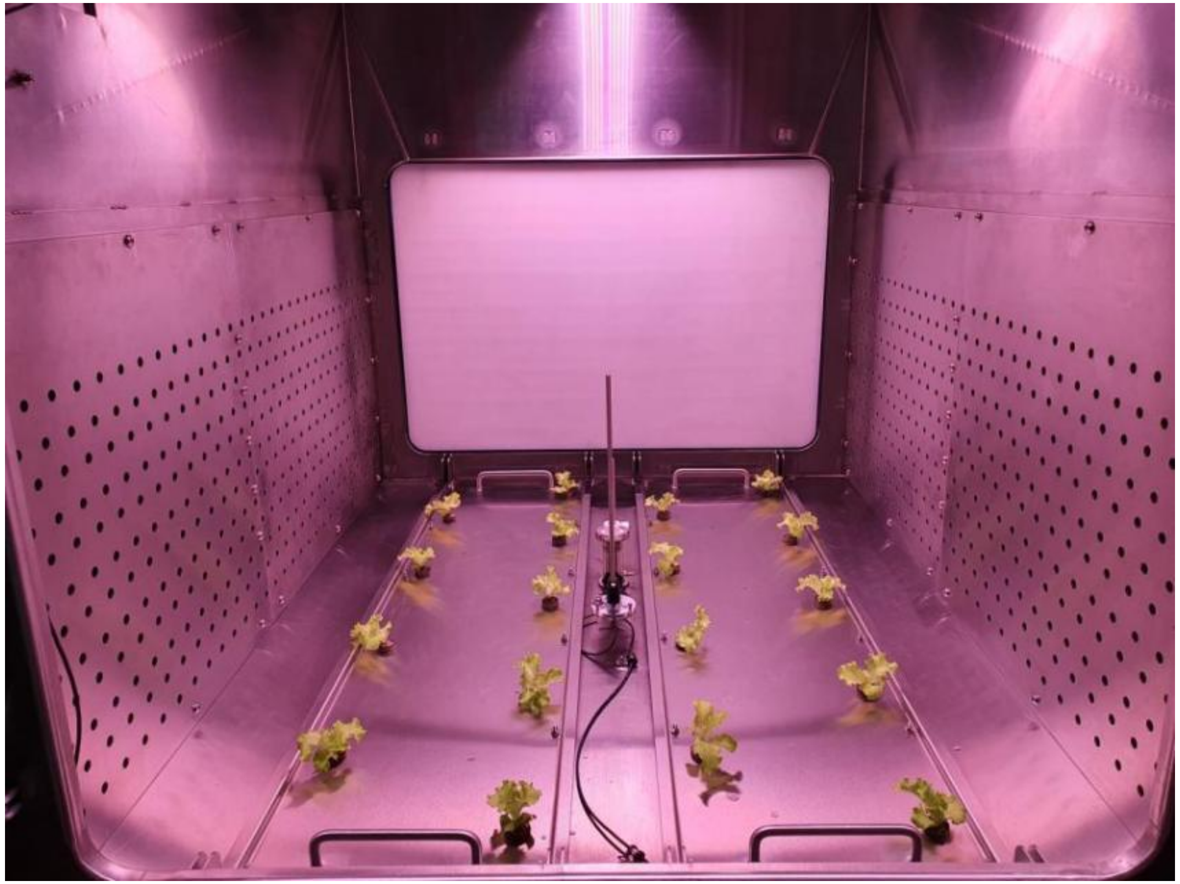
Growth conditions:

- Plant material: lettuce (*Lactuca sativa* L.), kale (*Brassica oleracea* L. var. *acephala*) and swiss chard (*Beta vulgaris* var. *cicla*) seedlings (three fully expanded true leaves)
- PCU cultivated area: 1.8 m^2
- Crop density: 10 plants m^{-2} (18 plants in total)
- Temperature and relative humidity: 26/20°C and 50%/70% RH day/night regime
- Photoperiod: 16h/8h day/night regime
- PPFD: 450 µmol m^{-2} s^{-1}
- CO_2 set point: 1000 ppm
- Nutrient solution set point: EC 1.9 mS cm^{-1} and pH 5.9
- Life Test duration: 28 days

Material and methods

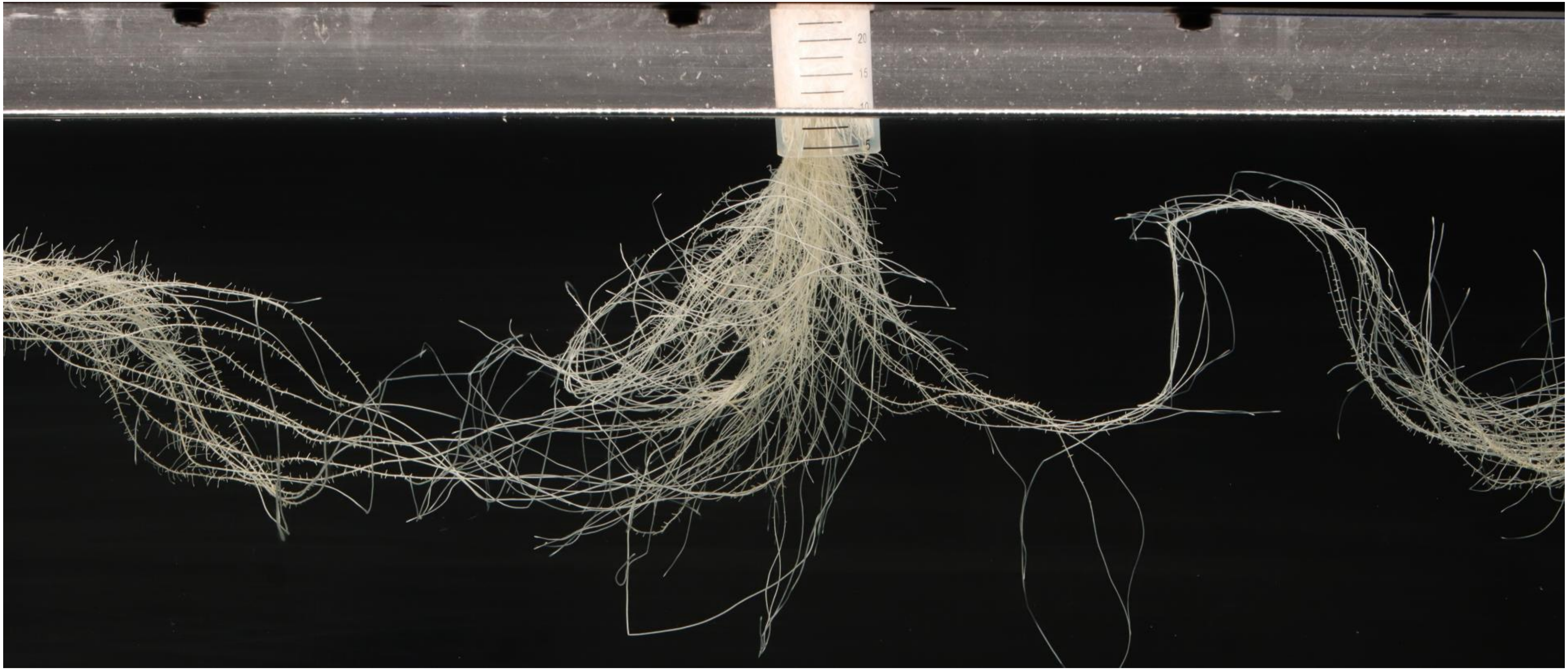
Seedling transplant





Material and methods

Deep water culture system



Material and methods

Plant harvest

Lettuce

Kale

Swiss chard

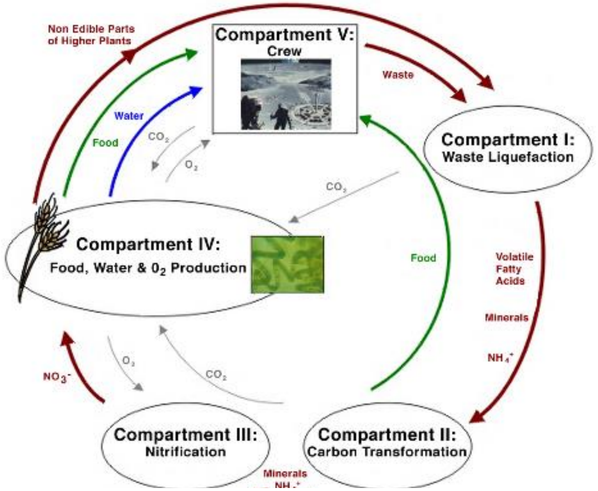
Main results

Biometric characteristics of plants

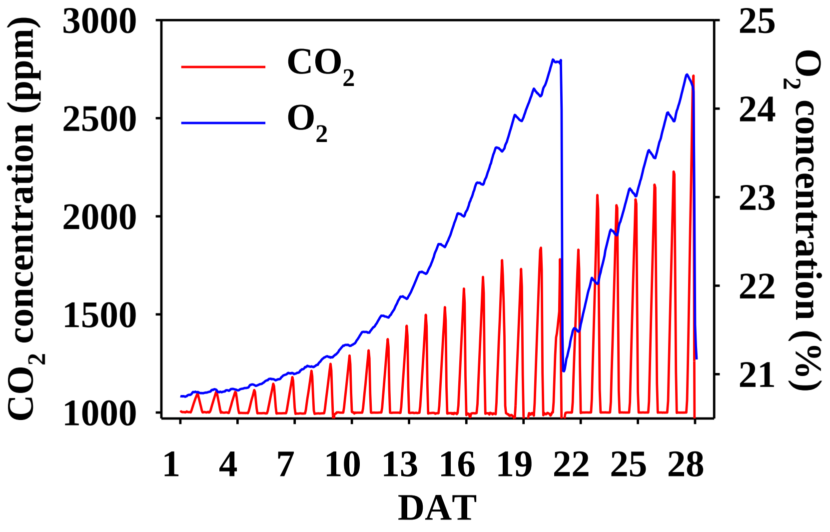
Species	Leaf area (cm² plant⁻¹)	Leaf number (no. plant)	Edible fresh biomass (g plant⁻¹)	Shoot dry weight (g plant⁻¹)	Roots dry weight (g plant⁻¹)	Plant dry weight (g plant⁻¹)	Harvest index	Dry matter of edible portion (%)
Lettuce	3675	78.72	342.7	23.05	3.26	26.32	0.88	6.84
Kale	2398	26.61	282.9	36.45	6.41	42.86	0.70	11.07
Swiss chard	3454	66.94	389.2	34.21	7.87	42.08	0.81	9.09

Main results

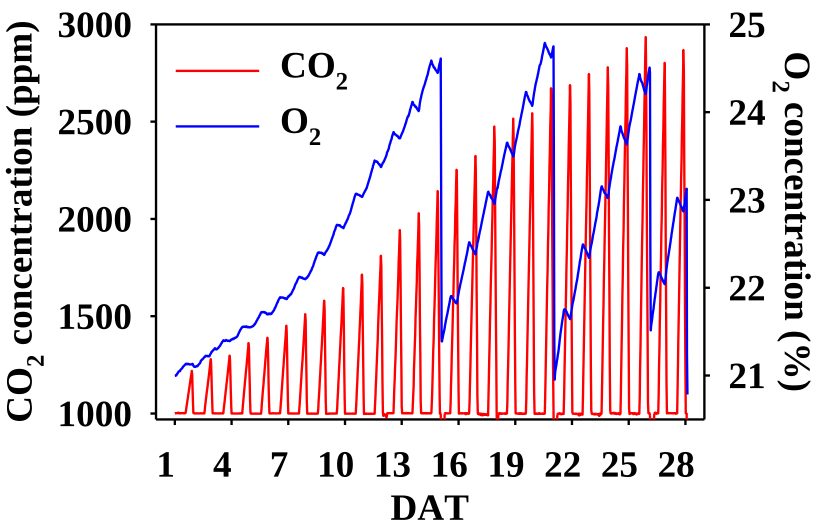
Food, water and oxygen production



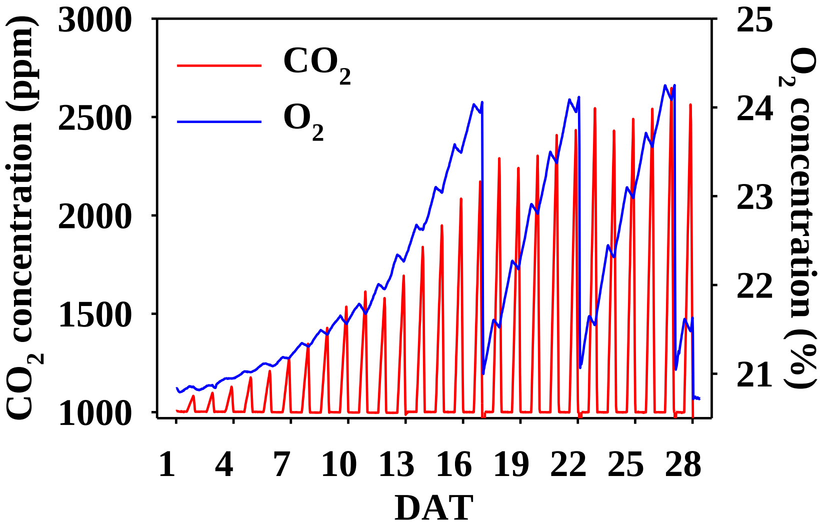
Species	Dry biomass	Edible fresh biomass	CO_2 assimilated	O_2 produced	H_2O produced	O_2/CO_2 balance
	(kg per cultivated unit)		(mol per cultivated unit)			
Lettuce	0.474	6.17	15.8	16.6	4094	1.05
Kale	0.772	5.09	24.8	28.9	6567	1.17
Swiss chard	0.758	7.01	22.1	22.5	5756	1.02



Lettuce



Kale



Swiss chard

MELiSSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

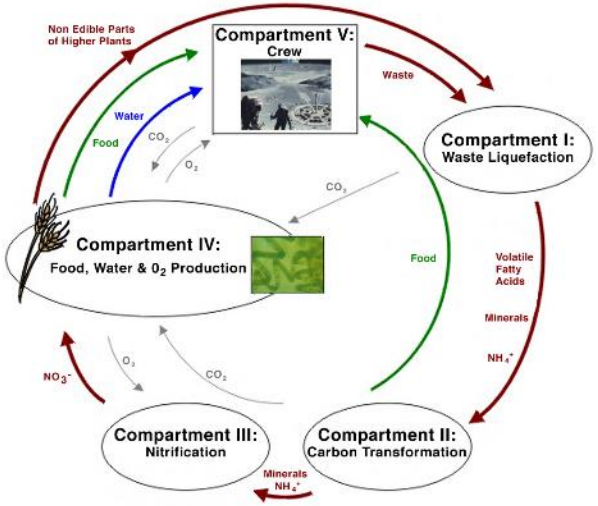
DIPARTIMENTO DI AGRARIA

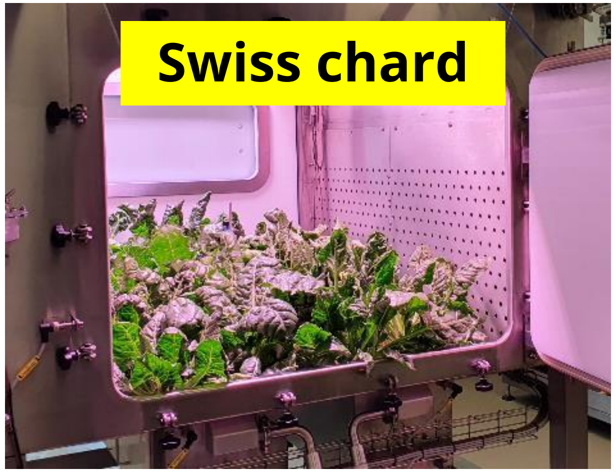
Main results

Water and oxygen production normalized for dry biomass and leaf area

Species	Dry biomass (g plant^{-1})	CO_2 assimilated	O_2 produced	H_2O produced
		(mmol per gram of dry biomass)		
Lettuce	26.32	33.3	35.1	8644
Kale	42.86	32.2	37.5	8512
Swiss chard	42.08	29.1	29.7	7598

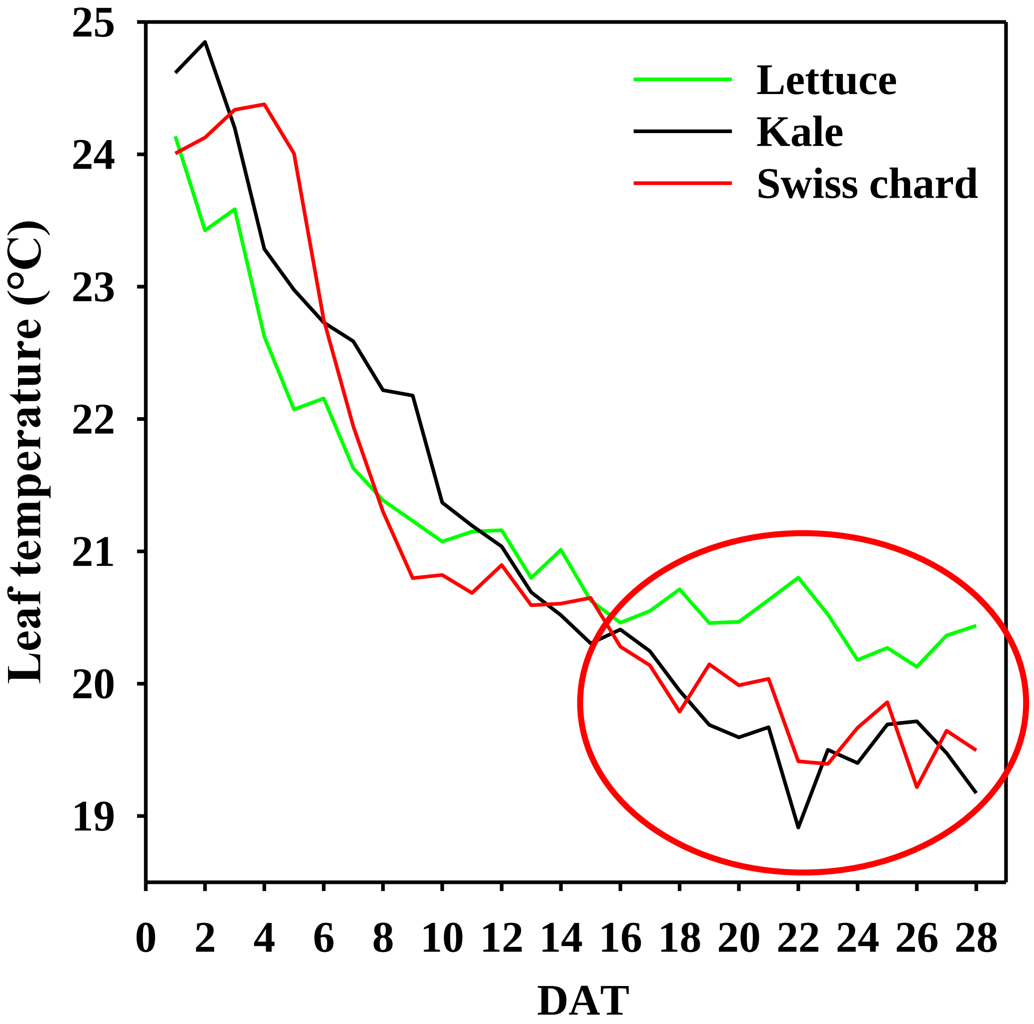
Species	Leaf area (cm^2 plant^{-1})	CO_2 assimilated	O_2 produced	H_2O produced
		(mol per m^2 of leaf area)		
Lettuce	3675	2.4	2.5	619
Kale	2398	5.7	6.7	1521
Swiss chard	3454	3.6	3.6	926

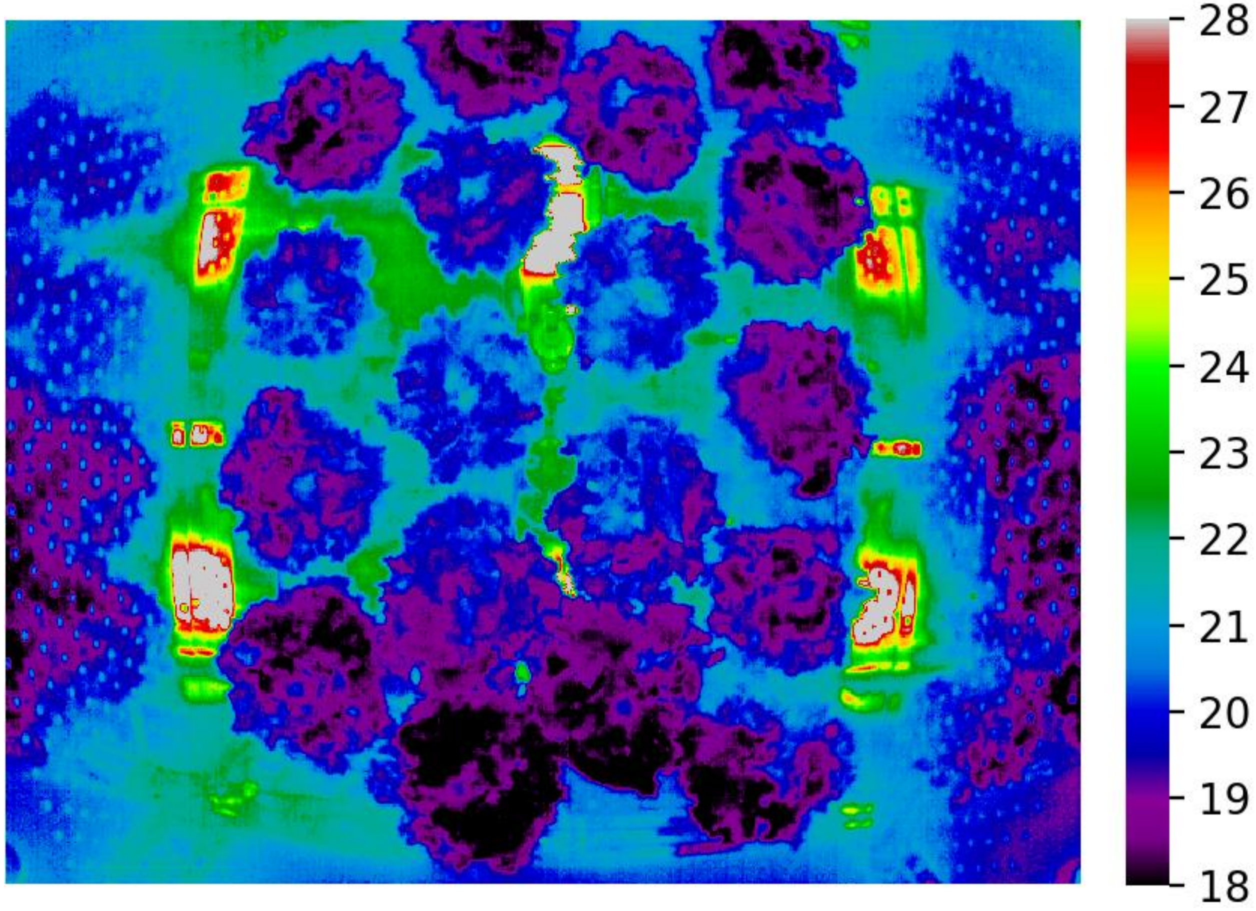




Main results

Leaf temperature trends





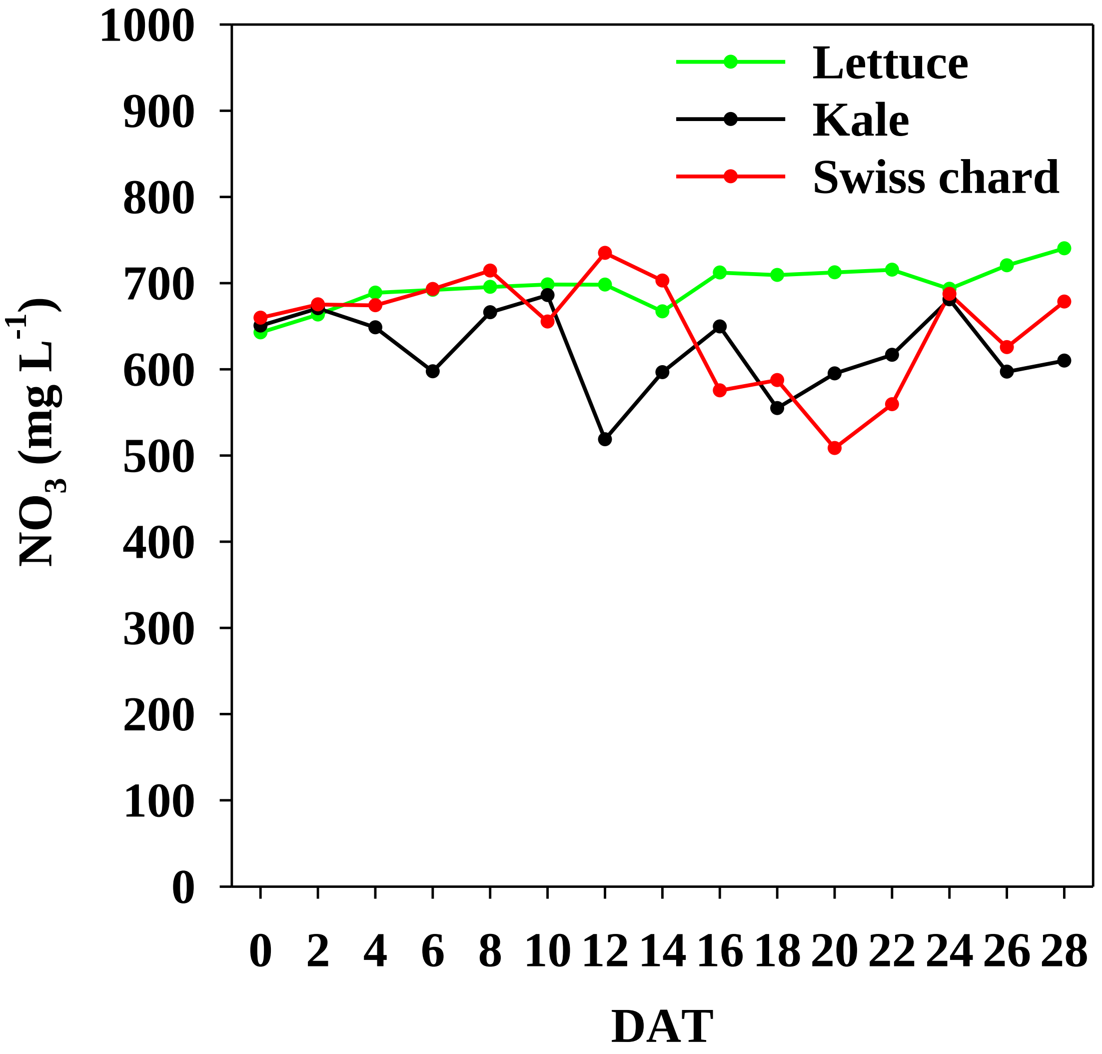
Main results

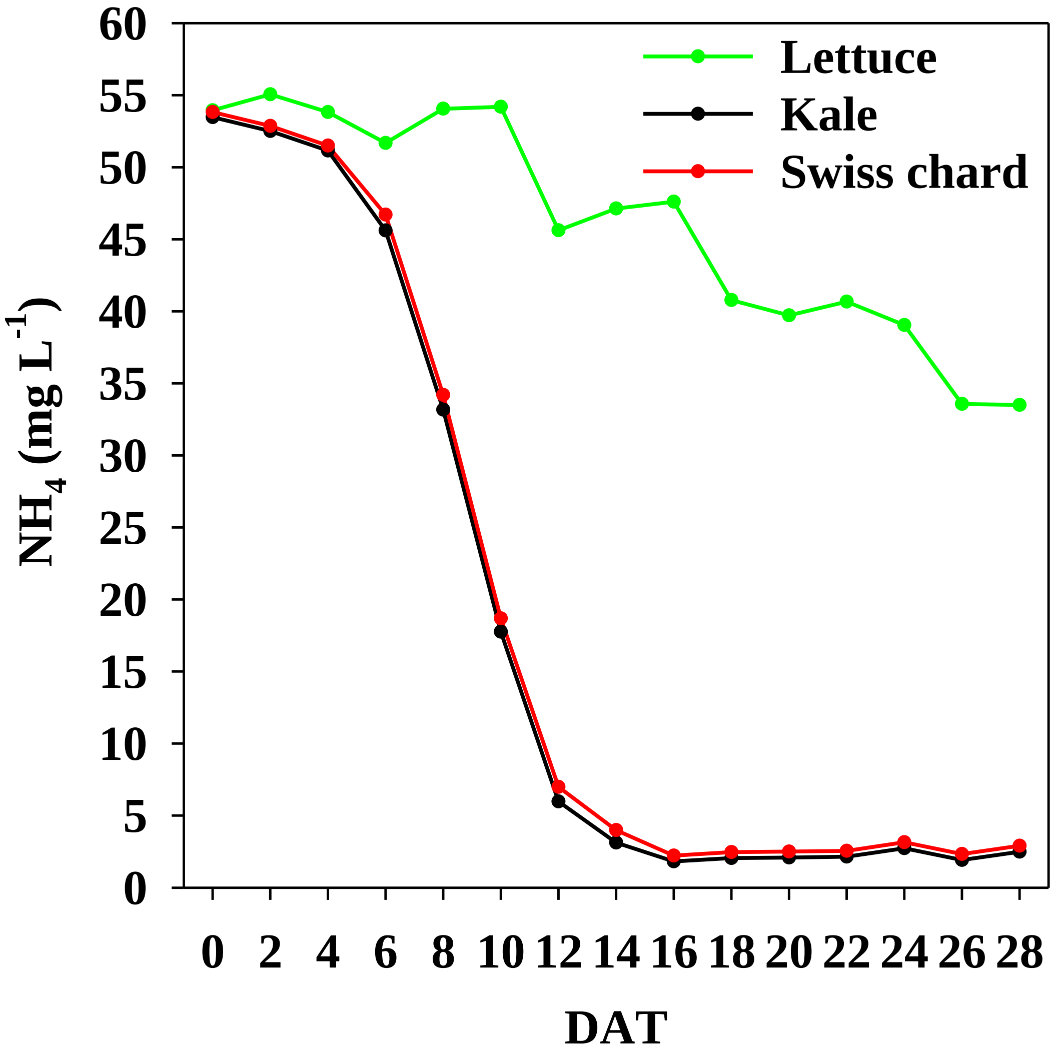
Shoot mineral and oxalate content

Species	N ($g\ kg^{-1}$ DW)	P ($g\ kg^{-1}$ DW)	K ($g\ kg^{-1}$ DW)	Ca ($g\ kg^{-1}$ DW)	Mg ($g\ kg^{-1}$ DW)	S ($g\ kg^{-1}$ DW)	Oxalate ($g\ kg^{-1}$ DW)
Lettuce	42.77	4.52	58.09	15.56	2.95	1.12	1.10
Kale	77.74	5.14	37.73	23.68	2.74	11.96	0.39
Swiss chard	61.86	10.06	93.97	3.20	7.43	1.06	61.05

Main results

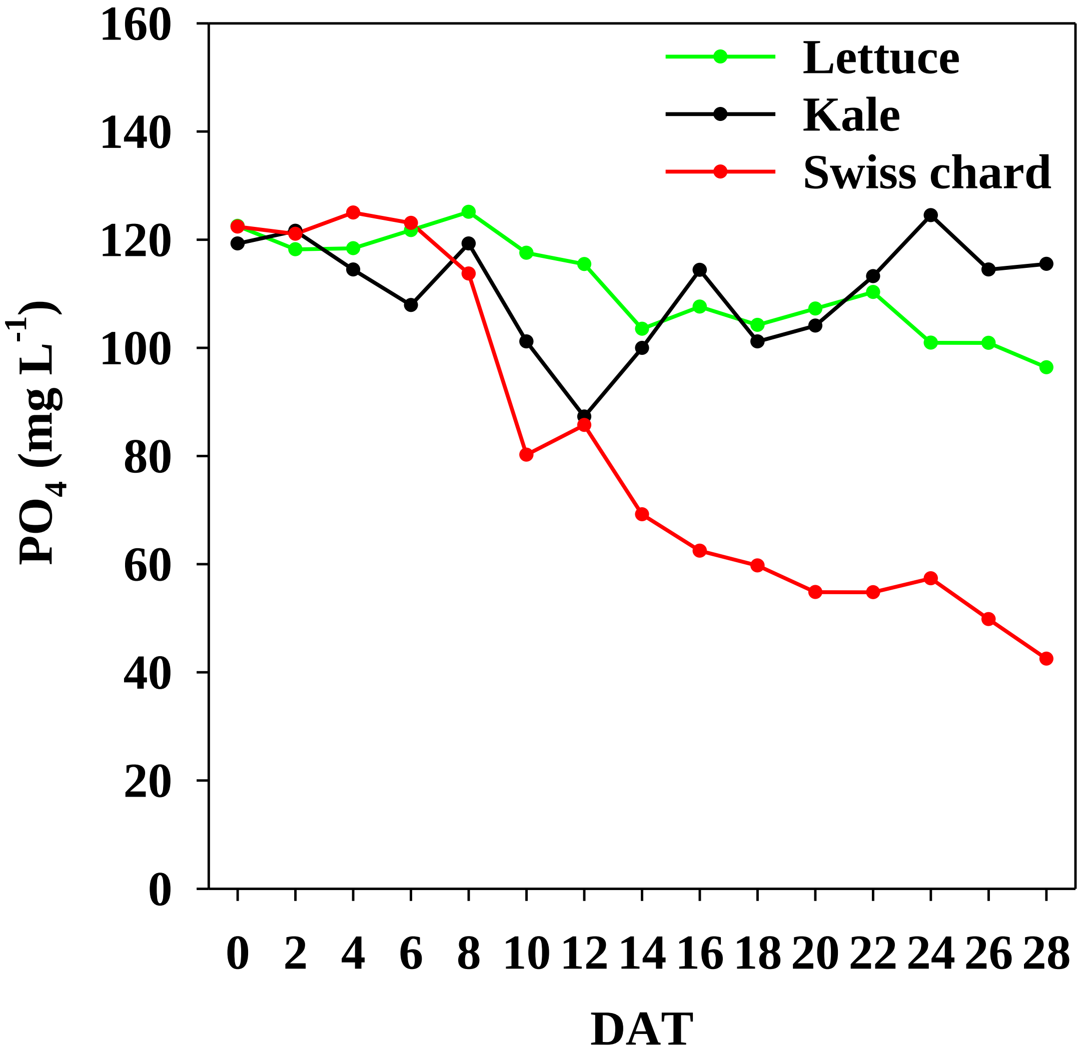
Evolution of the nutrient solution composition

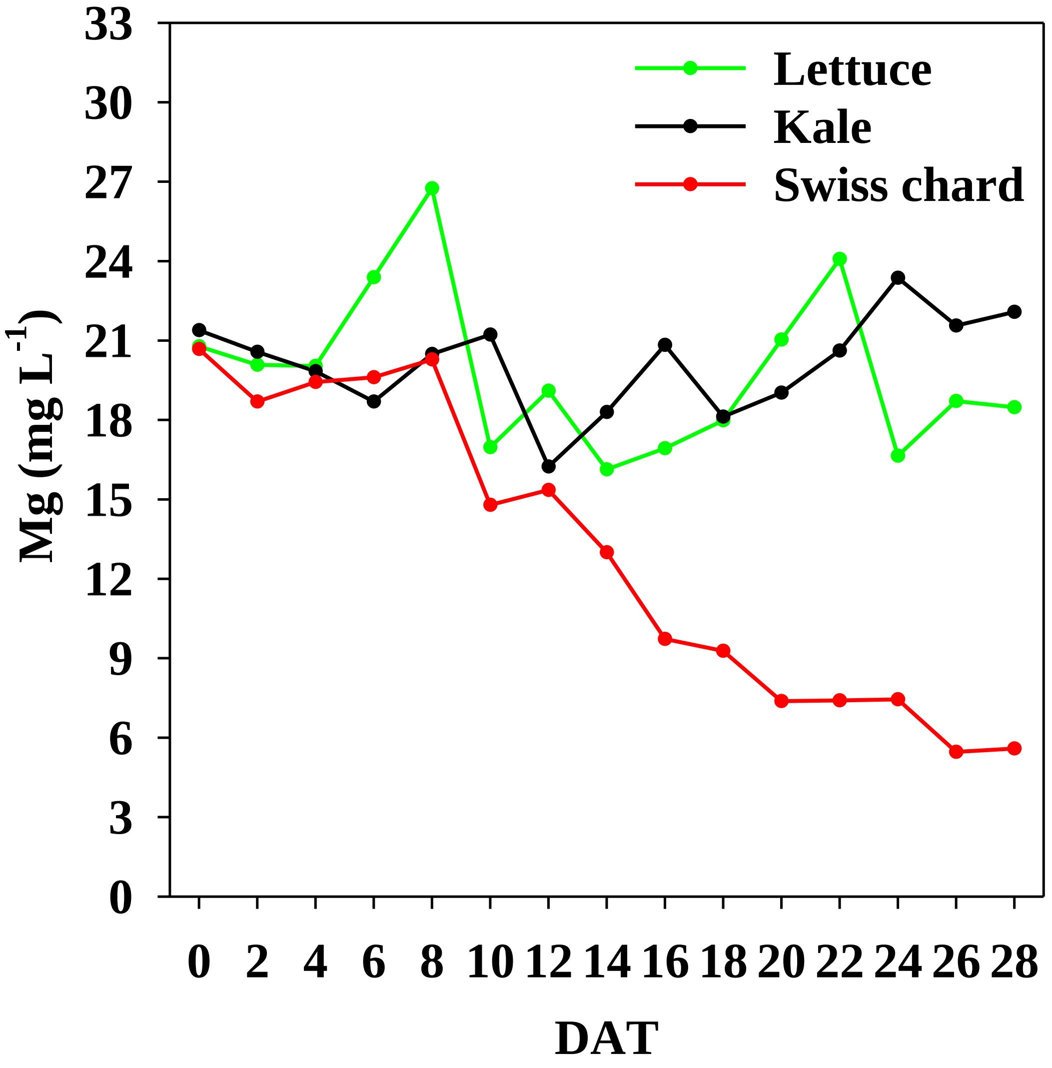




Main results

Evolution of the nutrient solution composition





Conclusions

- Kale and swiss chard produced more biomass, oxygen and transpired water per cultivated area than lettuce.
- Specifically, swiss chard maximized food production, while kale enhanced oxygen production.
- Different crops showed different nutrient uptake patterns.
- Our findings suggest that genotype selection to identify the top performing crops is a key factor to design crop production systems for BLSSs.
- Nutrient solutions tailored to different species would enhance nutrient uptake and crop performances.
- The PCU was proved to be reliable and able to perform the fine-tuned crop characterization (of very different crops) needed to optimize plant cultivation for life-support systems for Space.
- Overall, our results provided a reference dataset for future crop characterization of different plant species under different environmental conditions, as well as useful data for integrating the High Plant Compartment (HPC) of the MELiSSA loop.

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

THANK YOU.

Antonio Pannico

Department of Agricultural Sciences, University of Naples Federico II

antonio.pannico@unina.it

www.melissafoundation.org

Follow us

SPONSORS

ESTEE – EARTH SPACE TECHNICAL ECOSYSTEM ENTERPRISES

ThalesAlenia Space – a Thales / Leonardo company

SHERPA ENGINEERING

beyond gravity

ENGINSOFT

QINETIQ

BioX technologies

BLUE HORIZON

SPARTAN SPACE

frontiers

PARTNERS

esa European Space Agency
MELISSA FOUNDATION
ENGINSOFT
GHENT UNIVERSITY
Unil UNIL | Université de Lausanne

sck cen
SEMiLLA IPSTAR
SHERPA ENGINEERING
UNIVERSITY of GUELPH

vito
UAB Universitat Autònoma de Barcelona
UMONS Université de Mons
UCA UNIVERSITÉ Clermont Auvergne
University of Antwerp