

“Space and Urban farming tecnologie innovative di agricoltura sostenibile”



LUCA NARDI

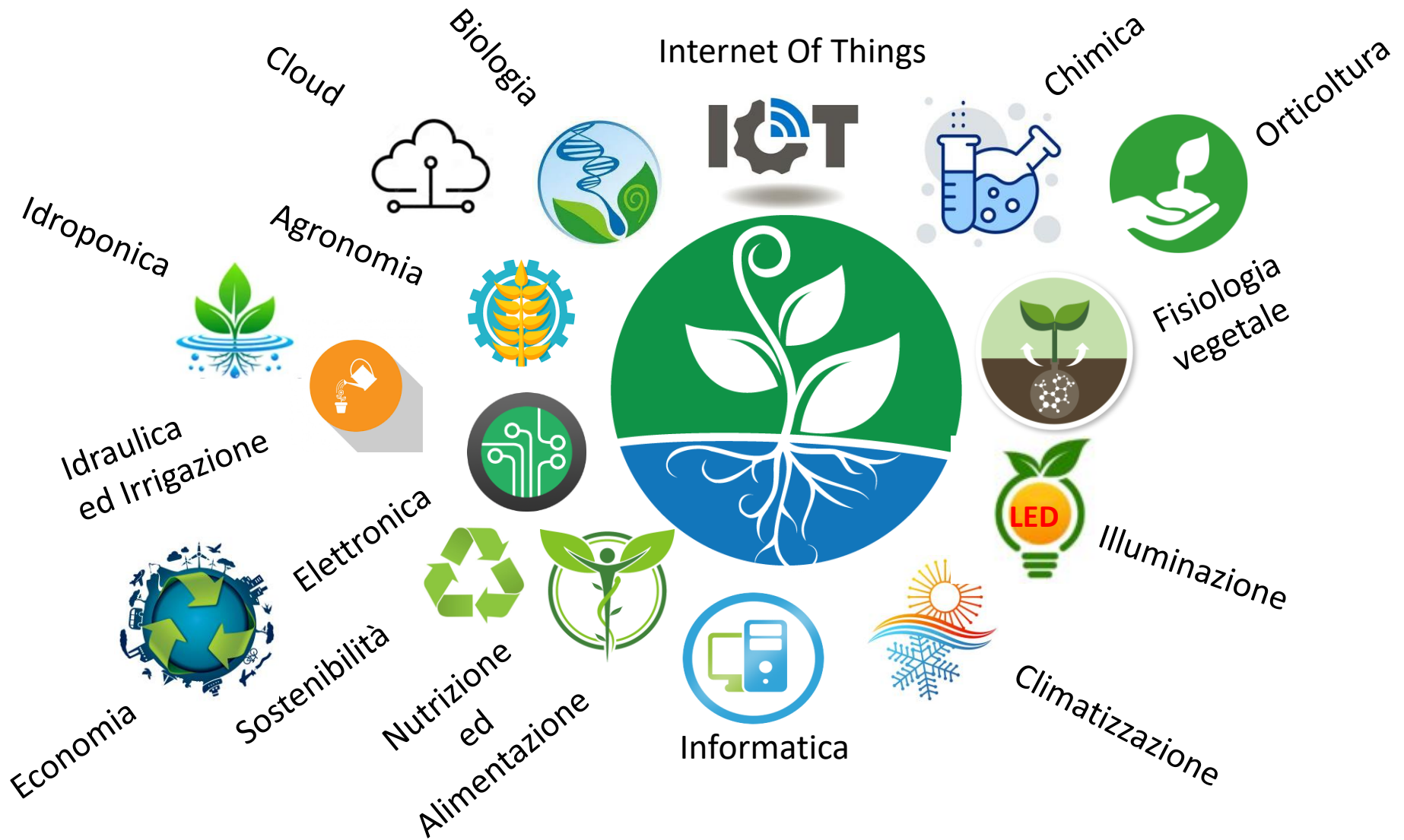
Divisione Biotecnologie e Agroindustria

Dipartimento Sostenibilità dei Sistemi Produttivi e Territoriali



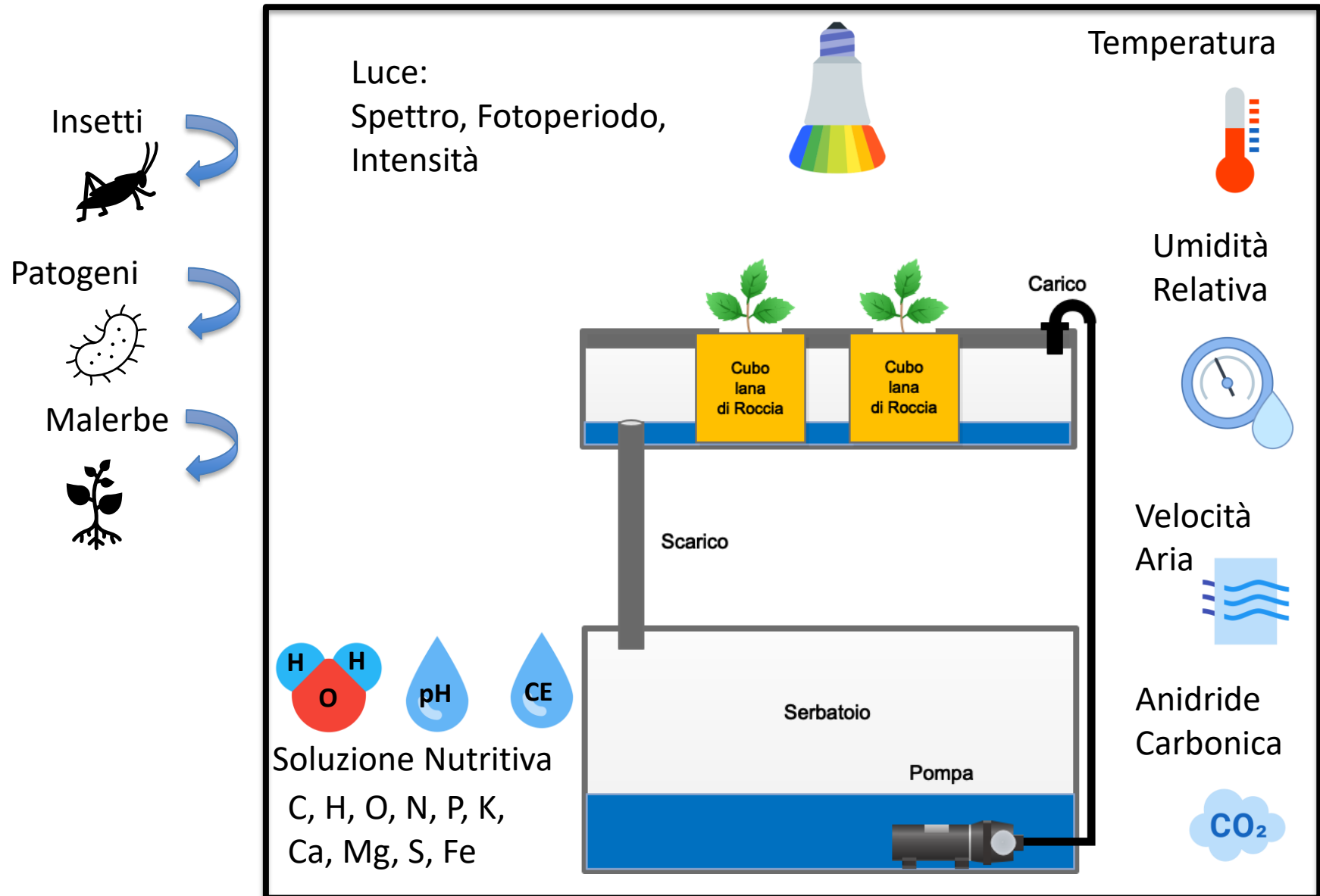
“Produzione di Ortaggi nello Spazio” - Roma 27 Ottobre 2023 17:00 – 19:00

Agricoltura 4.0 multidisciplinare



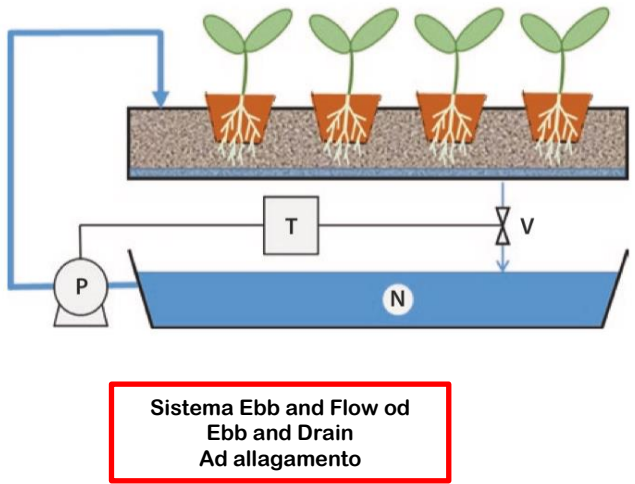
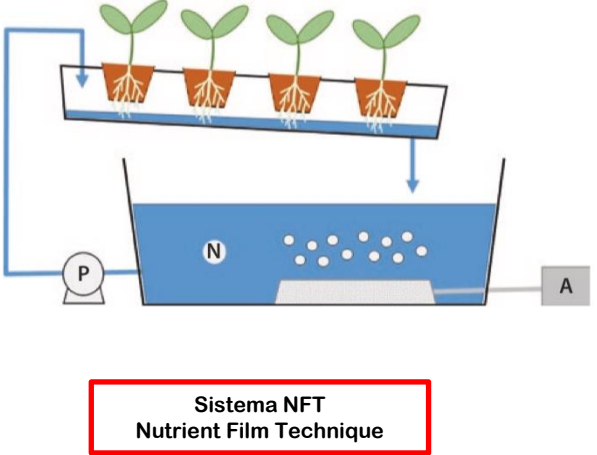
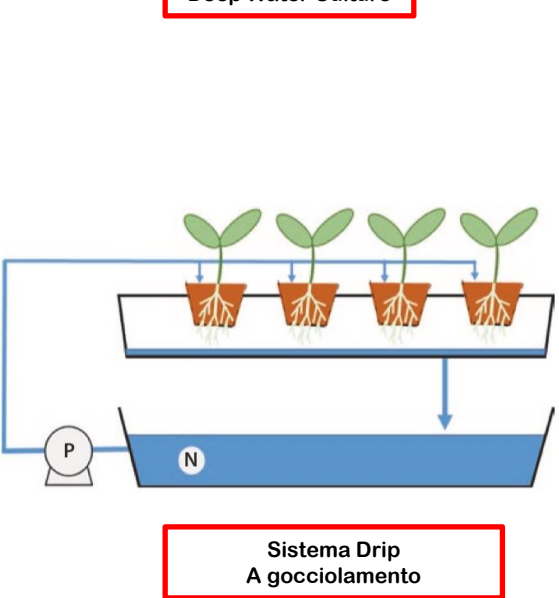
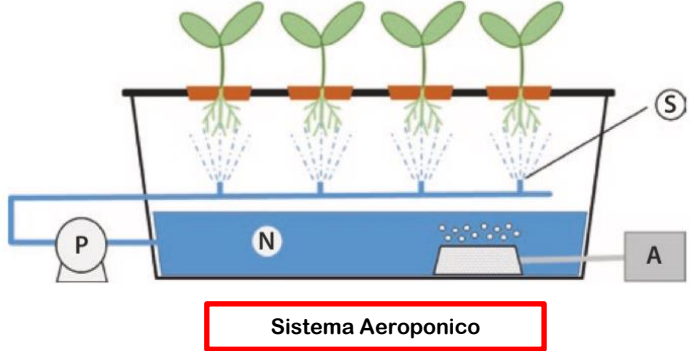
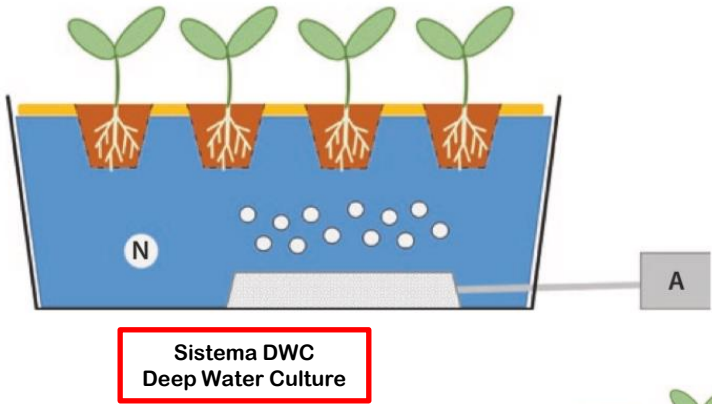


Agricoltura in ambiente controllato

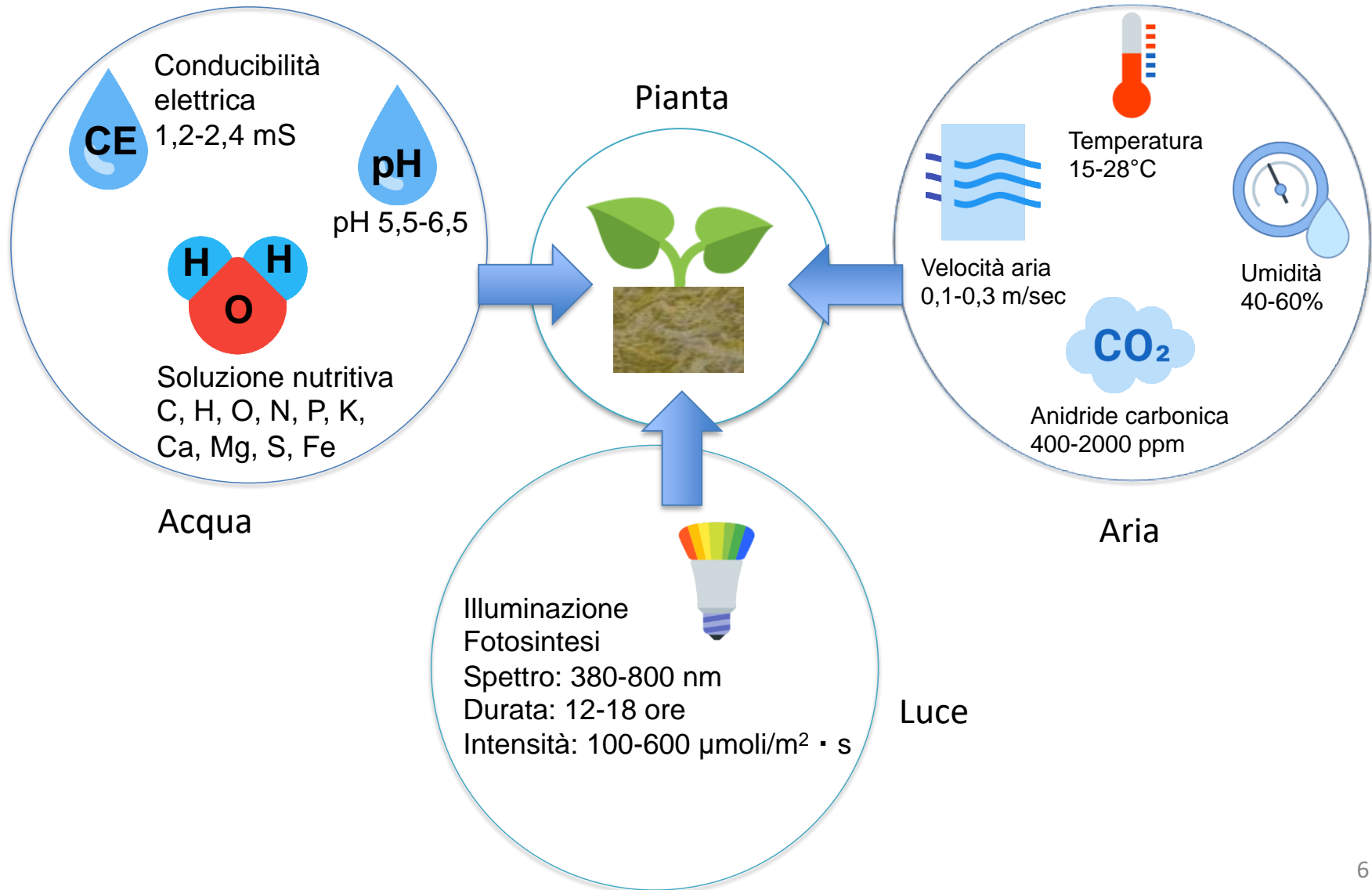


Coltura Idroponica

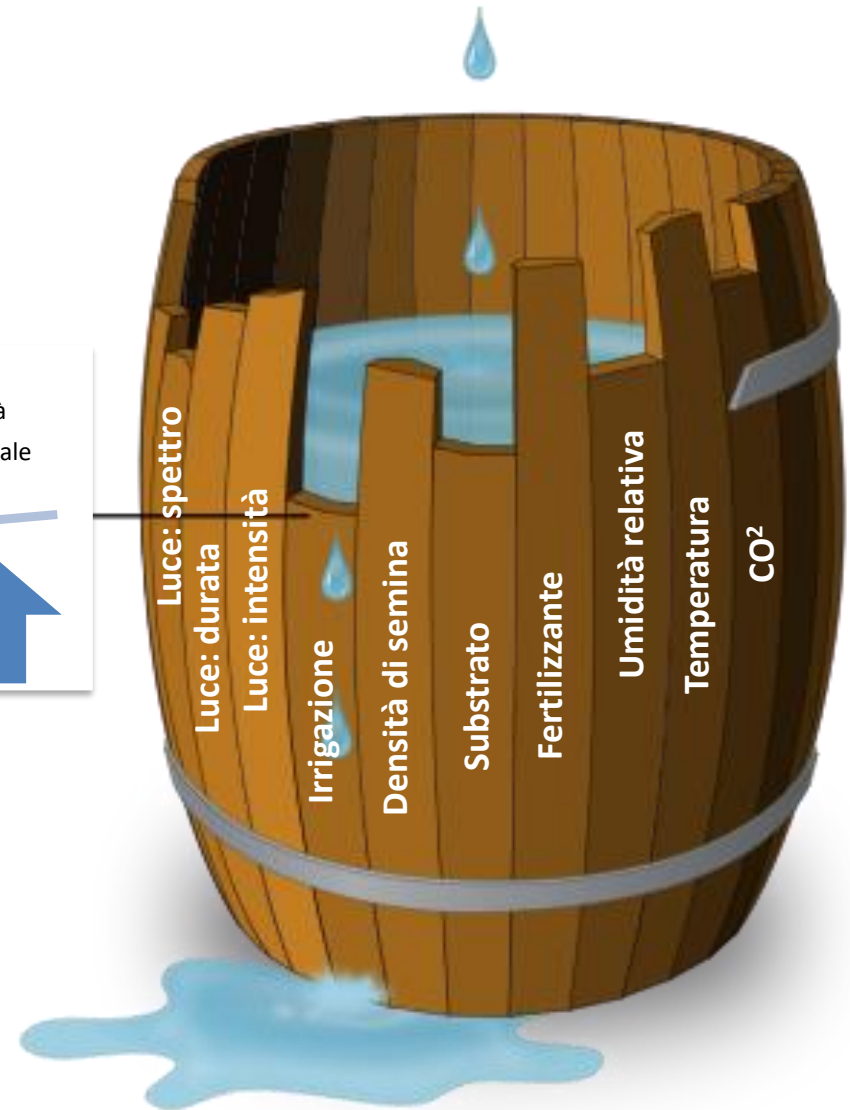
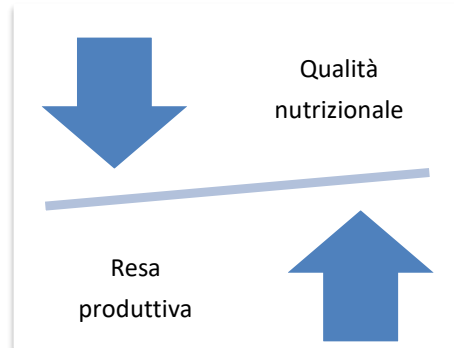
- Pompa aria A
- Soluzione nutritiva N
- Elettrovalvola V
- Temporizzatore T
- Pompa acqua P



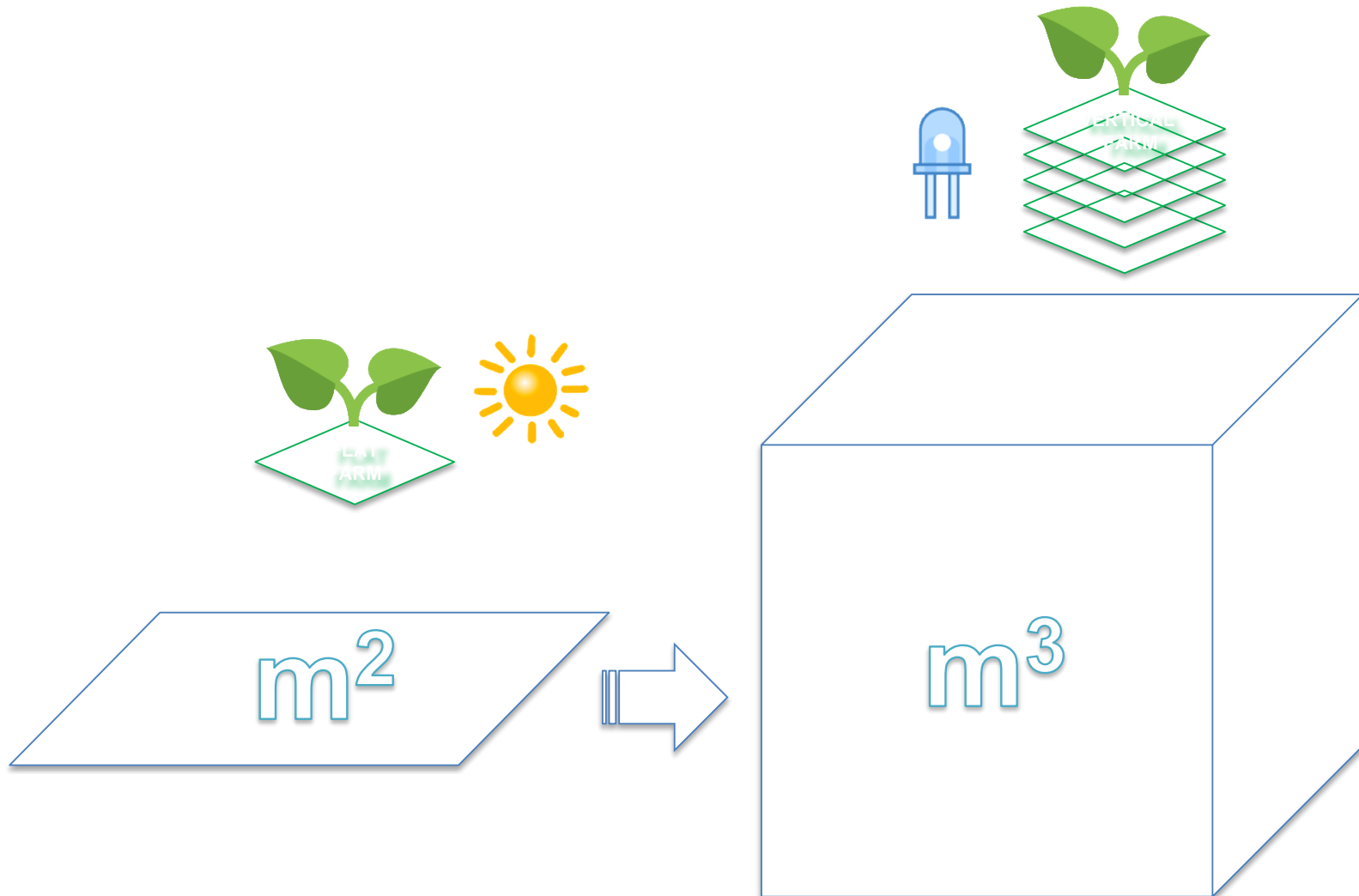
Principali parametri controllati



Resa produttiva/Qualità nutrizionale



Dal metro² al metro³



Nuove forme di agricoltura

Fattorie Container



Serre Idroponiche



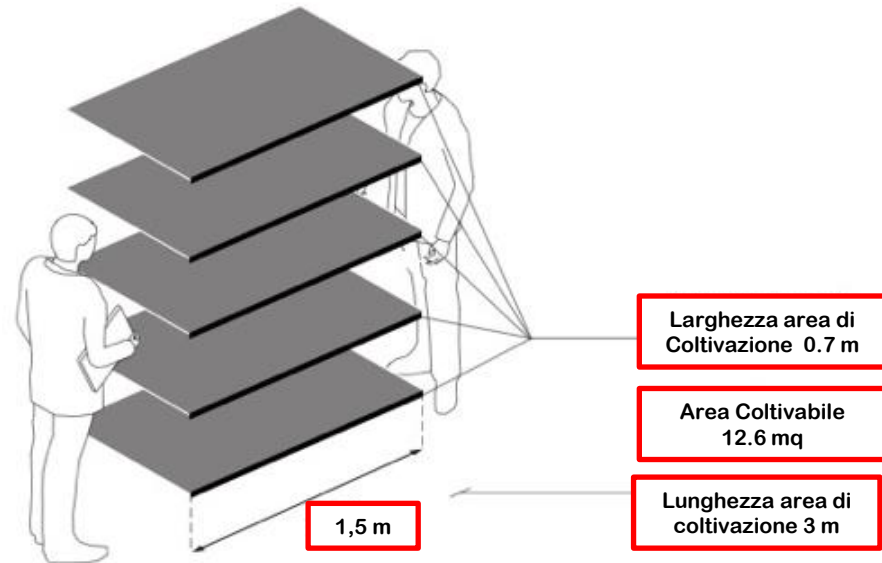
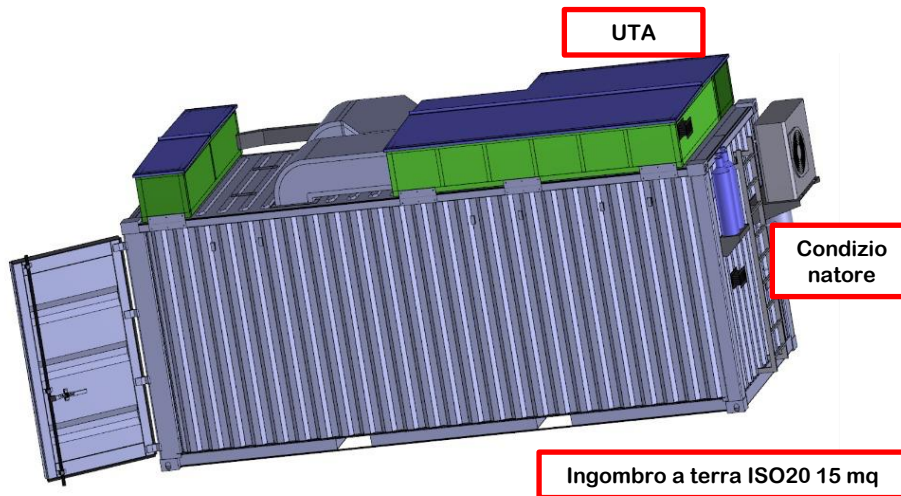
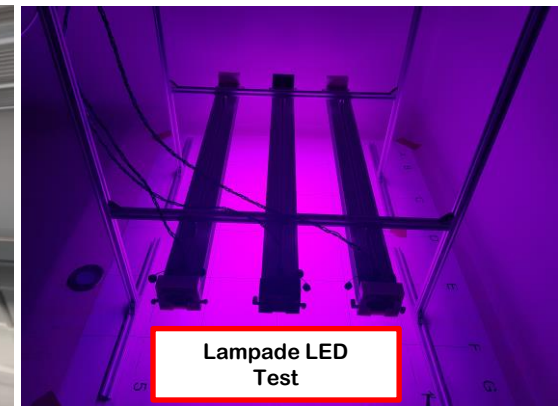
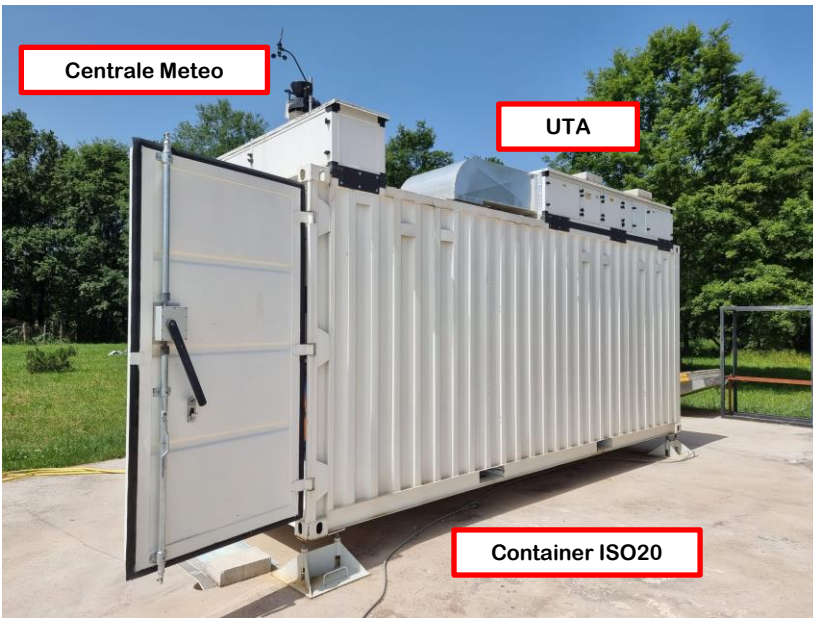
Fattorie Verticali Plant factories



Orto-domestici



Container farm



Incremento produttività

3x - 5x

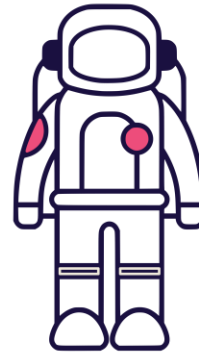
Stato dell'arte: International Space Station

Rifornimento da Terra



Ossigeno
Acqua
Cibo

Metabolismo umano



CO₂
Urina
Feci

Sistema raccolta

rifiuti



Un uomo di 80 kg necessita ogni
anno di

240 kg	cibo	~	1200 kg all'anno
320 kg	ossigeno		
640 kg	acqua		

Sulla stazione spaziale
internazionale

~ 85% riciclo acqua
~ 40% riciclo ossigeno
Rifornimenti ogni 2 mesi

ISS operazioni di rifornimento



1) HOHMANN ORBIT TRANSFER
(220 KM)

1) ISS ORBIT TRANSFER (440 KM)

} 3-6 ORE

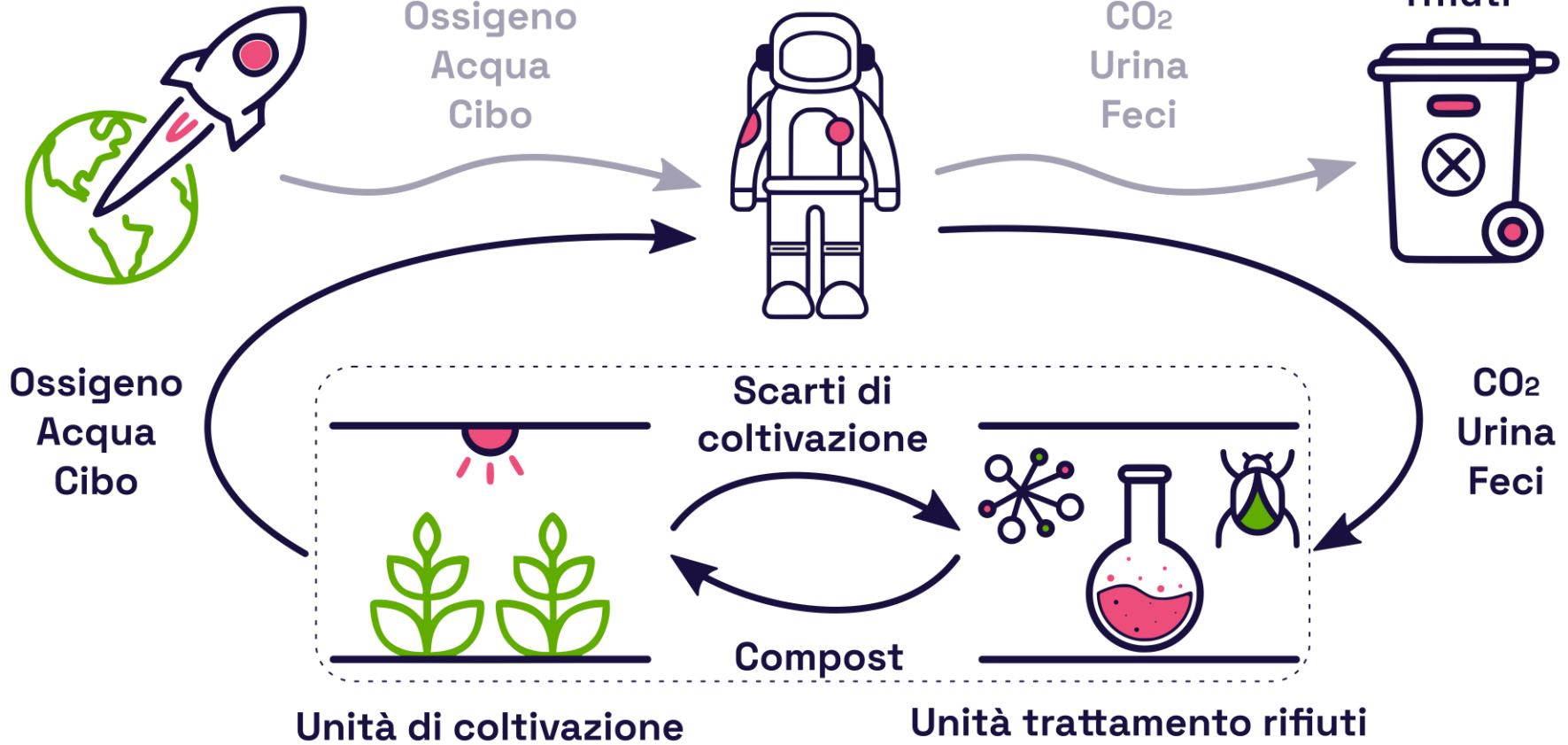


I sistemi biorigenerativi

Rifornimento da Terra

Metabolismo umano

Sistema raccolta
rifiuti



Biotechnology Lab Projects

2014 2015 2016 2017 2018 2019 2020 2021 2022

BIOxTREME

HORTSPACE

V-GELM

LOOPS-M

REBUS

GREENCUBE

SOLE

MICROx2

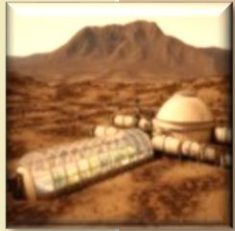
CHEF

MIG

IDROZAFF

NUTRI 3D

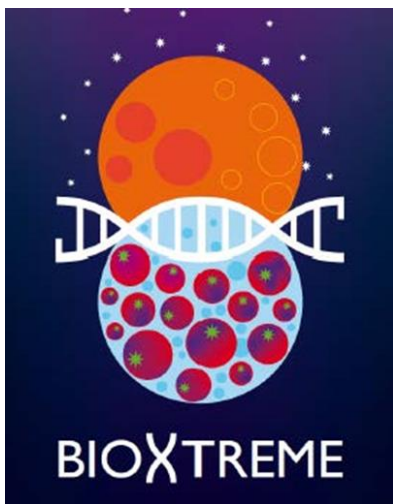
Space Farming



Urban Farming



Bioxtreme



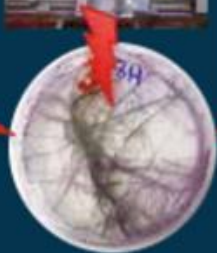
Pomodoro Microtom
"San Marziano"

Coltura di Radici

Studio di sistemi vegetali per la produzione di molecole bioattive (anticorpi, immunostimolanti, antiossidanti) per contrastare gli effetti avversi della vita nello spazio. Analisi delle risposte di questi sistemi allo stress che simula l'ambiente spaziale (Protoni, Raggi Gamma ed X).

Protons

Gamma & X rays



Produrre ovunque (missioni analoghe)

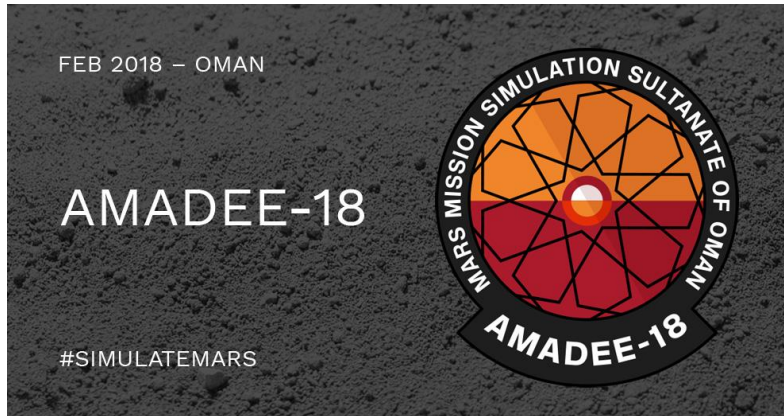


Armenia, 05Mar-08Apr2024

AMADDEE-24



Hortextreme

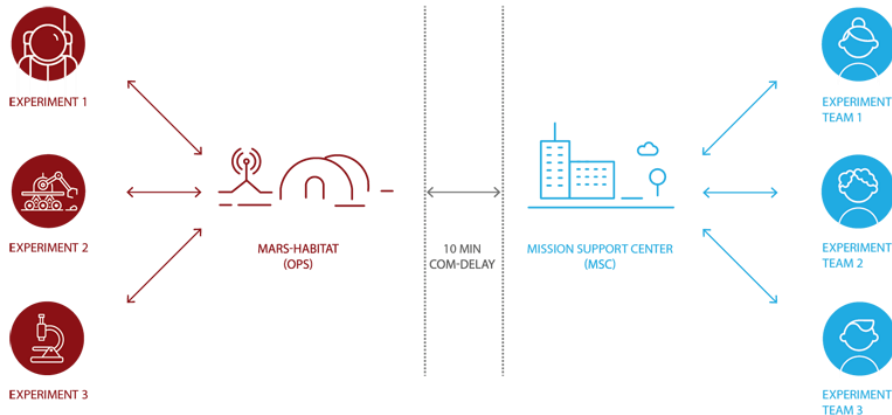


Objective:

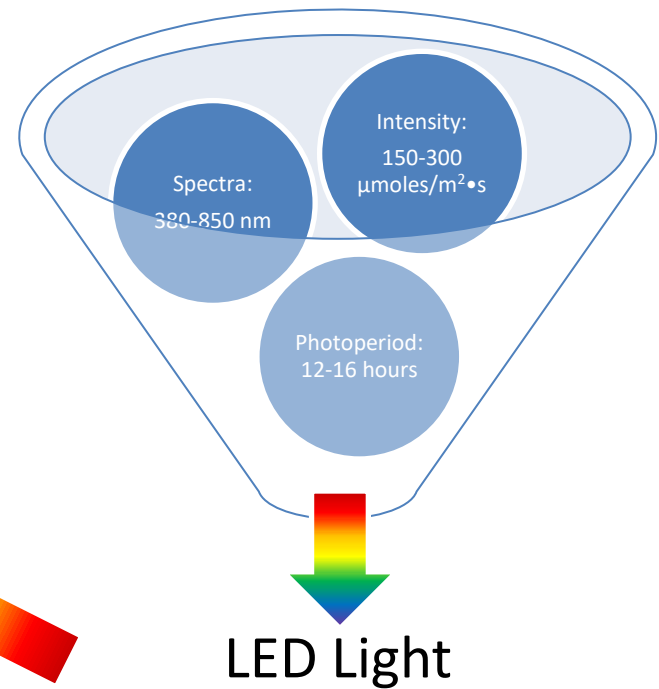
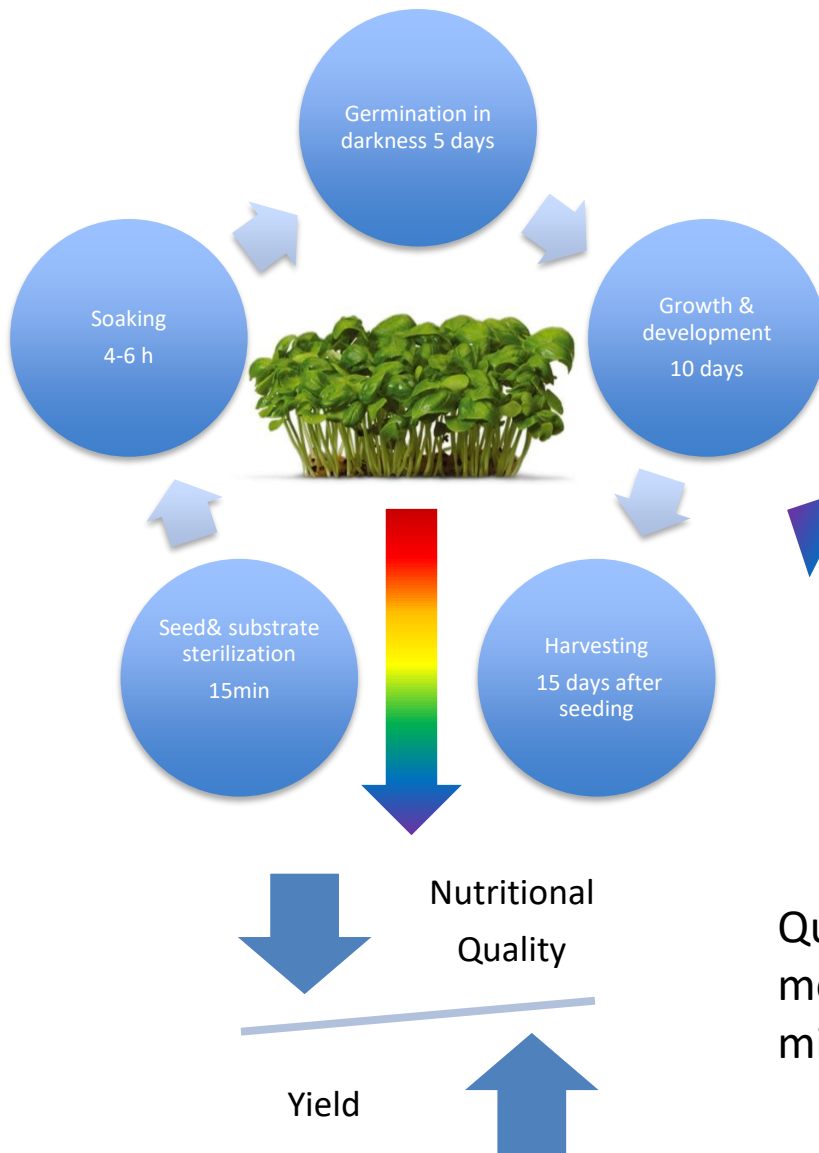
Identification of best plant growth conditions and Microgreens species selection based on adaptability to extreme environments

Experiment:

Protected HORTiculture in inflatable structures, resistant to EXTREME conditions, for the production of plants with high nutritional value.

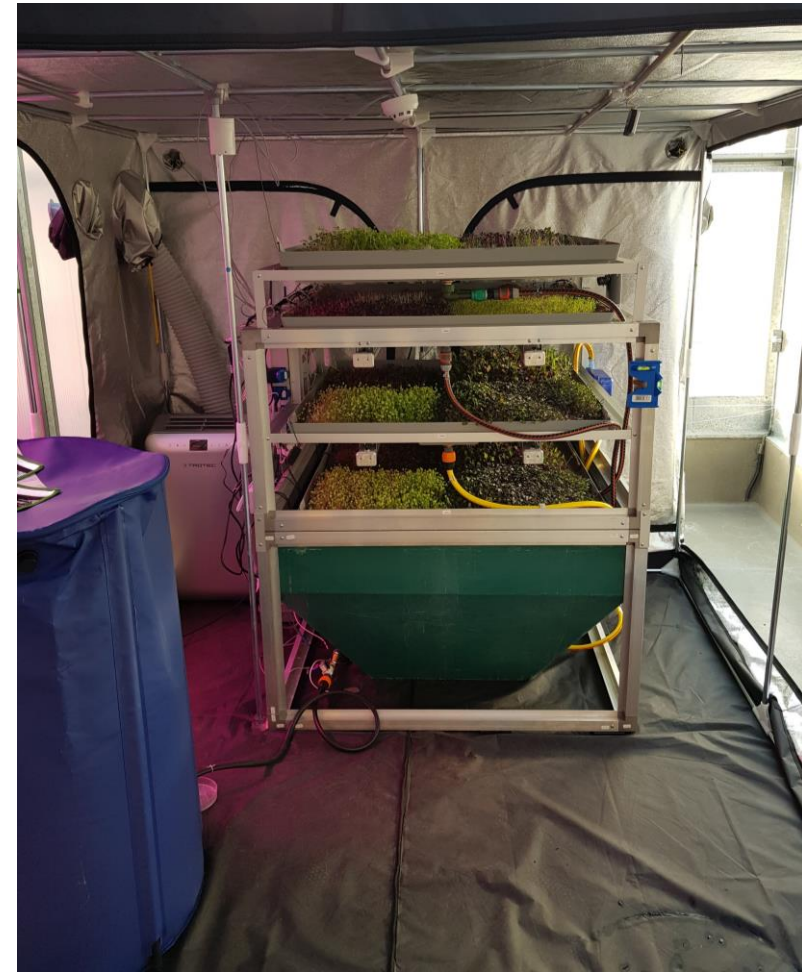
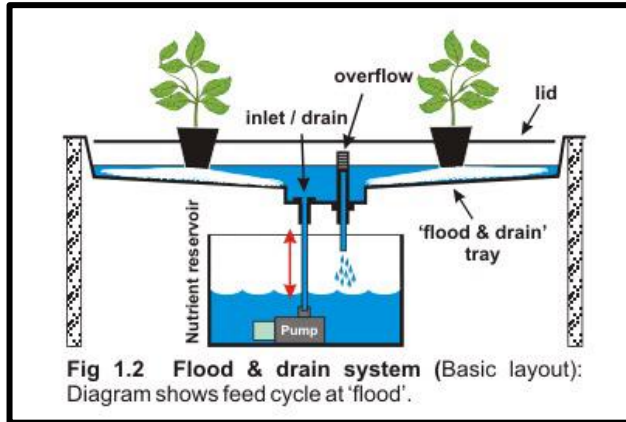


Objective

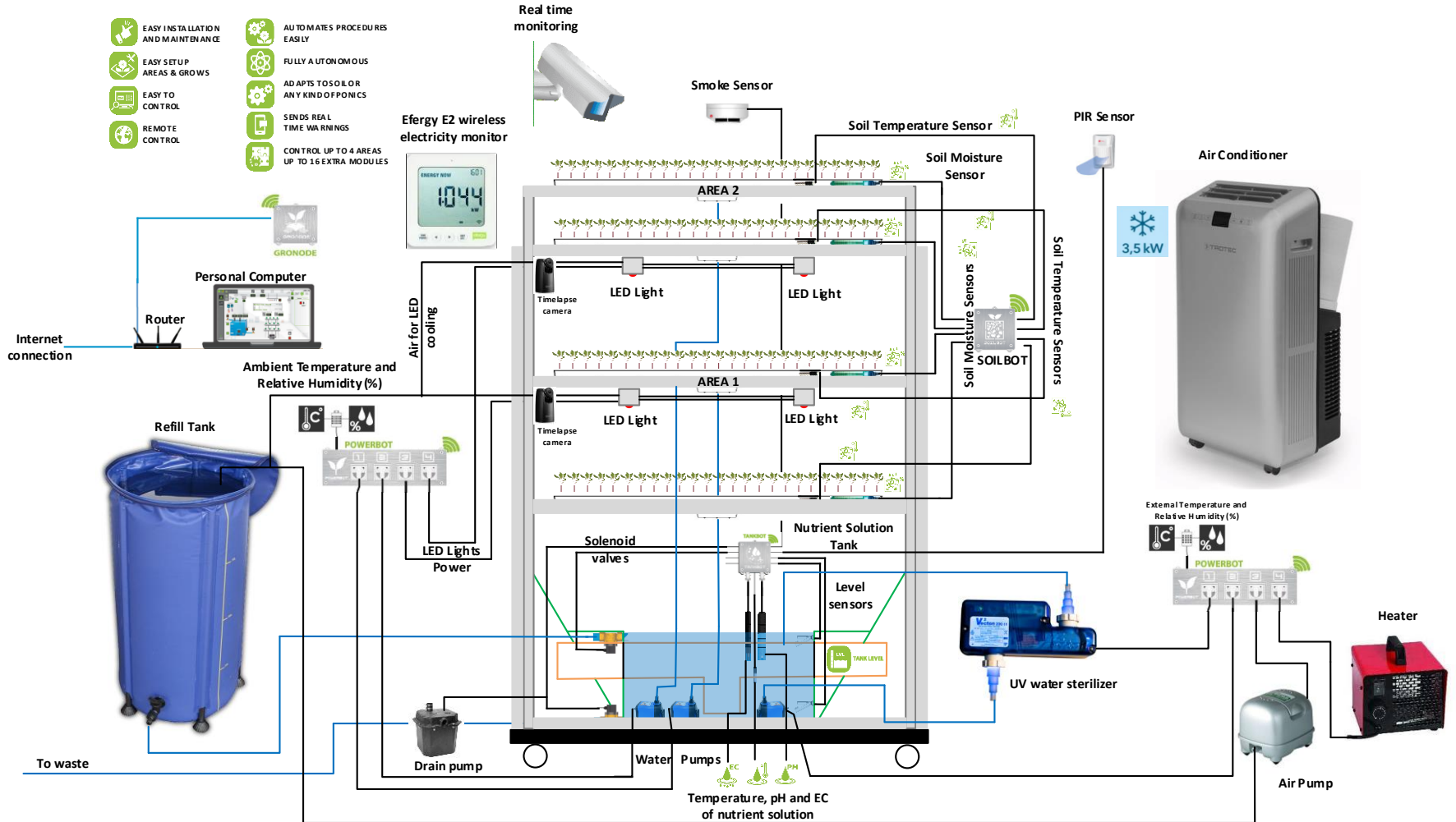


Quantify the effects of LED lights on the growth, morphology, yields and nutritional content of microgreens

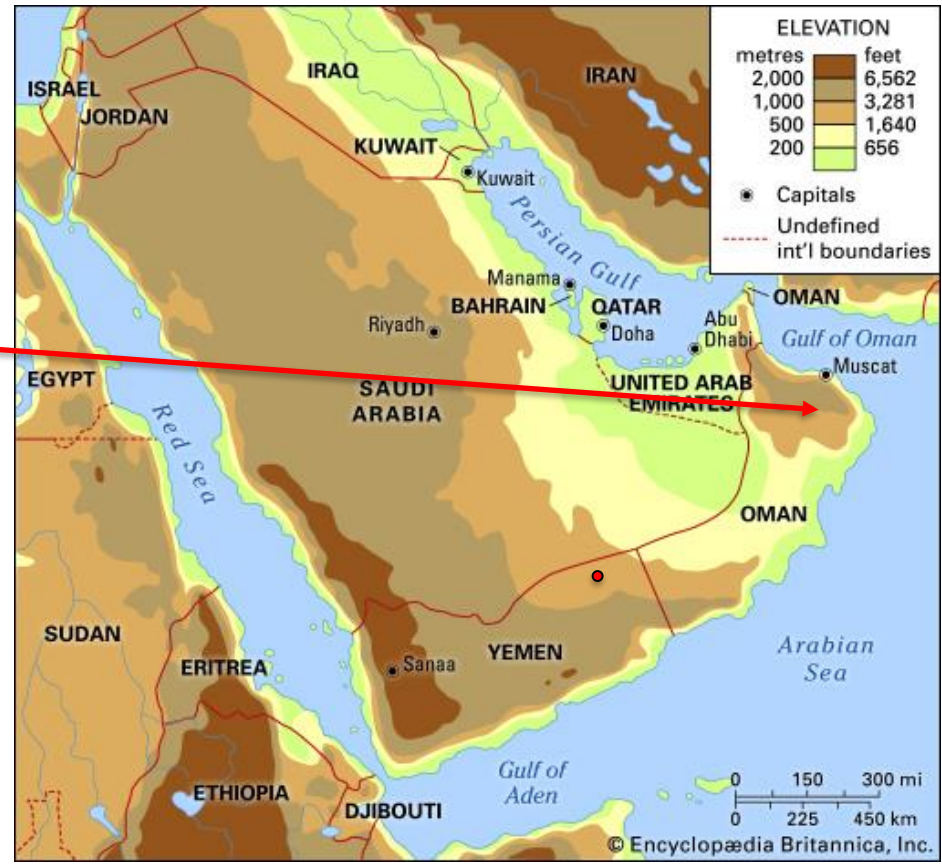
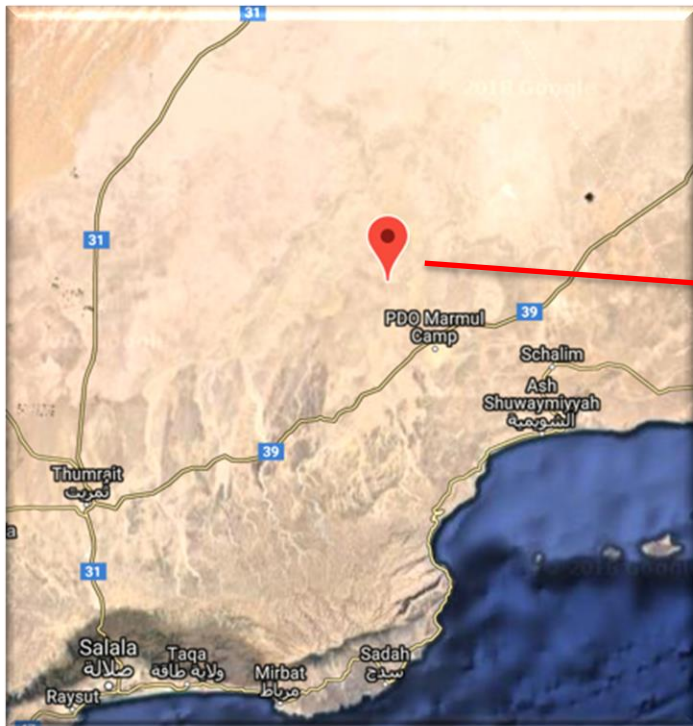
Hortspace closed loop hydroponics



Hortspace closed loop hydroponics



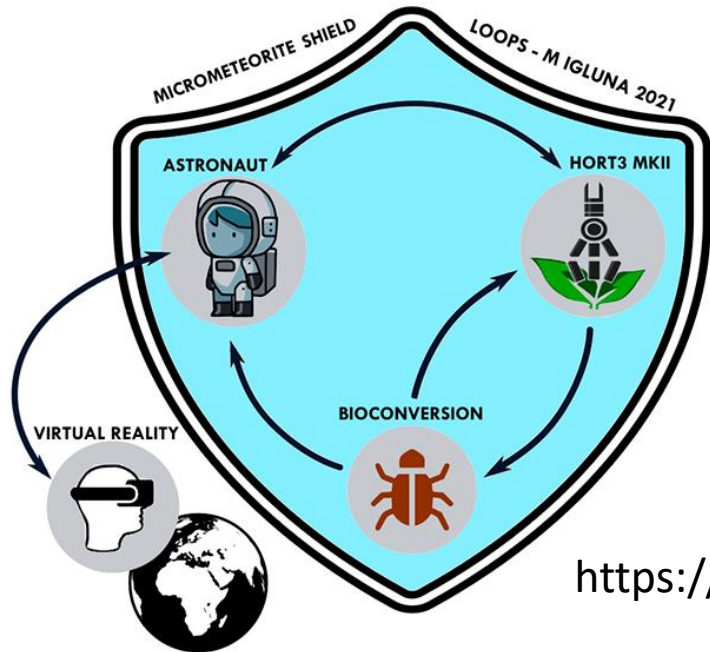
AMADEE18 Kepler Station



AMADEE18 Kepler Station



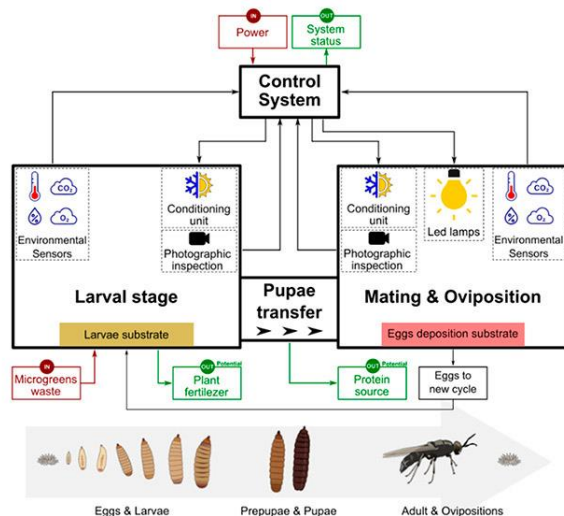
LOOPS-M: LUNAR OPERATIVE OUTPOST FOR THE PRODUCTION AND STORAGE OF MICROGREENS



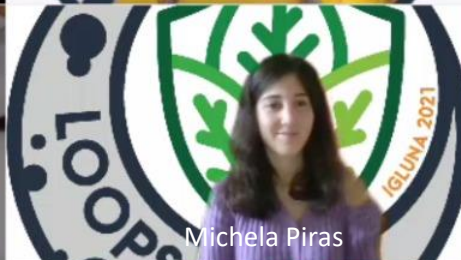
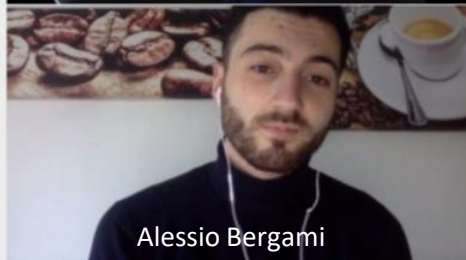
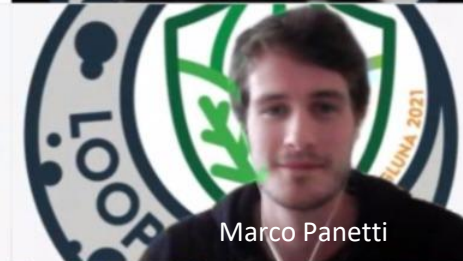
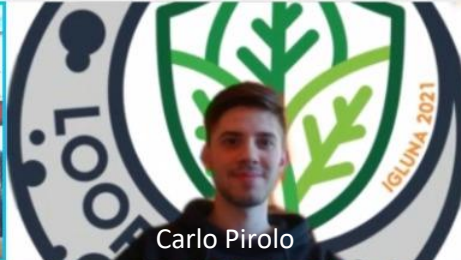
Sponsor:



<https://space-innovation.ch/igluna/projectteams/p02-loops-m/>



LOOPS-M: LUNAR OPERATIVE OUTPOST FOR THE PRODUCTION AND STORAGE OF MICROGREENS



Supervisor
Luca Gugliermetti
Luca Nardi
Elena Lampazzi
Paolo Marzioli
Prof Fabio Santoni

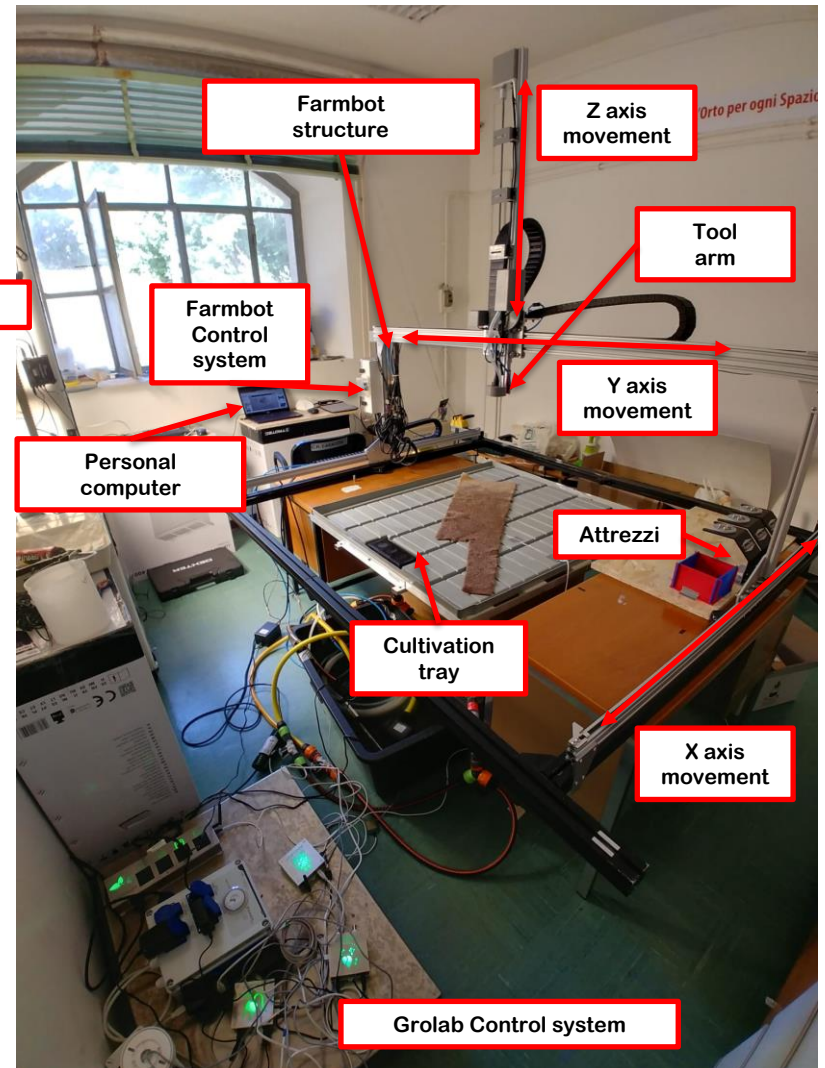
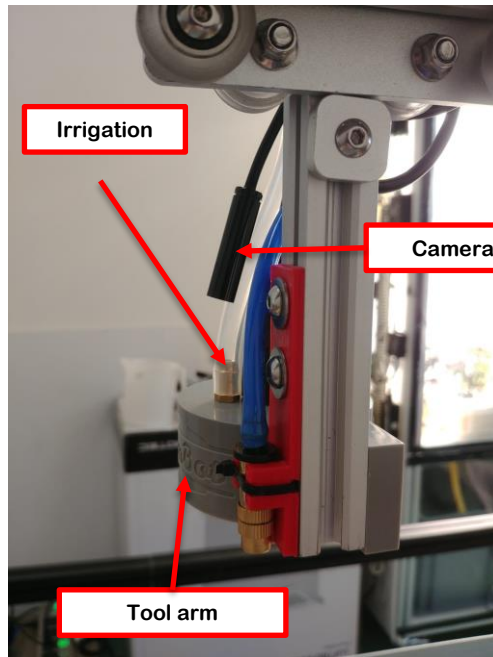
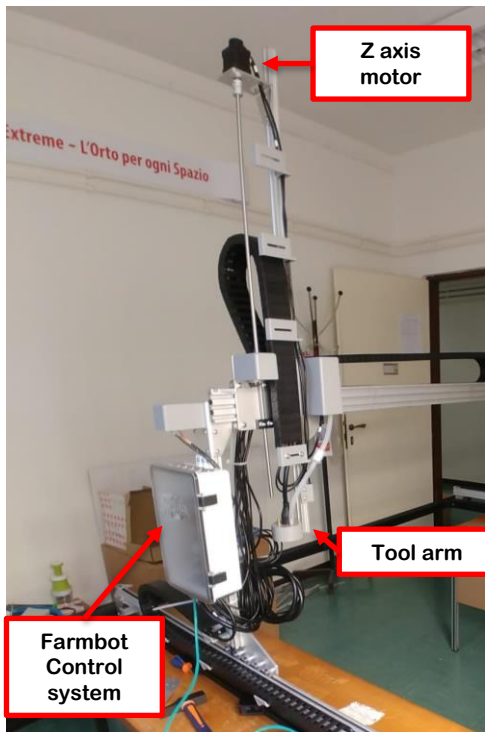


Damiano Salvitti
Valter Dragonetti
Stefano Martinelli



<https://www.spacecenter.ch/igluna/>

LOOPS-M: LUNAR OPERATIVE OUTPOST FOR THE PRODUCTION AND STORAGE OF MICROGREENS



<https://farm.bot/>

Progetti finanziati

SOLE    



MICROx2    



Unità di coltivazione

ReBUS     

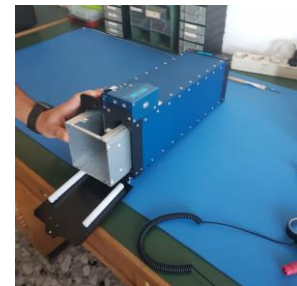
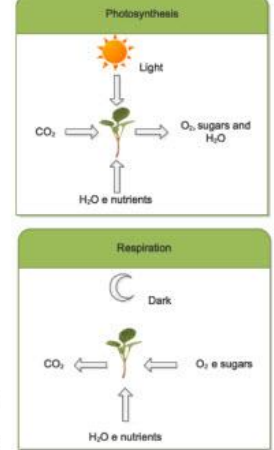
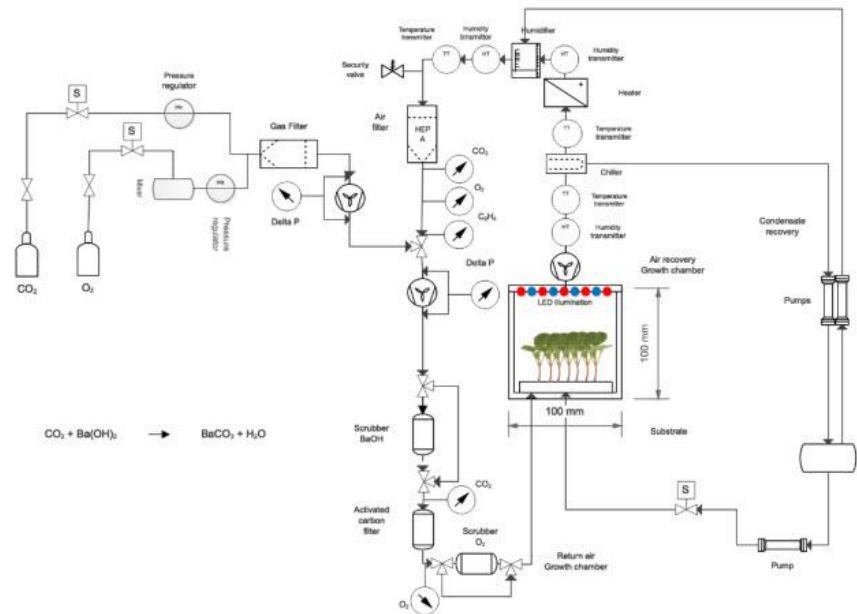
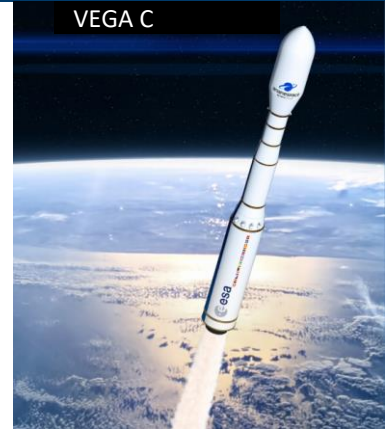
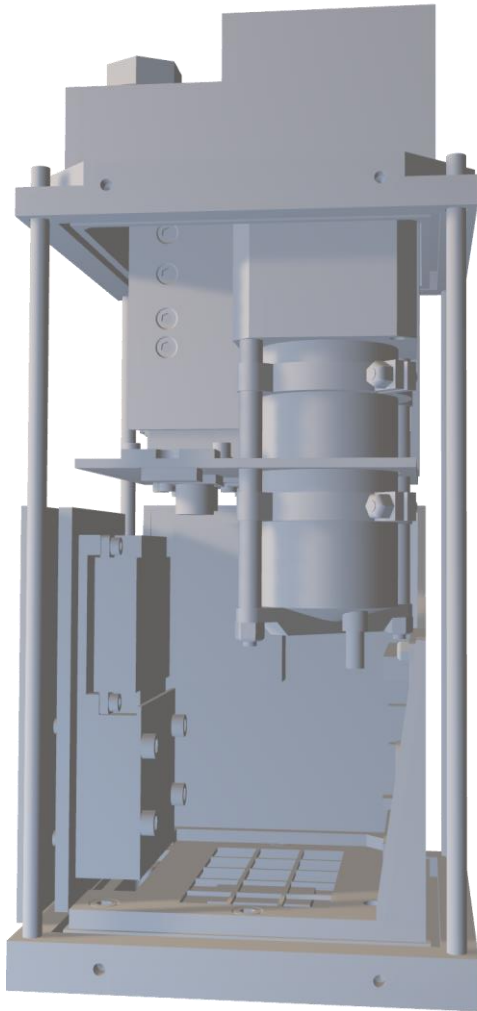




Unità trattamento rifiuti

Greencube: Microgreens cultivation in a Cubesat



Modulo di coltivazione (Progetto Microx2)

Rack



Drawer

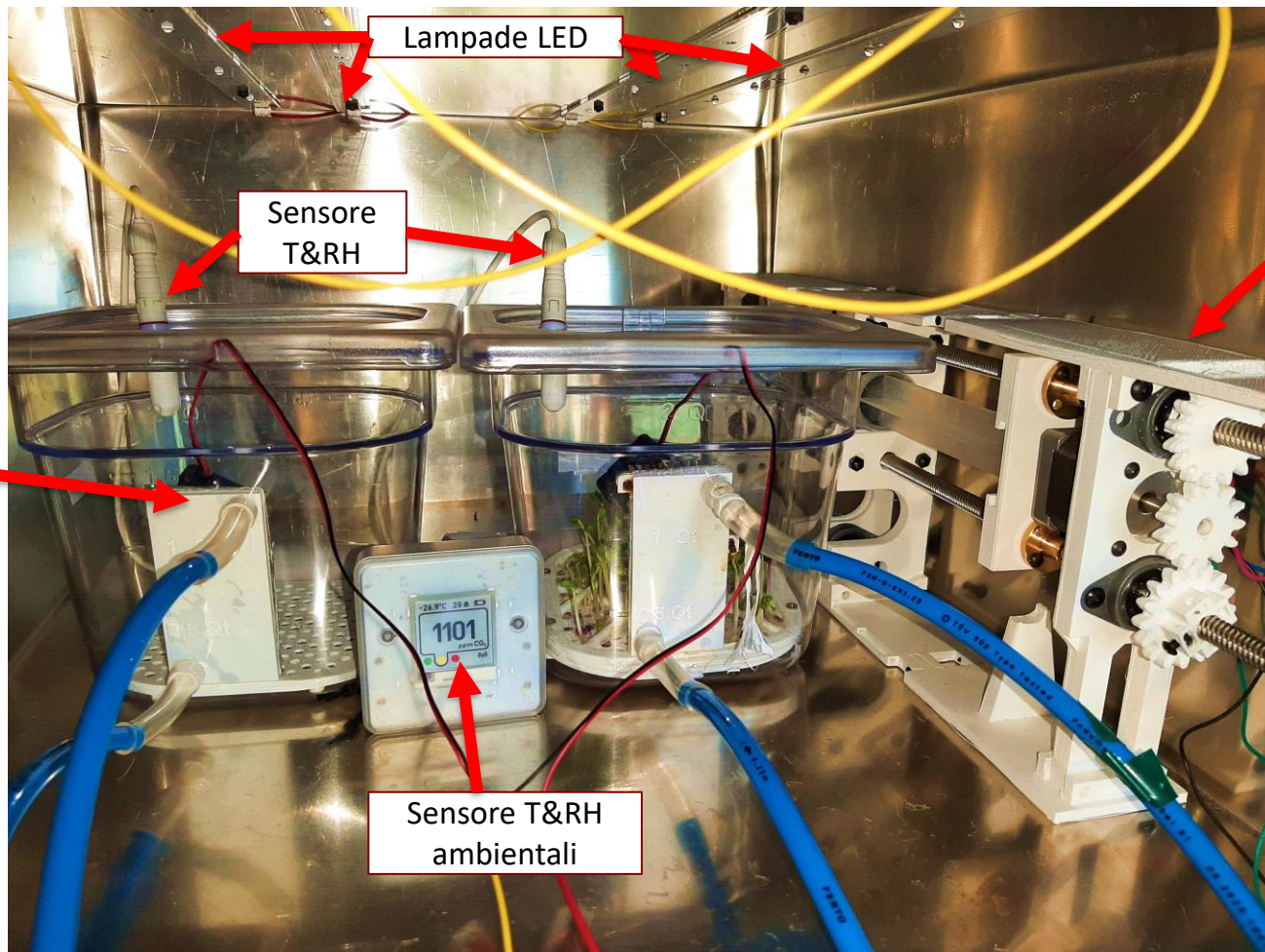


Contenitore



- Dotato di piastra freddante e fan per il controllo termico
- Piastra di semina e supporto del substrato prototipato e stampato in 3D
- Substrato in fibra di cellulosa
- Dotati di un Nutrient Delivery System indipendente e completamente controllabile

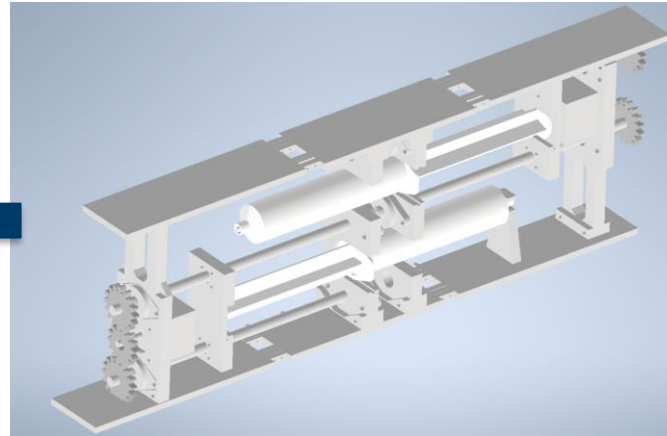
Modulo di coltivazione



Prototipizzazione rapida con stampa 3D

Utilizzo di Stampante 3D DELTA WASP 2040 Industrial X

Realizzazione dei componenti in PLA del Nutrient Delivery System e Heat Exchanger



3D Design:

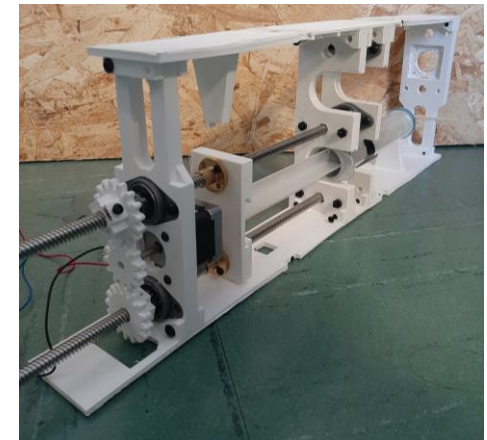
Autodesk Inventor > CAD

Simplify 3D > Slicer

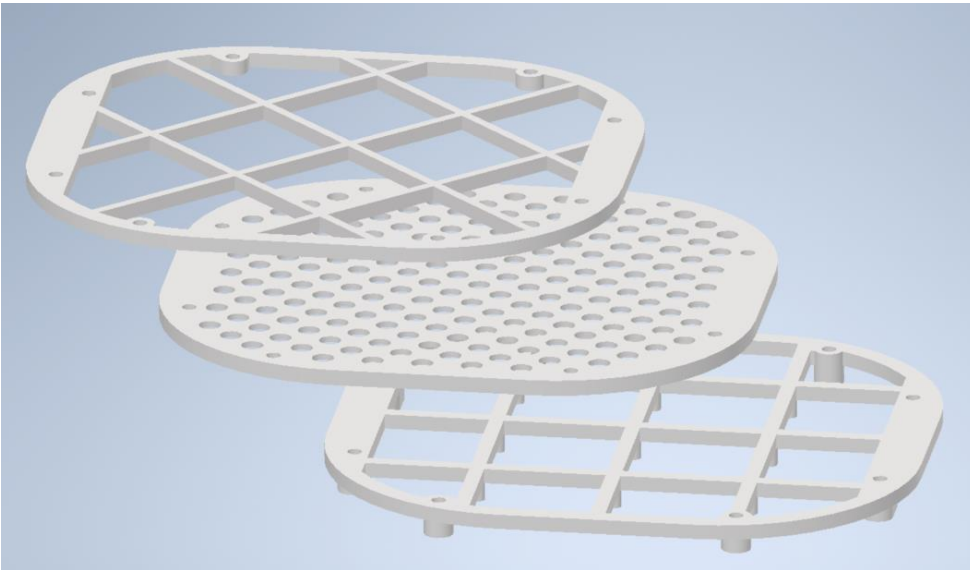
Realizzazione e montaggio:

PLA Bianco

Barre filettate senza fine e motori
stepper & driver

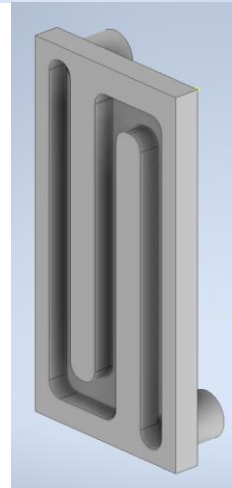


Contenitore di Coltivazione



Piastra di semina:

- Supportare i semi in microgravità
- Mantenere i semi aderenti al substrato
- Ridurre l'evaporazione del substrato di coltivazione



Cold Plate:

- Ridurre temperatura e RH all'interno dei contenitori
- Favorire la movimentazione dell'aria con un air fan
- Recupero della condensa per reintegro nel substrato (in progress)

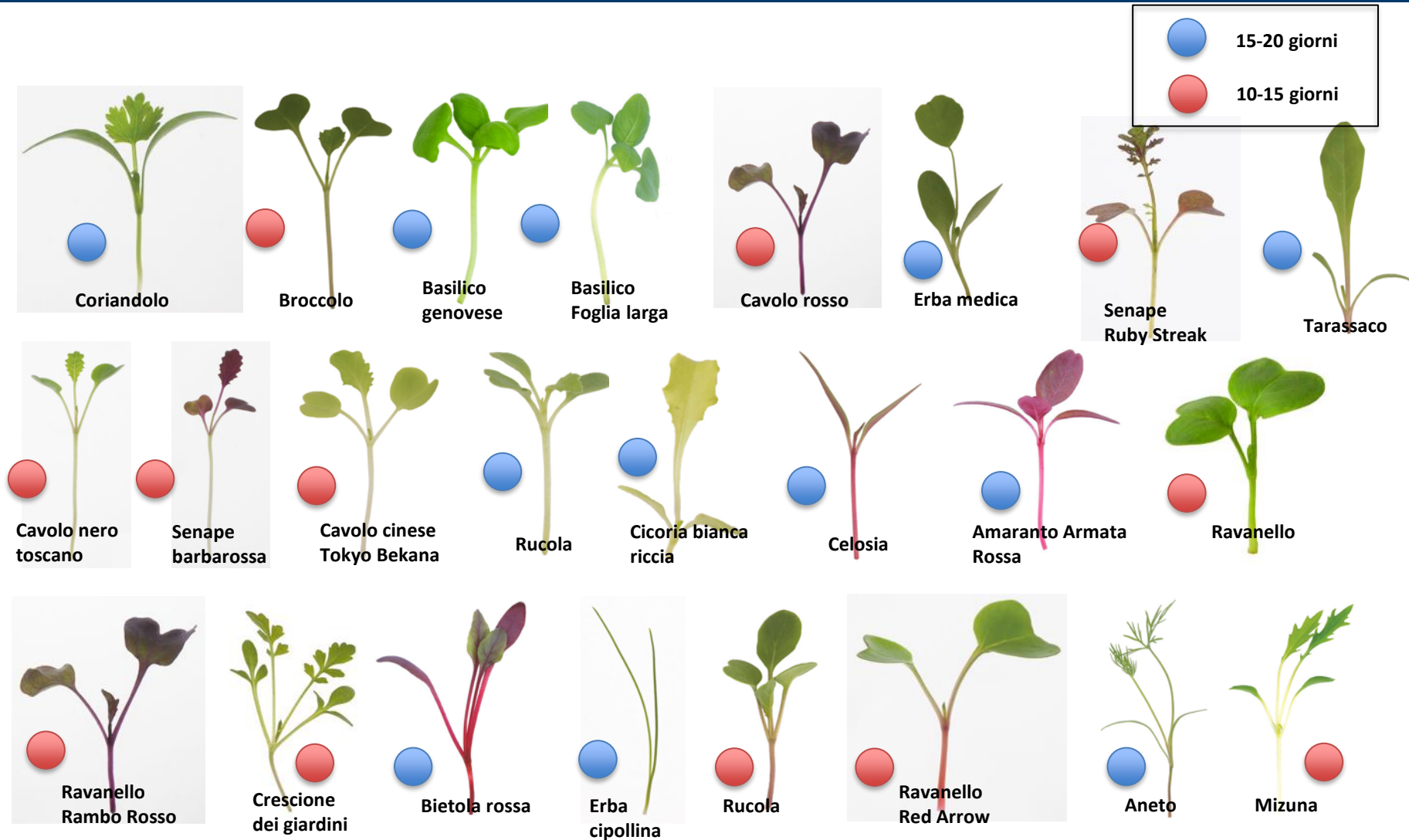
- Microgreens sono verdure, piante erbacee, erbe aromatiche piante selvatiche eduli raccolte a 7-14 giorni dalla semina e consumate in uno stadio giovanile quando le foglie cotiledonari sono pienamente sviluppate e compaiono le prime foglie vere con un'altezza della pianta senza radici di 5-9 cm
- Dai sapori intensi, colori vividi
- Generalmente ricche di fitonutrienti più delle piante a maturità da 4 a 40 volte più concentrate, eccellente sorgente di vitamine, carotenoidi e flavonoidi (elevata densità nutrizionale)



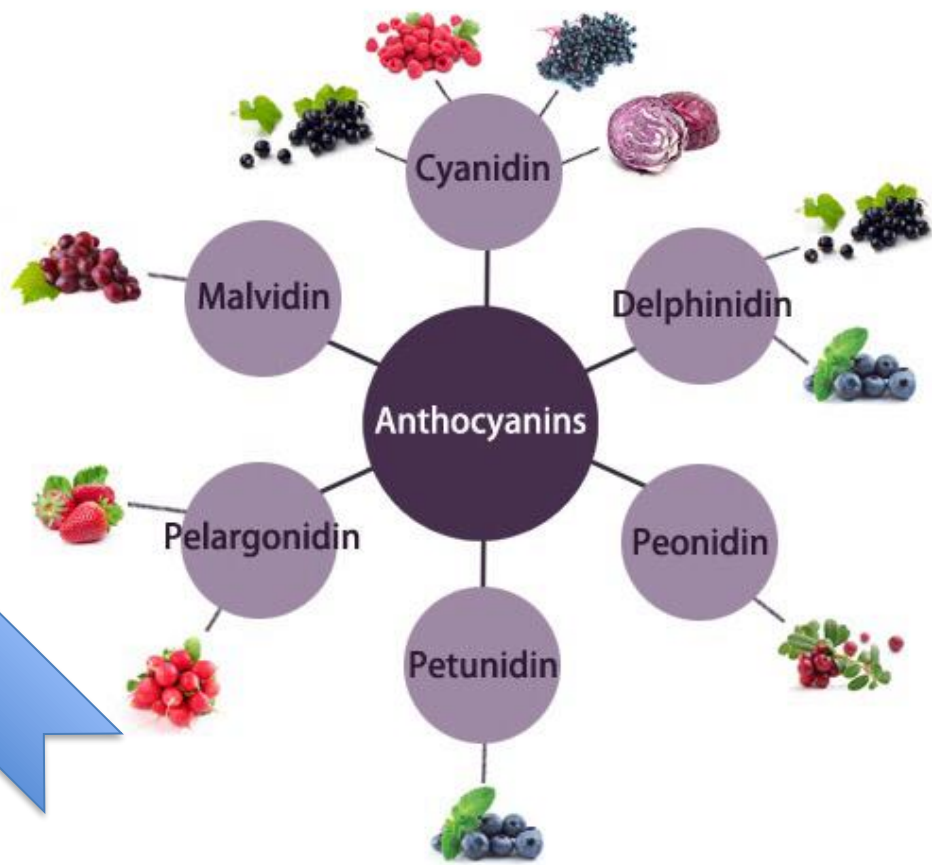
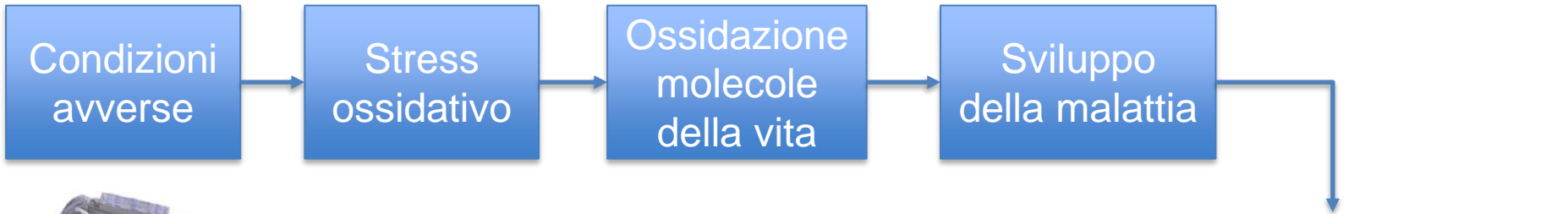
Microverdure



Principali parametri controllati

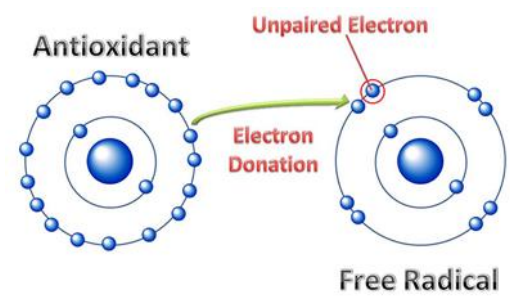


Effetti benefici delle antocianine sulla salute dell'uomo

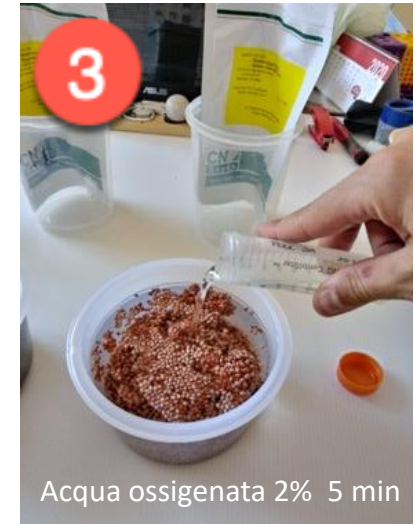


Invecchiamento, Cancro, Ipertensione, Malattie cardiovascolari, Asma, Infezioni

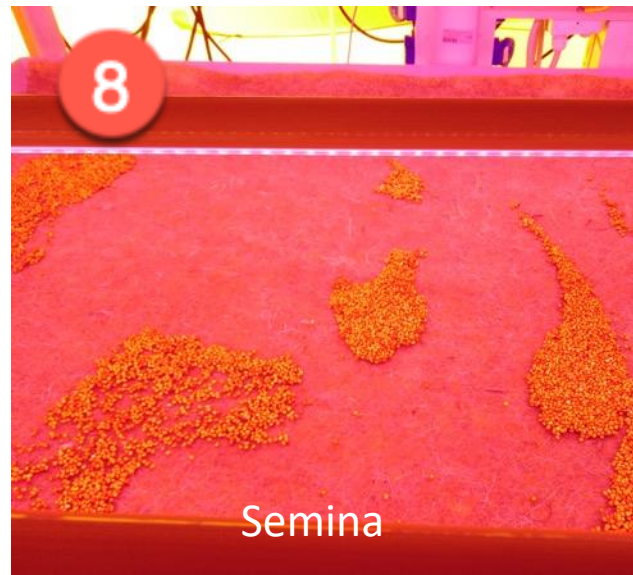
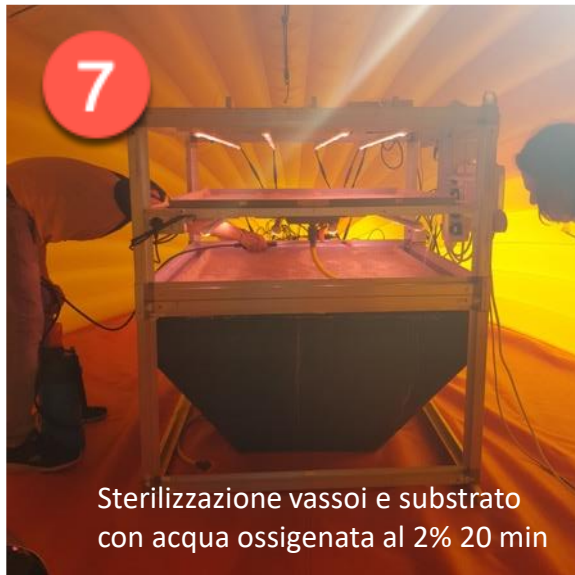
Terapia antiossidante



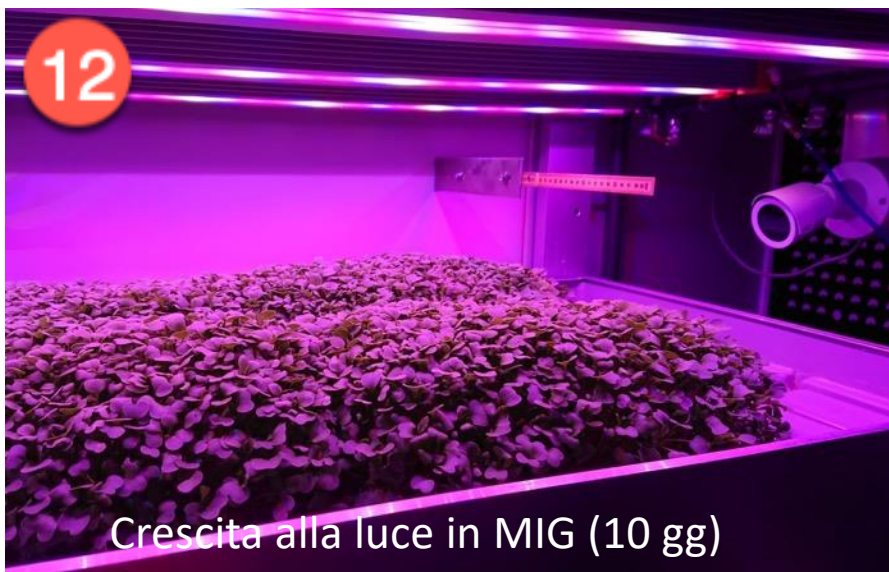
Microverdure: Sterilizzazione ed imbibizione



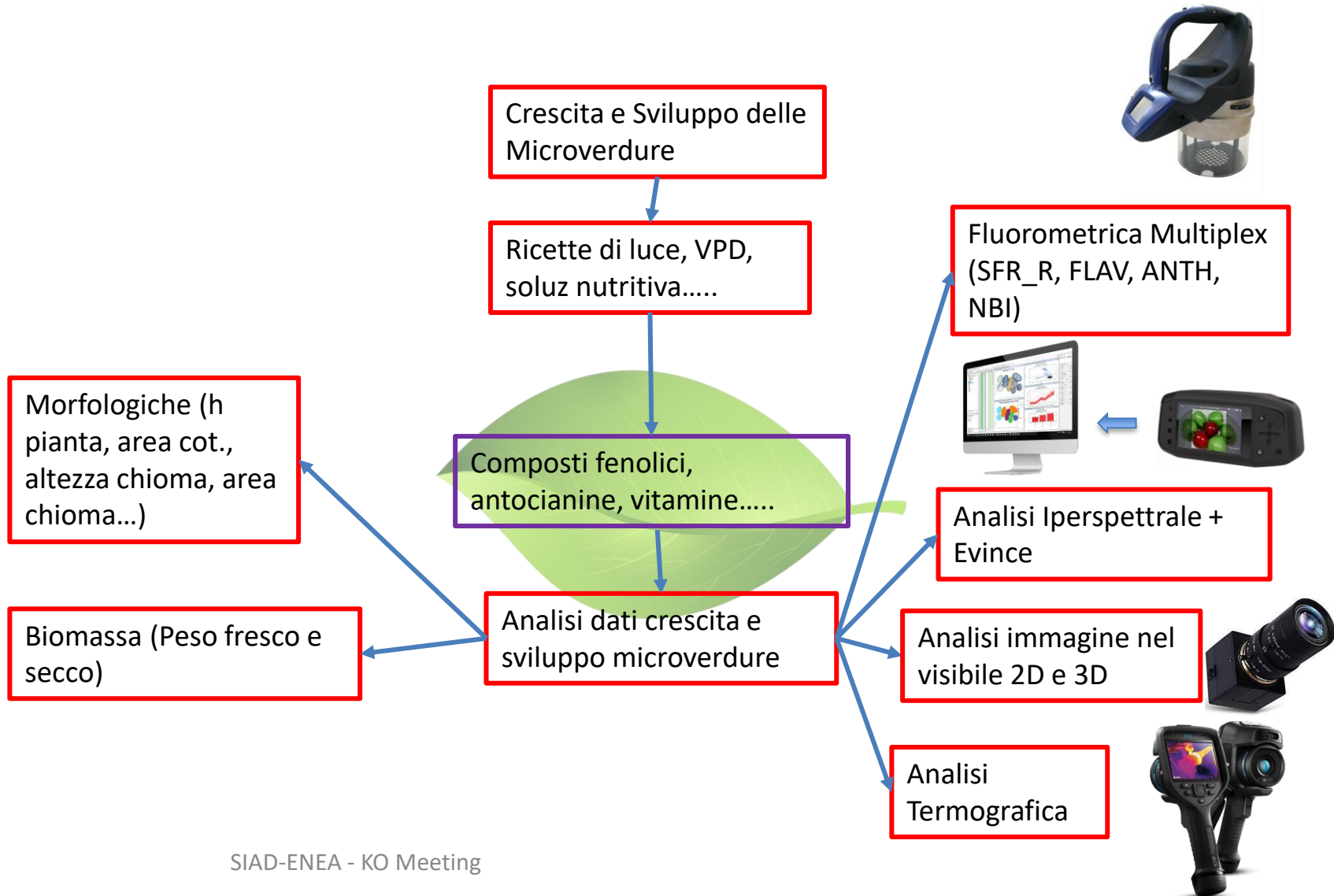
Microverdure: sterilizzazione substrato e semina



Microverdure: coltivazione



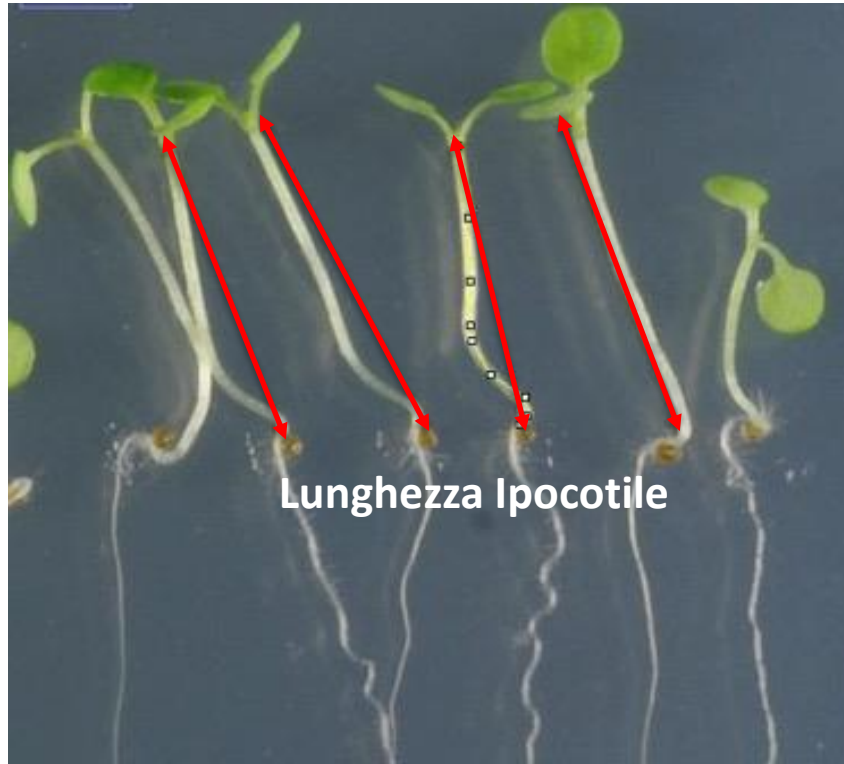
Cesoia a batteria



Peso fresco e Peso secco



Calibro Digitale (Lunghezza Ipocotile)



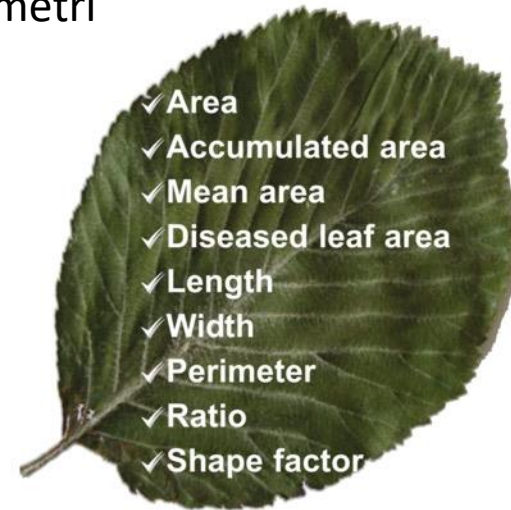
Il calibro digitale misura la lunghezza



Visualizzazione dati in tempo reale,
facilità di utilizzo

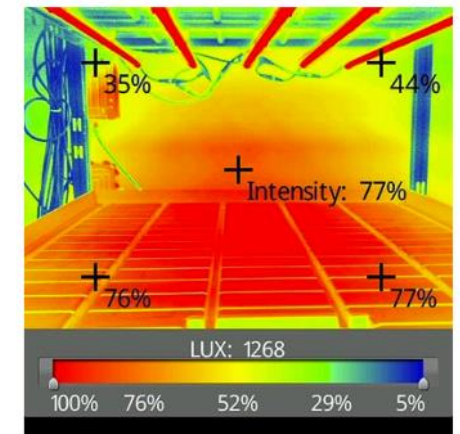
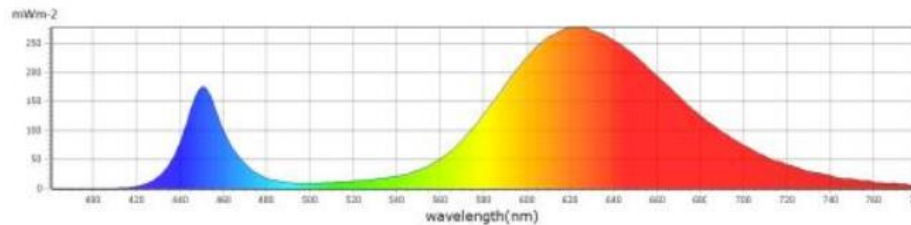
Misuratore Portatile Area Fogliare AM350

L'AM350 misura tutta una serie di parametri



Visualizzazione dell'immagine in tempo reale, Alta risoluzione, Portatile con batteria, Non-distruttivo, Operazioni facili e veloci, Immagazzinamento immagini e dati, Scarico immagini e dati via USB

Luci misura di intensità e spettro



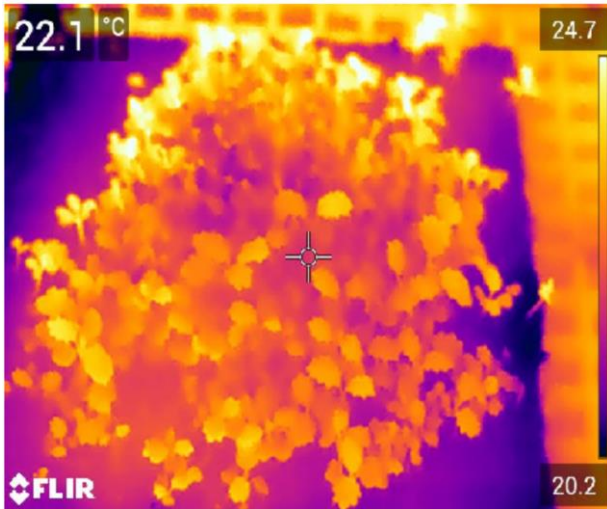
Caratteristiche

CCT : 0 K	x10 : 0,4857	delta-x : 0,4921	LambdaD : 690 nm	PPFD : 157,2 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$	S/P : 0,88	R3 : 0,0	R10 : 0,0
LUX : 7103 lx	y10 : 0,2974	delta-y : 0,2979	LambdaP : 620 nm	PFD : 170,4 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$	IRR : 33,53	R4 : 0,0	R11 : 0,0
t-Time : 440 us	u'10 : 0,3471	delta-u' : 0,3520	Purity : 39,98%	PFD-B : 17,27 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$	CQS : 0,0	R5 : 0,0	R12 : 0,0
x : 0,4921	v'10 : 0,4782	delta-v' : 0,4796	fc : 660,1	PFD-G : 32,02 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$	CRI : 0,0	R6 : 0,0	R13 : 0,0
y : 0,2979	X : 11731,29	Duv : 0,4756	Rf : 0,0	PFD-R : 107,9 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$	TLCI : 0,0	R7 : 0,0	R14 : 0,0
u' : 0,3520	Y : 7103,10	MEL : 2781 lx	Rg : 0,0	PFD-UV : 0,0004 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$	R1 : 0,0	R8 : 0,0	R15 : 0,0
v' : 0,4796	Z : 5006,75	LambdaPV : 278,1	GAI : 0,0	PFD-FR : 13,18 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$	R2 : 0,0	R9 : 0,0	

Spettro ed intensità delle diverse ricette di luce testate. In tabella per ogni lunghezza d'onda sono riportati i valori di flusso radiativo in micromoli $\cdot\text{m}^{-2}\cdot\text{s}^{-1}$.

PPFD Densità di Flusso Fotonico Fotosintetico; PFD Densità di Flusso Fotonico

Thermographic analysis



FLIR E75 camera measures

- Leaf temperature
- Evapotranspiration
- Plant stress



Advantages of the technology are

- Portable device for field measurement
- Non destructive measurement
- Non contact fast measurement
- Active sensing under any light/dark condition
- No preparation of the plant

Leaf Temperature sensor and VPD



Sensor performance

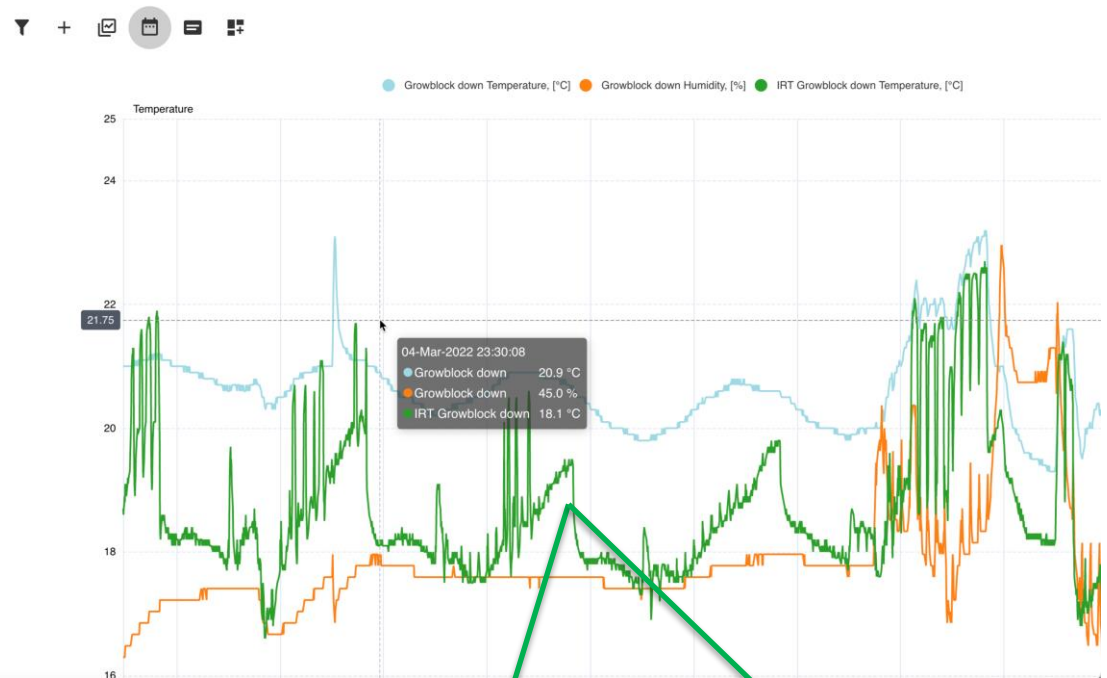
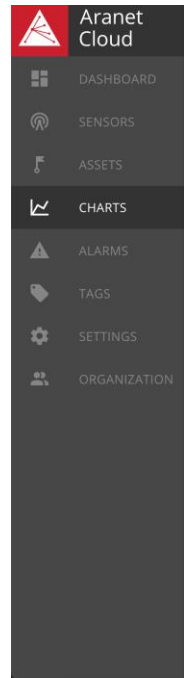
Range	-20 °C to 85 °C (-4 °F to 185 °F)
Resolution	0.1 °C (0.1 °F)
Recommended ambient temperature range	20 °C to 40 °C (-68 °F to 104 °F)
Recommended object temperature deviation	≤ +/- 3.0 °C (≤ +/- 5.4 °F)
Accuracy ¹ in the recommended range	< ±1.0 °C (< ±1.8 °F)
Goose-neck length	50 cm (20 in)
Field-of-view	5°



$$VPD = VP_{sat} - VP_{air}$$

$$VP_{sat} = \frac{610.7 \times 10^{((7.5 \times \text{Leaf temperature}) / (237.3 + \text{leaf temperature}))}}{1000}$$

$$VP_{air} = \frac{610.7 \times 10^{((7.5 \times \text{Leaf temperature}) / (237.3 + \text{leaf temperature}))}}{1000} \times \left(\frac{\text{relative humidity}}{100} \right)$$



Hyperspectral camera (Specim IQ) + Breeze (Prediktera)

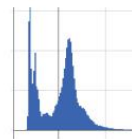
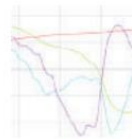
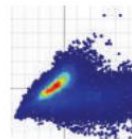


RGB IMAGE. Utilize the RGB image for viewing raw image data, PCA scores or response variables.

SCATTER 2D. Find image areas of interest. The density colouring is useful for discovering main features in the image.

LINE PLOT. Analyse the loadings of your multivariate model. Discover important spectral bands, which have high impact on the model.

HISTOGRAM. Use the histogram for viewing the distribution of your data.

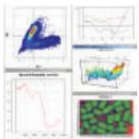
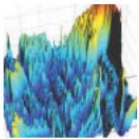
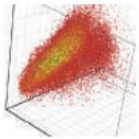
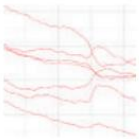


SPECTRAL PLOT. View the spectra of selected points in score plots or RGB images. Both raw spectra and transformed spectra can be shown in this way.

SCATTER 3D. Find pixels of similar spectral properties while working in three dimensions. It is fully rotatable in real-time.

CONTOUR 3D. View any two-dimensional data in three dimensions using the Contour 3D plot. It is fully rotatable in real-time.

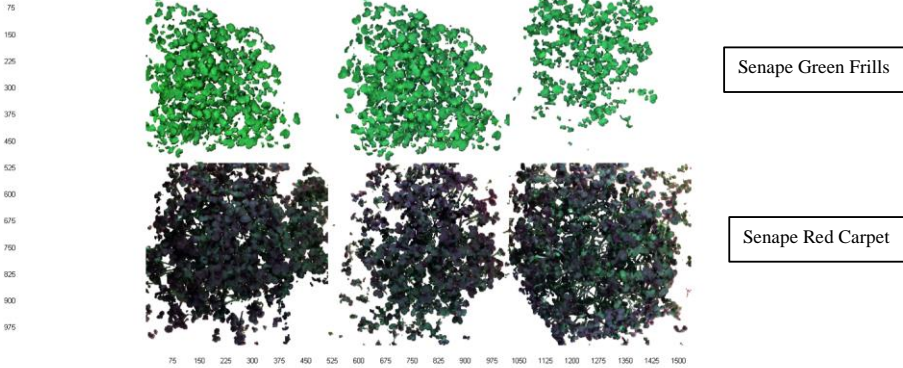
MODEL PLOTS. Create a series of useful plots for image analysis in a snap. The pre-defined model plots offer quick access to your image data.



Analisi Iperspettrale

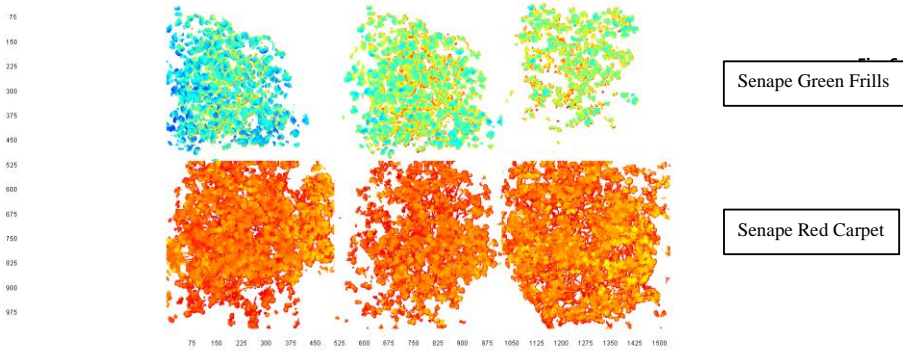
(A) ?

RGB Image (X Training)

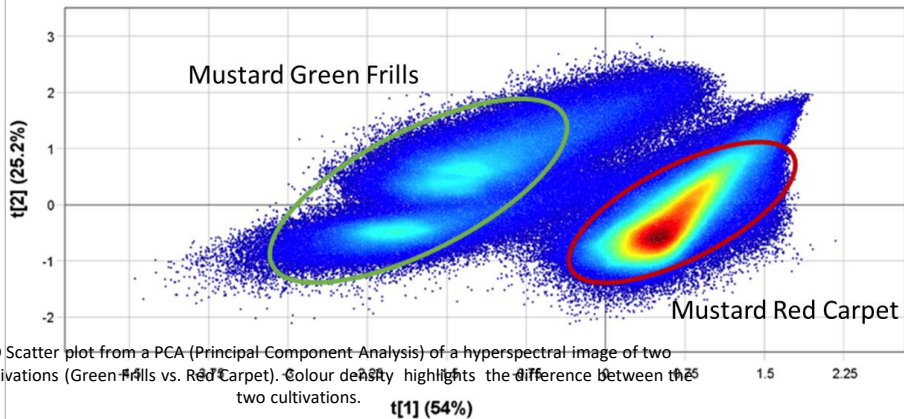


(B) ?

PCA Model - Contour 2D (T)
DataSet (Multi image import)



PCA Model - Scatter 2D (T)
DataSet (Multi image import)



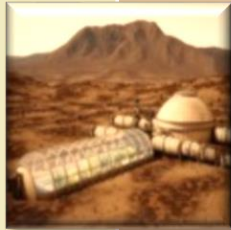
2D Scatter plot from a PCA (Principal Component Analysis) of a hyperspectral image of two cultivations (Green Frills vs. Red Carpet). Colour density highlights the difference between the two cultivations.

Biotechnology Lab Projects

2014 2015 2016 2017 2018 2019 2020 2021 2022

Space Farming

BIOxTREME



HORTSPACE

V-GELM

LOOPS-M

REBUS

GREENCUBE

SOLE

MICROx2

Urban Farming



CHEF

MIG

IDROZAFF

NUTRI 3D

Container farming: CHEF, MIG, IDROZAFF e MICROx2



CHEF PROJECT



Italian national agency for new technologies, energy and sustainable economic development

Powered By



Cofinanced By

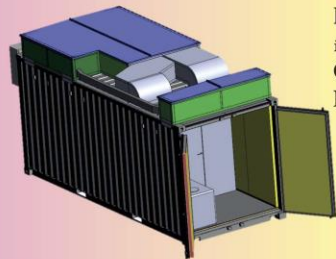


SEALED, STERILE, FULLY COMPUTERIZED HYDROPONIC GREENHOUSE IN A SHELTER

Authors: G. Pontetti e M. Lemme [G & A Engineering], E. Benvenuto e L. Nardi [ENEA SSPT-BIOAG]

Design & Development of a Vertical Farm inside an ISO 20 standard Shelter for Computerized Cultivation of Microgreens & Baby Leaf

PLUG, SEED...WAIT... ENJOY!

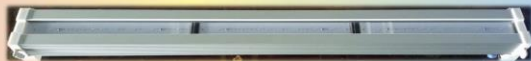


HMI of the Last Generation For Fully Management



Closed Cycle
ISO 8 Clean Class
Electronic Cultivation Recipe
Fully Automated: from seed to harvest
Latest Technologies Inside

New-Generation Multispectral LED Lamps with Dimmable Light, Wavelength Selection and air/liquid heat dissipation.



Contacts:
giorgia@pontetti.com, maurizio.lemme@gaengineering.com, eugenio.benvenuto@enea.it, luca.nardi@enea.it

Military Innovative Greenhouse



Gemelli



Fondazione Policlinico Universitario A. Gemelli
Università Cattolica del Sacro Cuore



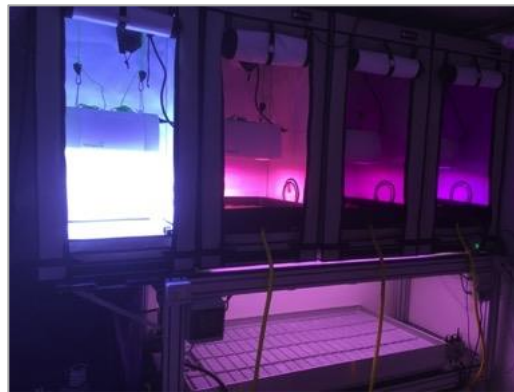
UNIVERSITÀ
DEGLI STUDI
DELL'AQUILA

Impianti di Coltivazione

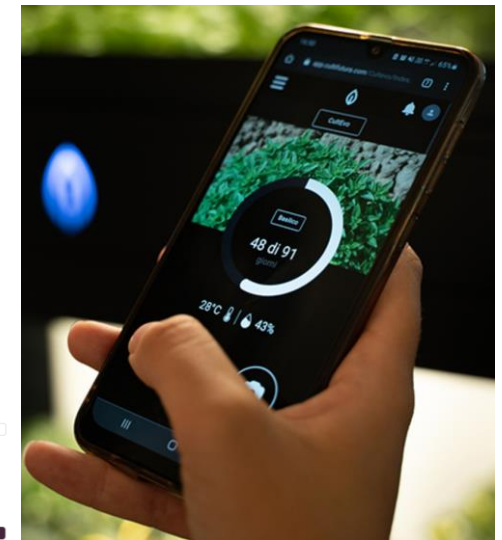
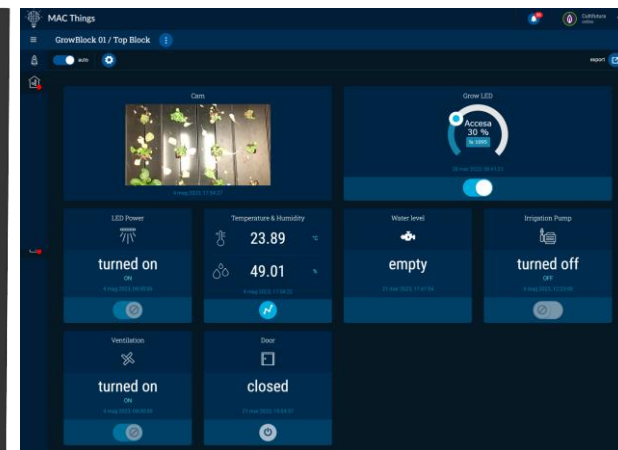
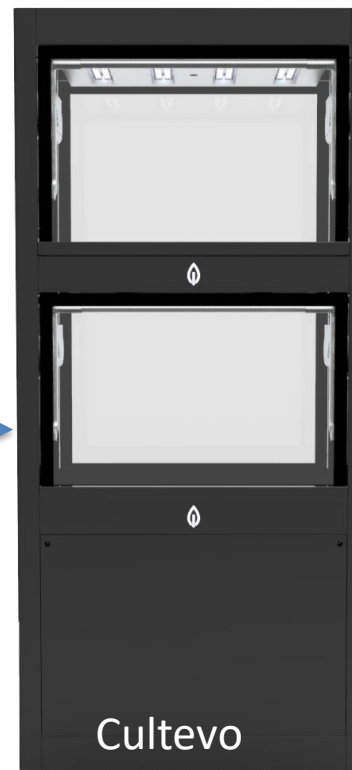
- Serra a contenimento con livello di biosicurezza 2 (S)



- Camere bianche a contenimento di classe ISO 5 (ISO 14644-1) (C)



Orto-domestici: from Growblock to Cultevo



Utente CultEvo



Desktop



Macchina del caffè



Frigorifero



<https://www.cultifutura.com/cultevo>



Special Products Line



Special Product's Line S.p.A.

Industria Farmaceutica



Messa a punto di protocolli di coltivazione (luci led e fertilizzanti) e realizzazione di sistema multilivello di produzione di piante di *Nicotiana benthamiana* per la produzione di vaccini

Per una vita migliore nello spazio...e nelle città

