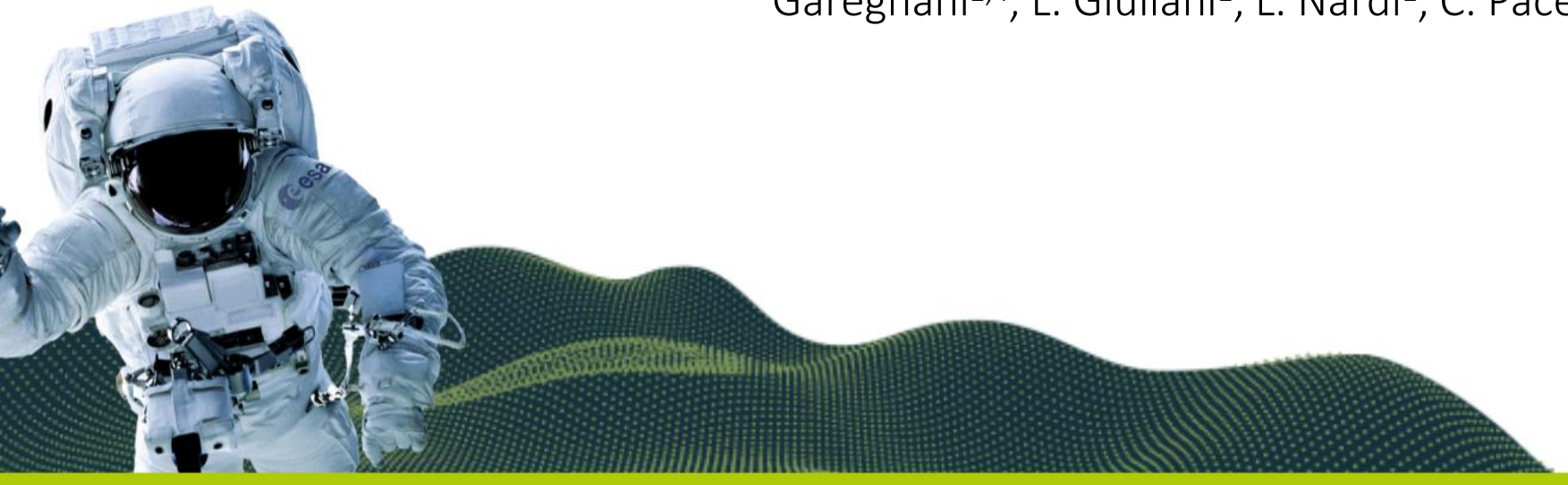
MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR FUTURE

SOLE project: a hydroponic greenhouse demonstrator for fresh food production in space

E. Bennici[1], E. Benvenuto[1], M. Crisconio[2], A. Desiderio[1], E. Di Mascio[3], Francesca Ferranti[2], M. Garegnani[1,4], L. Giuliani[1], L. Nardi[1], C. Pacelli[2], G. Pontetti[2], M. E. Villani[1]



ELETTRONICA GROUP

COMPANY HISTORY

1996

G & A ENGINEERING

Foundation

2 DEPT

PRIVATE RESEARCH CENTER

For Microelectronic for Space Application

INNOVATIVE SME

Defence and Aerospace

PMI INNOVATIVA

registroimprese.it

COMPANY HISTORY

May 2022

G & A Engineering® INDUSTRY → EltHUB ELETTRONICA GROUP

PRIVATE RESEARCH CENTER
For Microelectronic for
Space Application

INDUSTRY
Defence, Aerospace,
Hydroponic,
Automotive, Medical

EltHUB ELETTRONICA GROUP
- 70% ELETTRONICA GROUP Defence | Cyber | Security
- 30% PONTETTI Family

THE COMPANY

18.000

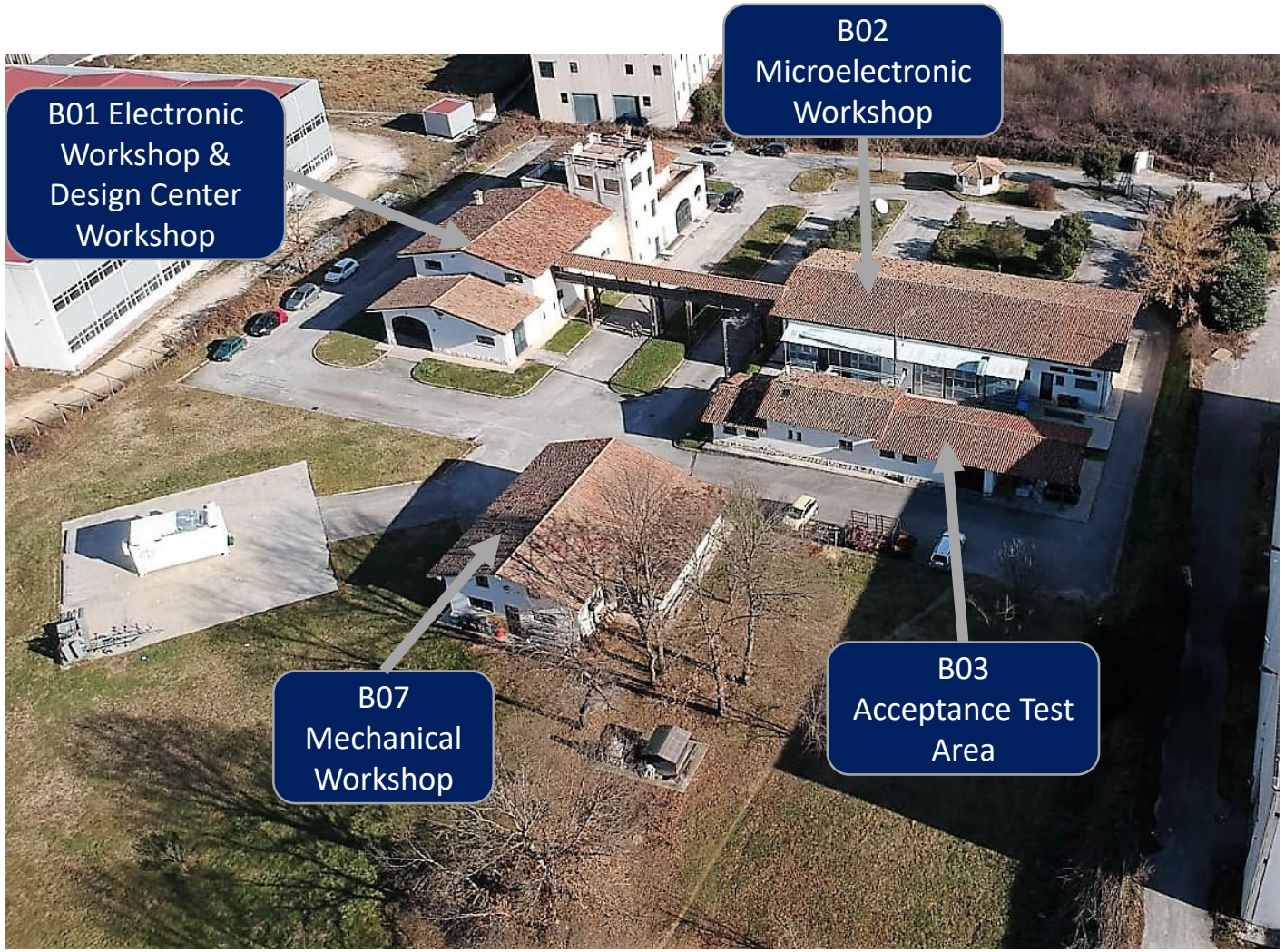
SQM

5

WORKSHOPS

SA 8000
BUREAU VERITAS
Certification

ISO 9001
ISO 14001
BUREAU VERITAS
Certification



THE COMPANY

A personnel focused company having a mix of skills, high tech internal technologies and industrial processes

14

2.5
M€
TURNOVER

70%
ELETTRONICA GROUP
Defence | Cyber | Security

5 LOB

2
Research Projects
PON Agrifood
& PNRM

MAIN CUSTOMERS

Elettronica S.p.A.
Leonardo S.p.A.
Airbus Italia S.p.A.
Malvern Panalytical BV
ELT GmbH
Private Companies

CEA

An entire LOB dedicated to create a line of hydroponic products.

- ✓ RobotLamp, the best performing LED lamps on the market
- ✓ RobotFarm, the hydroponic greenhouse in the size of a washing machine
- ✓ Hydrowall, the hydroponic vertical farm in the size of a planter
- ✓ MIG, the vertical farm in container ISO20 for extreme applications
- ✓ SOLE, the hydroponic vertical farm designed to cultivate in Space

A Patent for Electronic Cultivation Recipe for CEA systems

FARMING HAS NEVER BEEN EASIER

THE « SOLE » PROJECT

A plant greenhouse demonstrator for the soilless cultivation of plants, based on solid state artificial lighting (LED).

The project studied the best light recipes for duration, intensity and spectral quality, optimized to achieve the different phases of plant growth.

The goal is to use this demonstrator to support research for future manned space missions, to carefully evaluate the resources needed to produce adequate quantities of fresh food, reducing the astronaut's operating times.

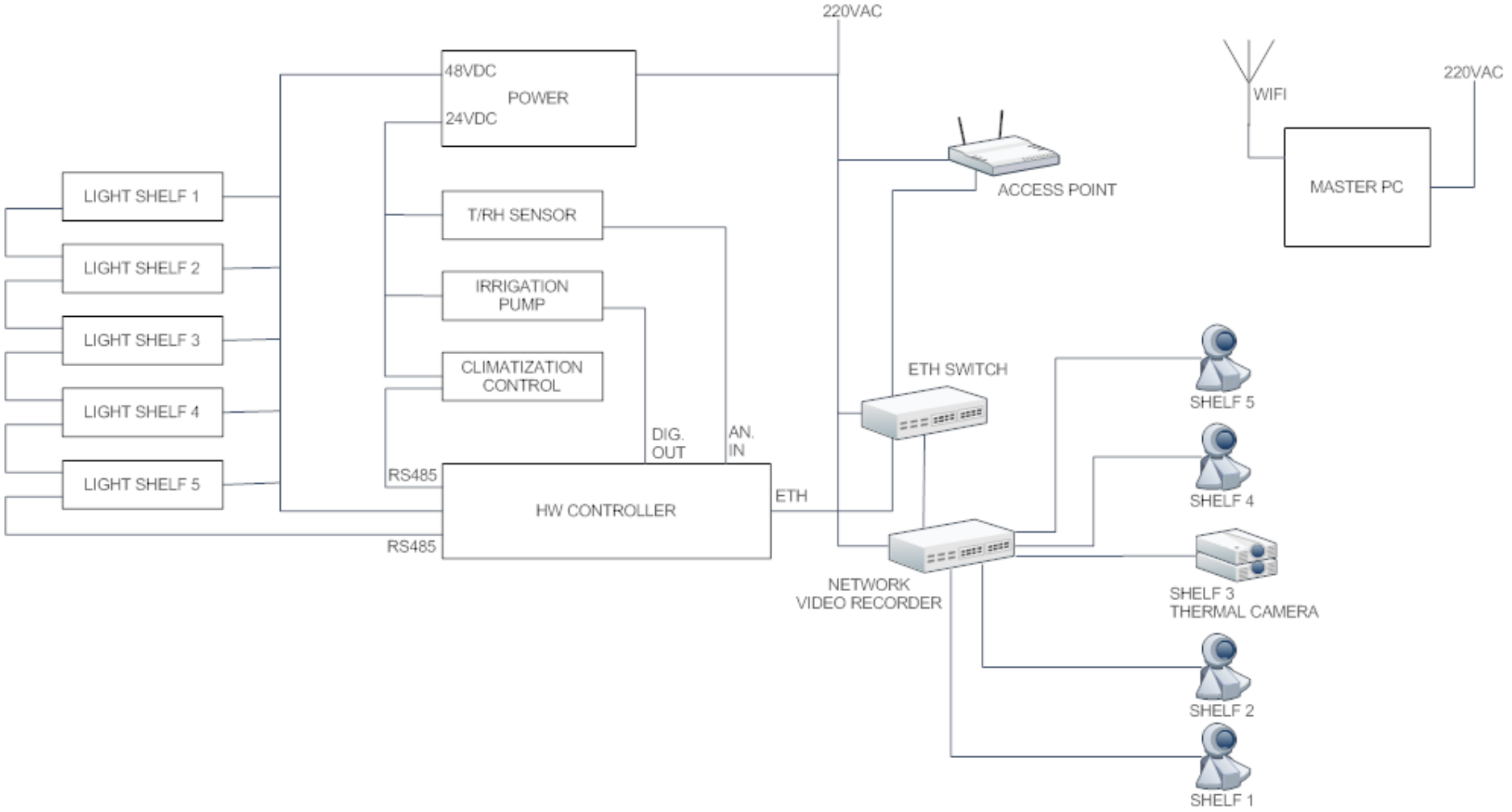
BACKGROUND

Future human long-term space exploration demands for fresh food production during missions, independently on periodic supplies from Earth.
The possibility to grow plants in space positively impacts both astronaut diet and psychological wellbeing.
It has been estimated that a facility of a few cubic meters is sufficient to supply the diet of 4 to 6 crew members with key vitamins and fresh bioactive substances.
Soilless cultivation is the best suited for production of high quality food in space, where resources are limiting factors.
In this context, the project SOLE aimed to realize a hydroponic cultivation module based on LED lighting systems for growing plants, specifically microgreens, for space applications.

SOLE DEMONSTRATOR

SOLE is a hydroponic vertical farm built in a closed environment, fully controlled and the light radiation for photosynthesis (PAR) is provided by Proprietary LED lamps.
The cultures are arranged on 5 trays that can be lighted independently, while climate and irrigation parameters are in common.
The command and control system is Proprietary and is divided into MASTER and HW CONTROLLER units. The MASTER consists of a PC external to the device, while the HW CONTROLLER consists of a Proprietary board with microprocessor. The two units communicate with a MODBUS protocol over Ethernet through the Wi-Fi network of SOLE. The MASTER has the task of providing the HMI interface, managing the automatic execution of cultivation recipes processes, allowing maintenance operations and storing system operating data, the HW CONTROLLER has the responsibility of managing the hardware by applying the commands from the MASTER.

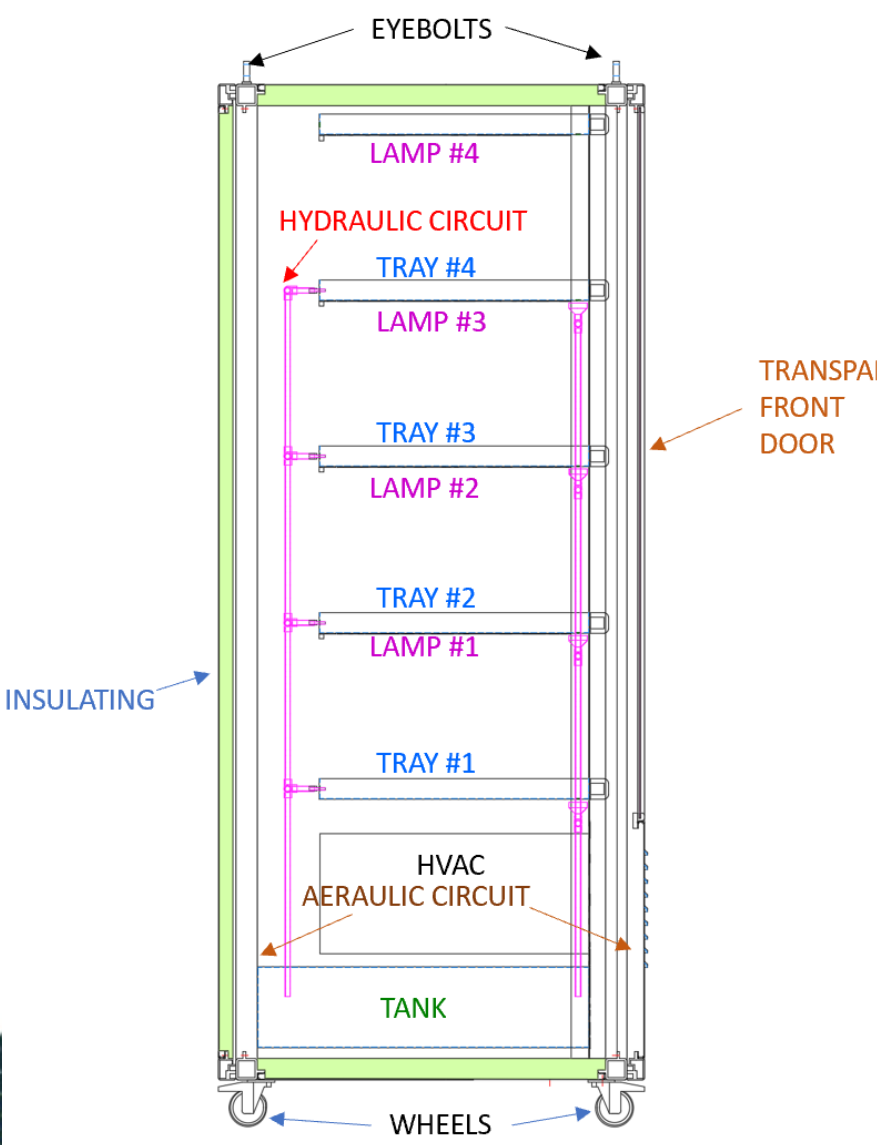
BLOCK DIAGRAM

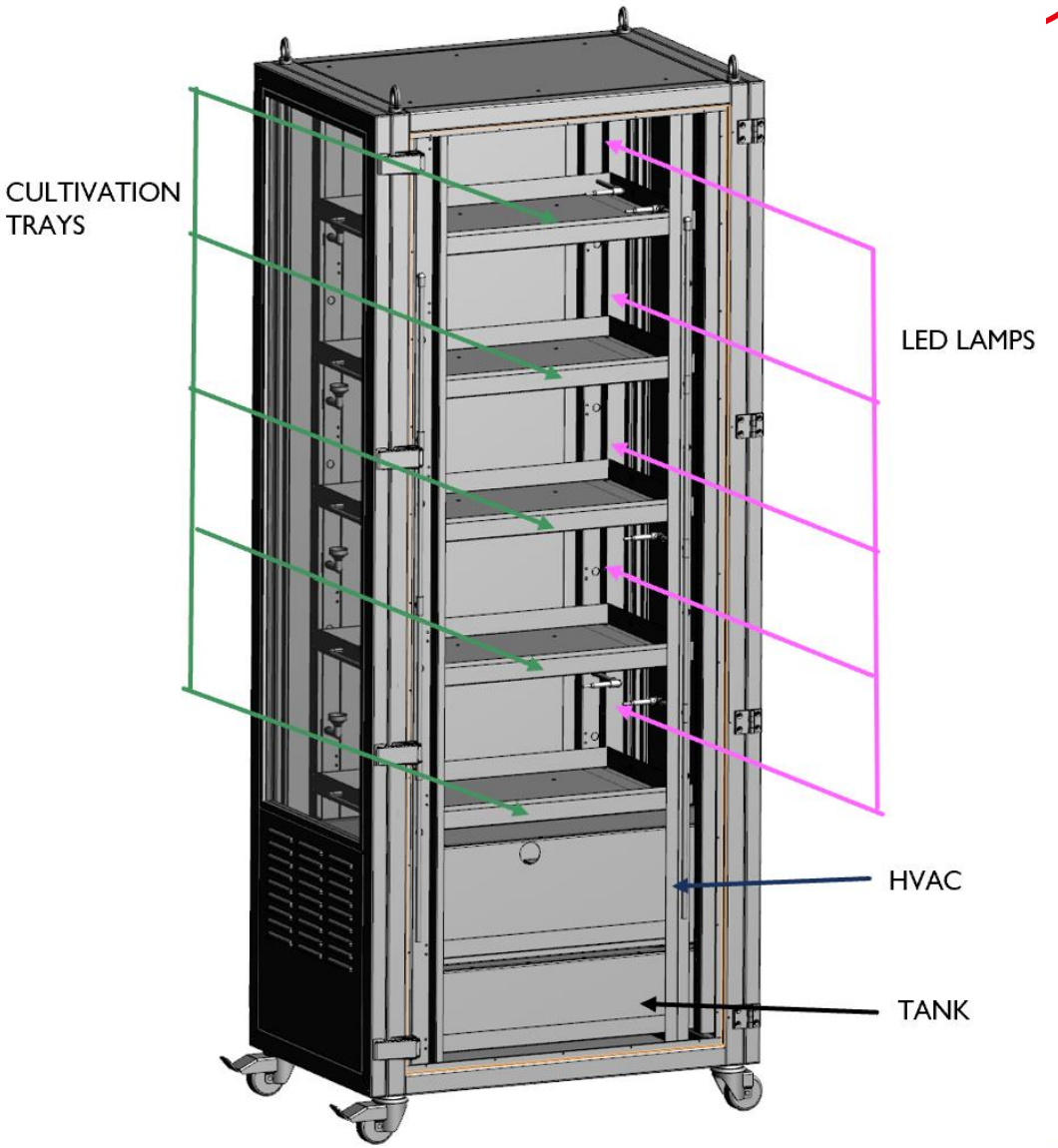


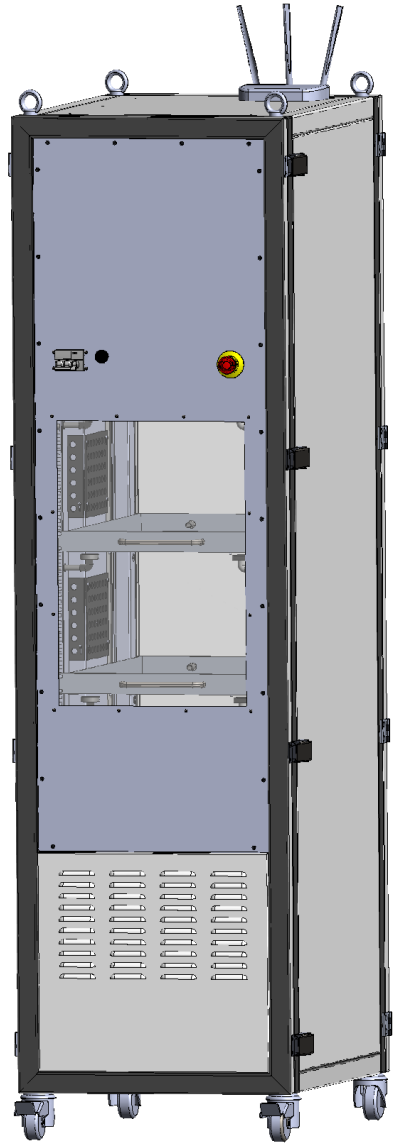
DEMONSTRATOR DESIGN

The SOLE demonstrator has been designed for the automatic hydroponic cultivation of microgreens, babyleaf and dwarf species.
It consists of a modular cabinet implemented with cultivation trays, light, HVAC, aeraulic and hydraulic systems.
The cabinet was realized in aluminium alloy, which ensure excellent mechanical properties and low weight. It was insulated to minimize energy dispersal and external environmental influence and was equipped with temperature, pressure and relative humidity sensors, else than real-time video monitoring system.
The demonstrator can be operated and controlled remotely using a LAN connection and a simple user-friendly HMI.

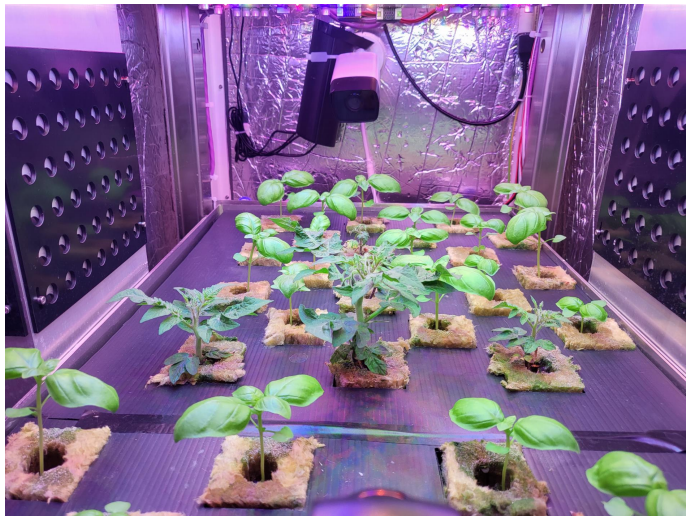
SOLE DEMONSTRATOR



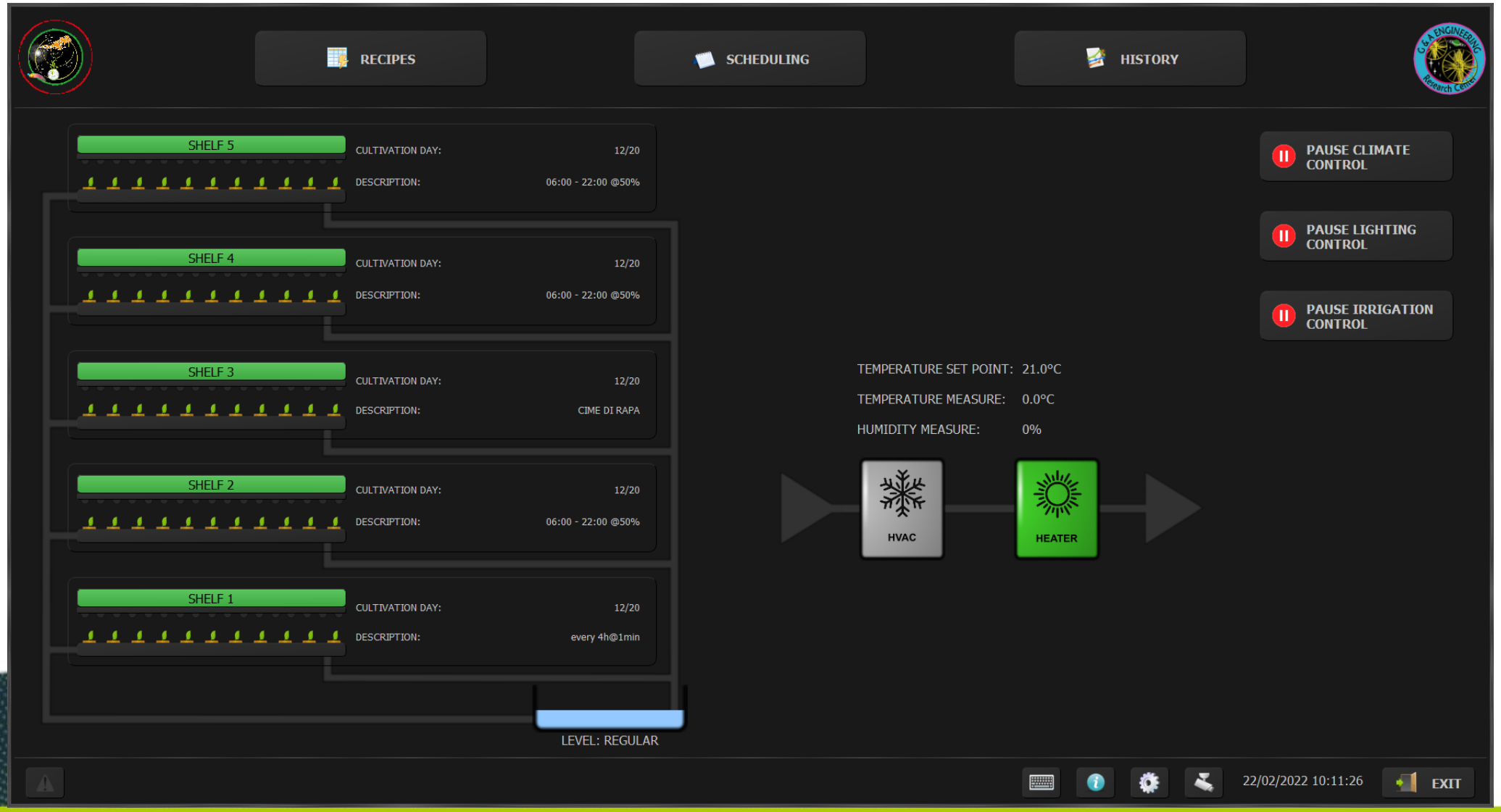




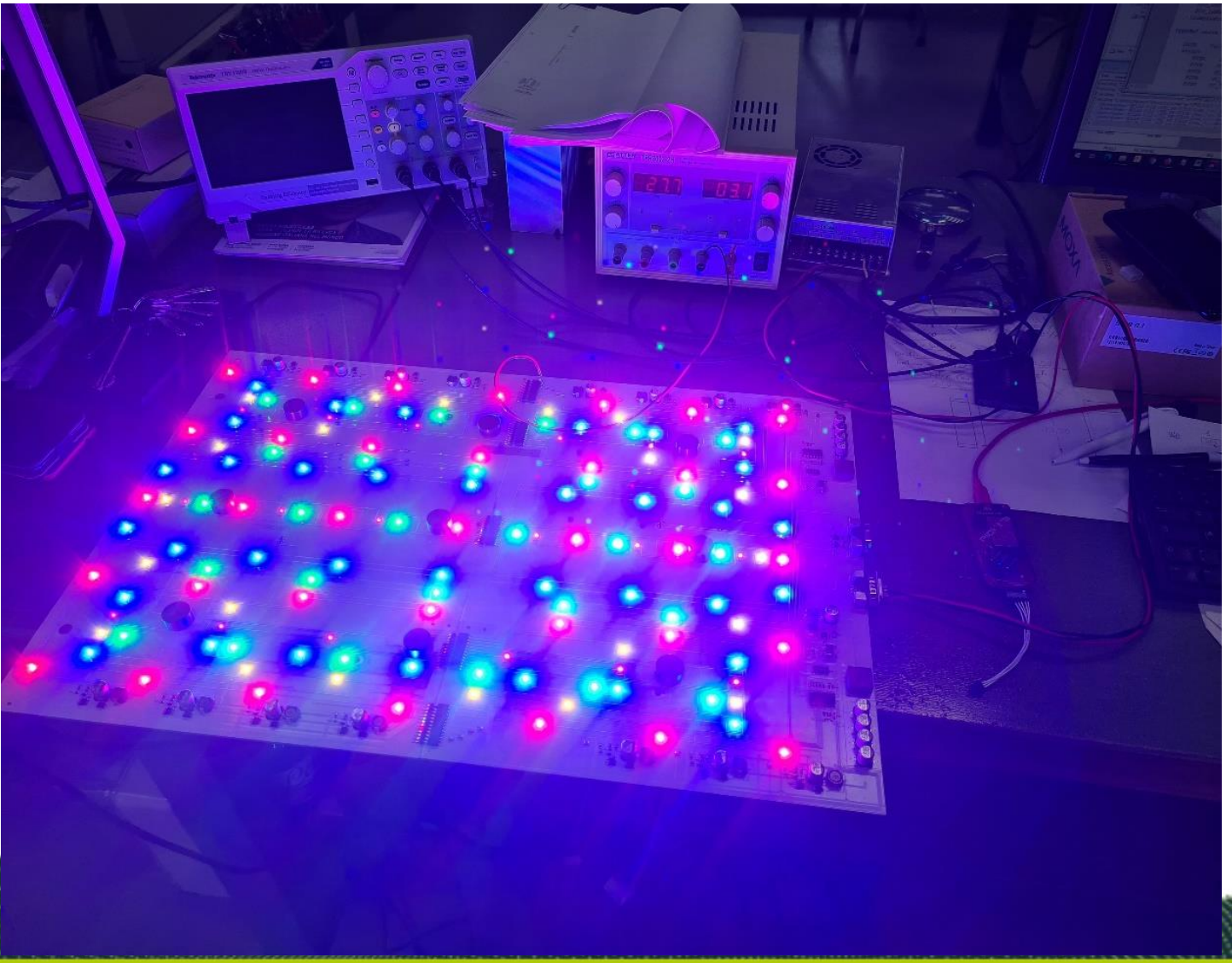
SOLE DEMONSTRATOR



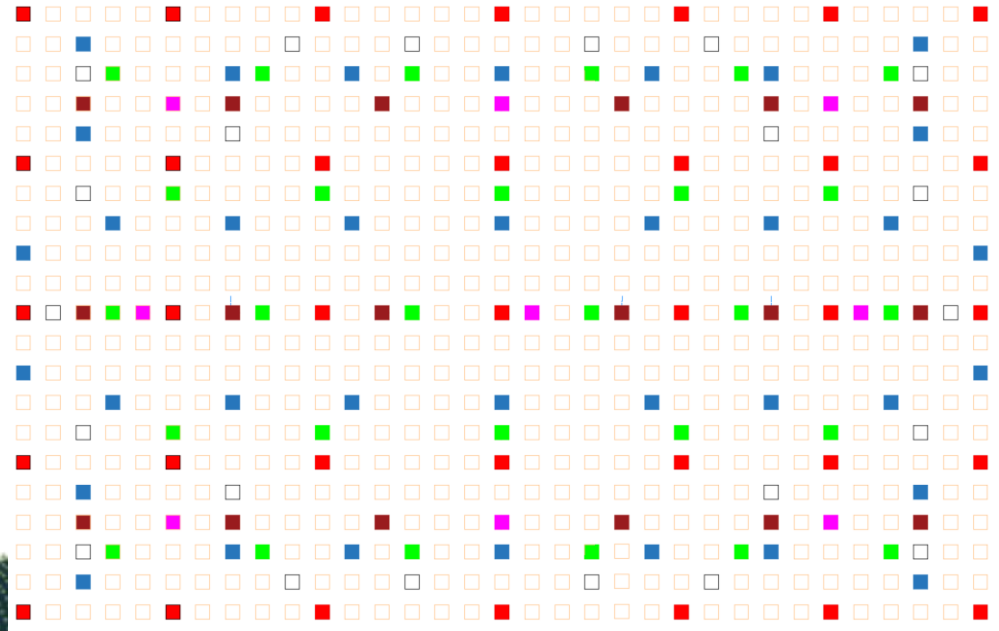
SOLE HMI


RECIPES
SCHEDULING
HISTORY
SHELF 5
CULTIVATION DAY: 12/20
DESCRIPTION: 06:00 - 22:00 @50%
SHELF 4
CULTIVATION DAY: 12/20
DESCRIPTION: 06:00 - 22:00 @50%
SHELF 3
CULTIVATION DAY: 12/20
DESCRIPTION: CIME DI RAPA
SHELF 2
CULTIVATION DAY: 12/20
DESCRIPTION: 06:00 - 22:00 @50%
SHELF 1
CULTIVATION DAY: 12/20
DESCRIPTION: every 4h@1min
LEVEL: REGULAR
PAUSE CLIMATE CONTROL
PAUSE LIGHTING CONTROL
PAUSE IRRIGATION CONTROL
TEMPERATURE SET POINT: 21.0°C
TEMPERATURE MEASURE: 0.0°C
HUMIDITY MEASURE: 0%
HVAC
HEATER
22/02/2022 10:11:26
EXIT

SOLE LED LIGHTS



COLOR	WAVELENGHT	DOMINANT
Deep Blue	439 – 461 nm	451 nm
Far Red	720 – 740 nm	730 nm
Hyper Red	635 – 666 nm	660 nm
True Green	513 – 545 nm	521 nm
UV-A	380 – 440 nm	395 nm
White	3000K	N/A



CULTIVATION CONDITIONS

Temperature:	+21°C to +25°C, adjustable
Relative Humidity:	40% to 60%, adjustable
Irrigation Cultivation Recipe:	1.30 min every 4 hours, adjustable
Recipe Cultivation Lights:	18 h Light, 6 h Dark
	150 µmoles/m^2·s
	Red 40% - Green 20% - Blu 40%

CULTIVATION CONDITIONS

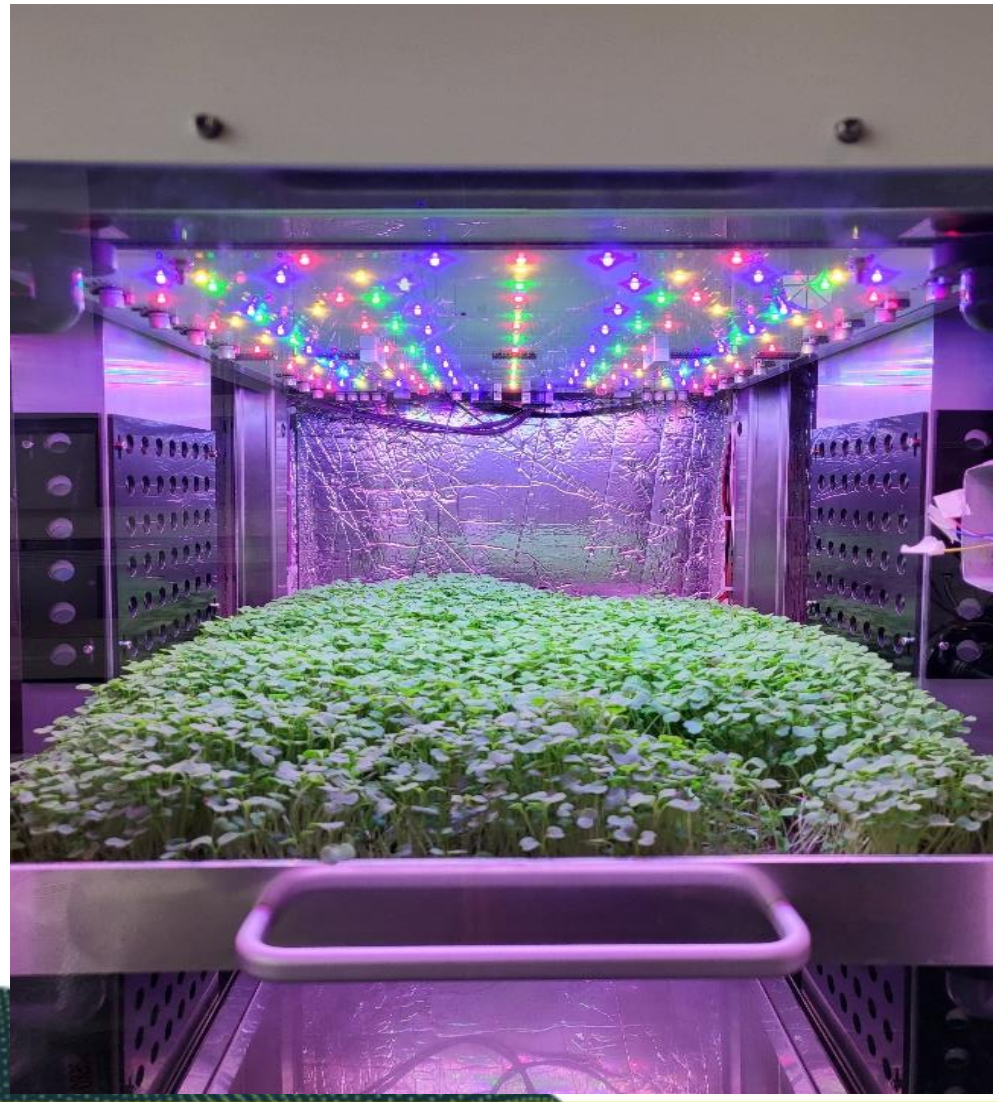
Nutritive Solution:	Custom Prepared pH 7
Cultivation Surface:	68 x 43 cm = 2.924 cm^2
Seed Germination:	48h @ dark, +25°C, 90% RH In this phase the imbibition of the seed takes place. The seed swells and metabolic processes are activated.

CLEAN, SANITIZATION & SOWING

Before starting the cultivation it is necessary to carry out a cleaning and sanitizing cycle in order to guarantee the absence of pathogens for cultivation.
The procedure used is summarized below:

- Sterilize the seed in a 2% v/v hydrogen peroxide aqueous solution for 10 minutes
- Rinse in demi-water three times
- Dry the seeds in clan sterile paper
- Clean all cultivation trays with a 2% v/v hydrogen peroxide aqueous solution
- Cut out the Greenfelt mats to match the grow trays dimension
- Sterilize the Greenfelt by spaying hydrogen peroxide 2% v/v for 15 min before sowing
- Sterilize the tank with a 2% v/v hydrogen peroxide aqueous solution
- Prepare the nutrient solution to fill the tank
- Place the Greenfelt mats on the cultivation trays and carry out a watering cycle with the nutrient solution
- Sow

CULTIVATIONS TEST



TURNIP TOPS

CULTIVATIONS TEST

TRAY DIVISION	
LETTUCE	BROCCOLI
CABBAGE	RADISH

CULTIVATIONS TEST

TRAY DIVISION	
MUSTARD	BEANS
LENTILS	ROCKET

CULTIVATIONS TEST

TRAY DIVISION	
CUCUMBER	CHARD
ROCKET	VALERIAN

CULTIVATIONS TEST

TRAY DIVISION	
CHICKPEAS	ENDIVE
CHICORY	RED CABBAGE

CULTIVATIONS TEST

TRAY DIVISION	
KOHLRABI	CLOVER
TURNIP TOP	BRUSSELS SPROUT

CULTIVATIONS TEST

TRAY DIVISION	
RED CABBAGE	RADISH
BROCCOLI	ROCKET

EXPERIMENTAL TRIALS

SOLE cultivation experiments were conducted in **ENEA**'s facilities.

Morphometric (hypocotyl height, cotyledons area, fresh and dry weight), **fluorometric** (Multiplex index analysis SFR_R, FLAV, ANTH) and **hyperspectral analysis** (Specim IQ camera + Evince sw) were conducted on red and green microgreen species: Radish (*Raphanus sativus*) and Mustard (*Brassica juncea*).

Microgreens hydroponic cultivation
3 replicas/light recipe
20 samples/replica

4 Genotypes
Red and Green Mustard
Red and Green Radish

3 Light spectra
150 µmol/m²s
12h photoperiod
L1 60% R, 20% G, 20% B
L2 40% R, 20% G, 40% B
L3 20% R, 20% G, 60% B

Non-destructive analysis

Fluorometric analysis
Multiplex (SFR_G, FLAV, ANTH_RG)

Hyperspectral image analysis

Destructive analysis

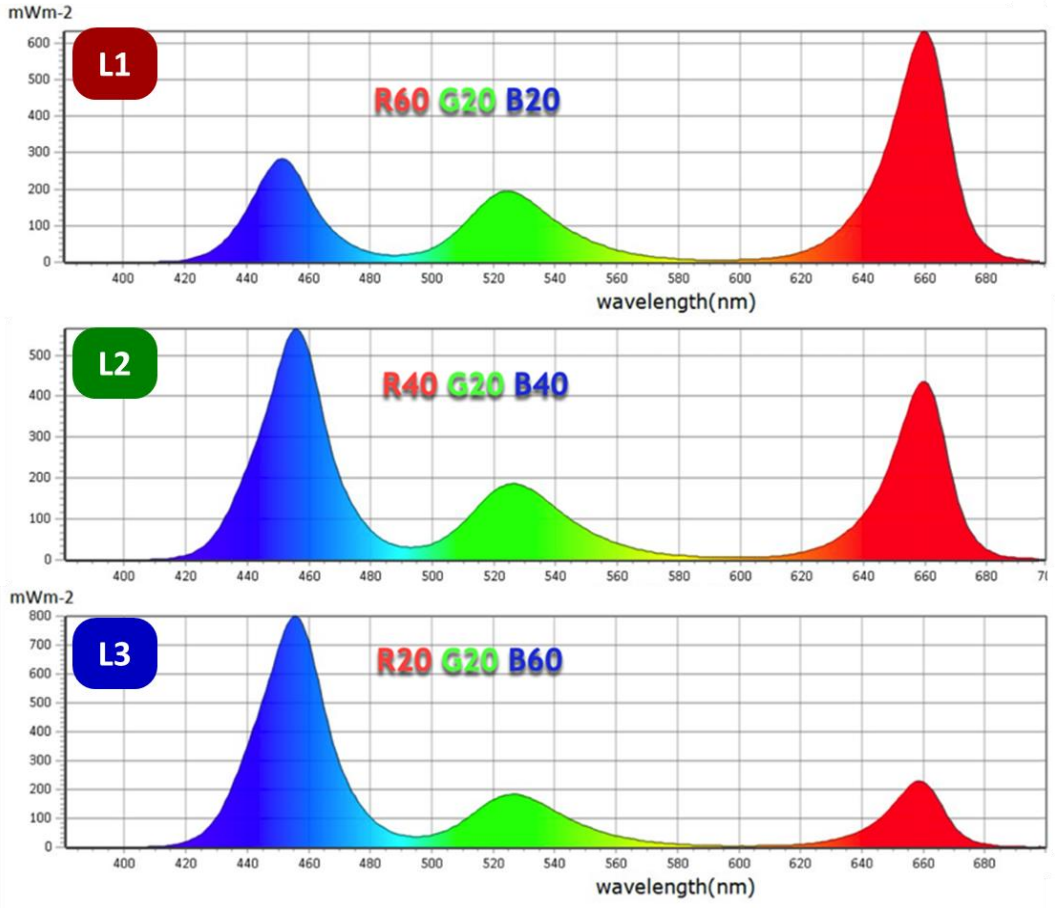
Morphological parameters
(Plant height, Cotyledon area)

Biomass production
(wet and dry weight)

EXPERIMENTAL TRIALS

Plants were cultivated with three different light recipes to evaluate the best spectra in terms of primary and secondary metabolism development.

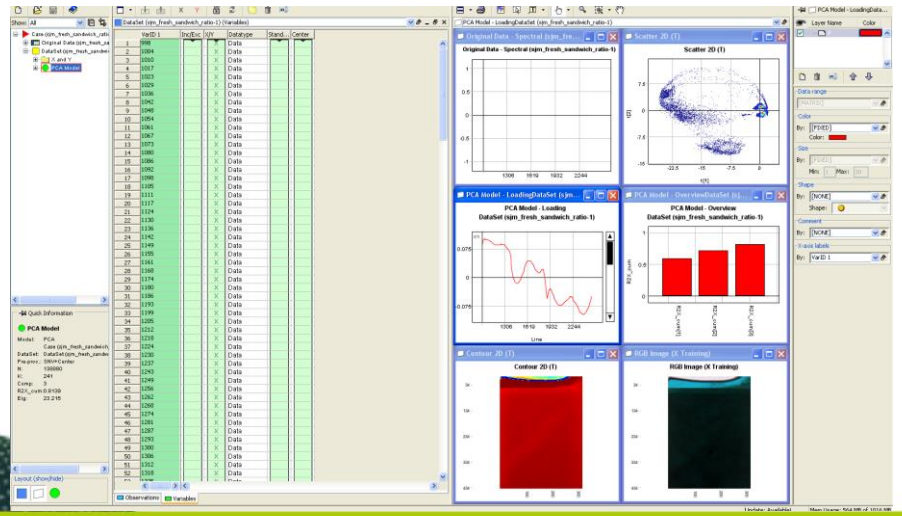
3 Light spectra
150 µmol/m²s
12h photoperiod
L1 60% R, 20% G, 20% B
L2 40% R, 20% G, 40% B
L3 20% R, 20% G, 60% B



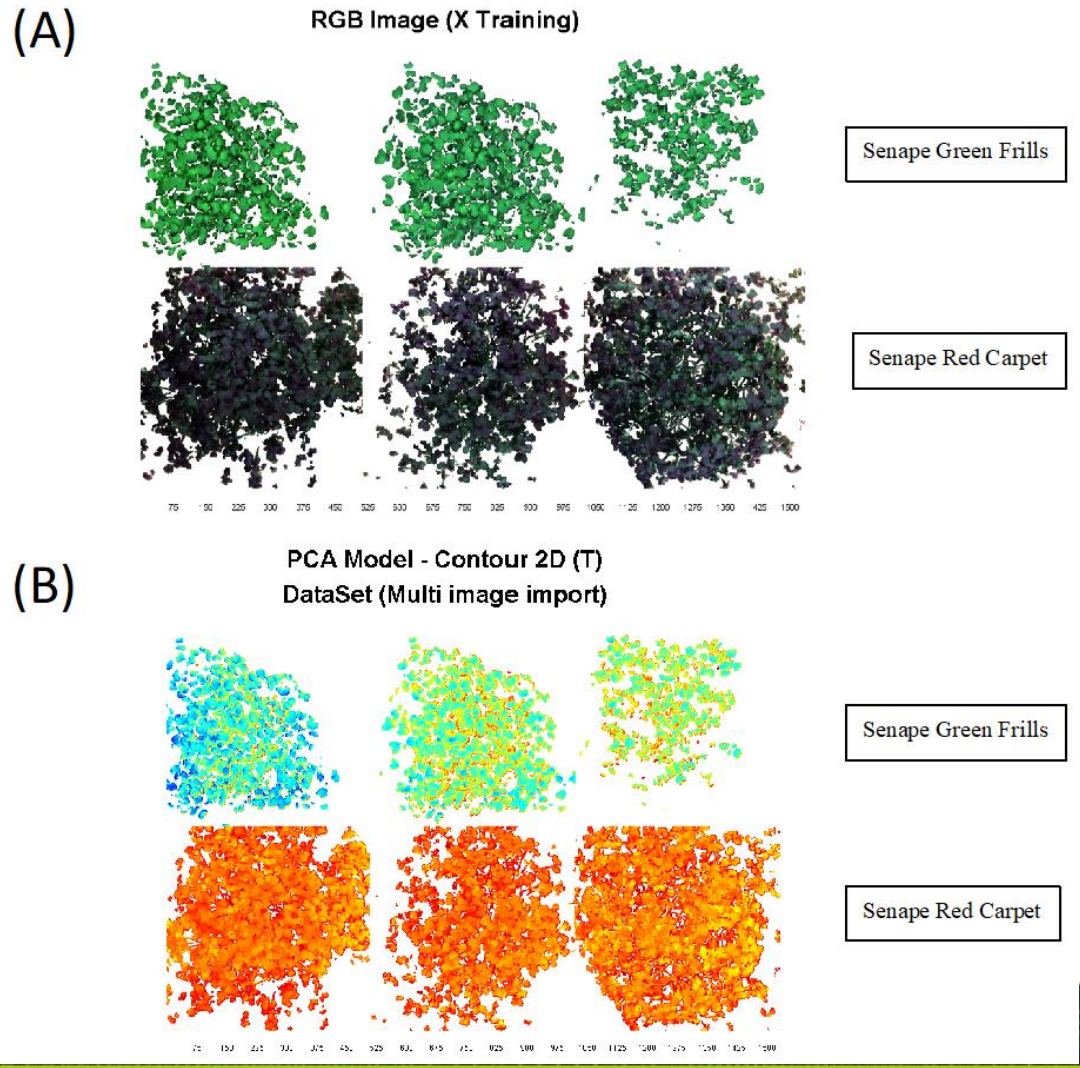
HYPERSPECTRAL ANALYSIS

The images were acquired by means of a **Specim IQ** hyperspectral camera, with an acquisition interval between 400-1000 nm.

The **Evince software** was used for the analysis of the images, the extraction and processing of the data present in the images, which allows to process, analyze and obtain results thanks to the integrated advanced statistical analysis package specific for hyperspectral images

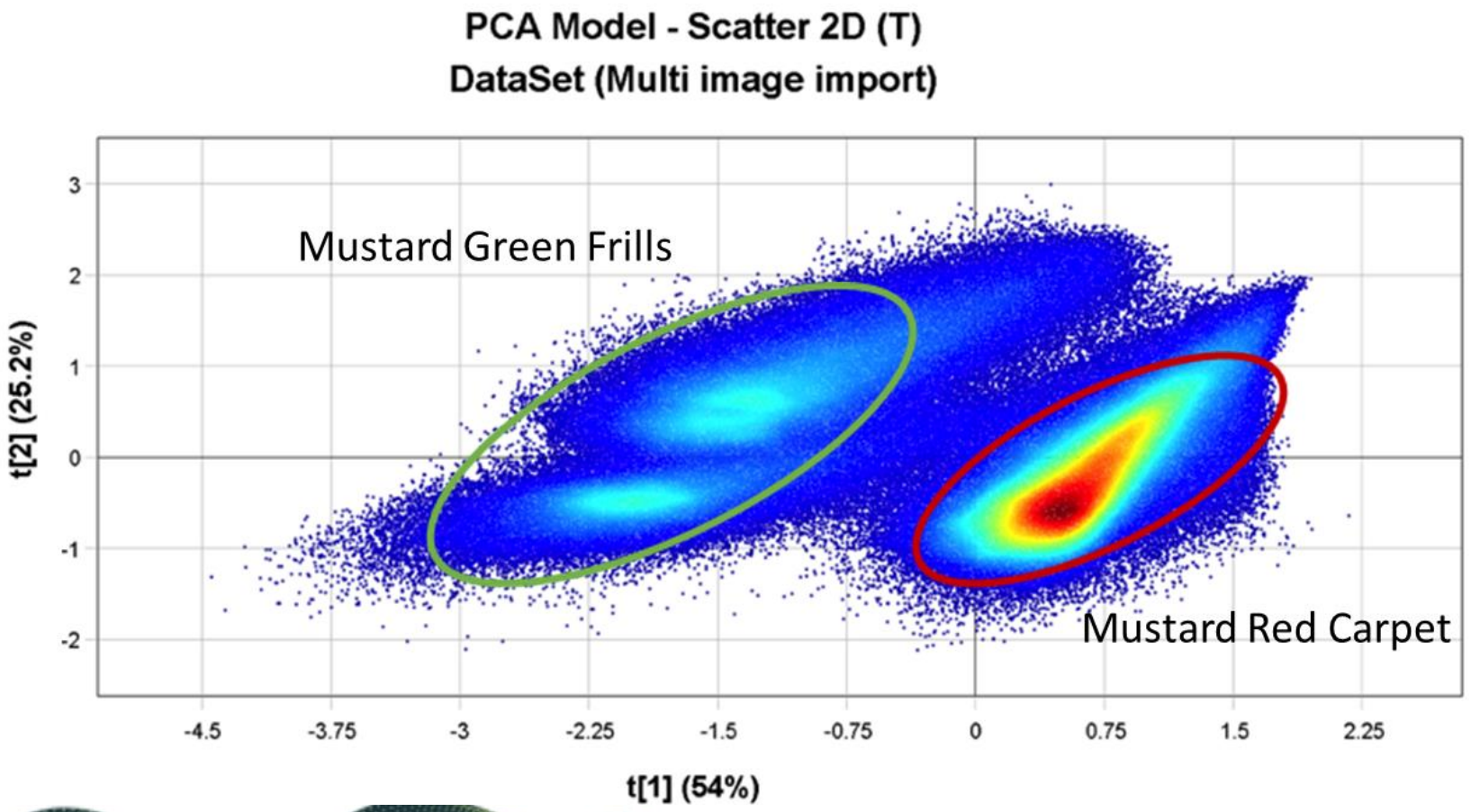


HYPERSPECTRAL RESULTS



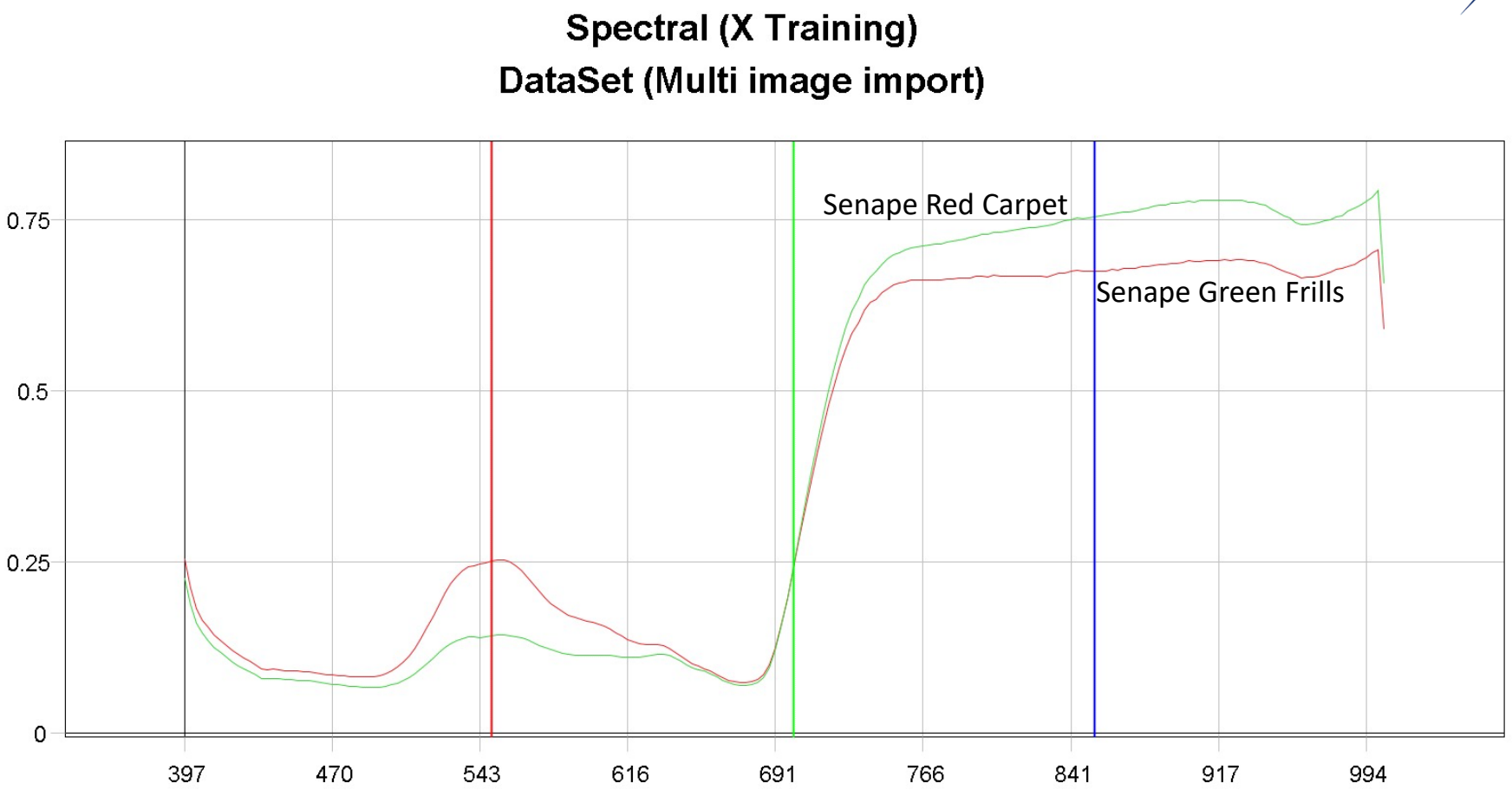
RGB image of the Green Frills and Red Carpet mustard samples used for display in RAW format (A) on which the PCA (Principal Component Analysis) analysis was conducted and of the responses due to the analyzed variables (B).

HYPERSPECTRAL RESULTS



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

HYPERSPECTRAL RESULTS



Lines Plot for the analysis of average spectral data, which allow to identify spectral bands discriminating between Mustard "Green Frills" and "Red Carpet"

FLUOROMETRIC ANALYSIS

Fluorometric analysis with Multiplex (ForceA portable fluorometer):

- **SFR_R** index related to leaves chlorophyll concentration
- **FLAV** index related to leaves flavonols concentration
- **ANTH_RG** index related to leaves anthocyanins concentration

ForceA
VOIR POUR AGIR

CALCOLI DEL MULTIPLEX

- FLAV content

$$FLAV = \log \frac{FRF\_R}{FRF\_UV}$$

- Anthocyanins content

$$ANTH = \log \frac{FRF\_R}{FRF\_G}$$

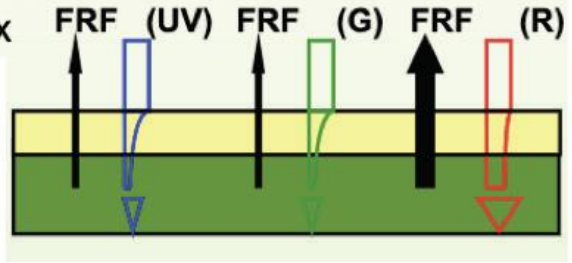
$$ANTH = \log \frac{5000}{FRF\_R}$$

- Chlorophyll content

$$SFR = \frac{FRF\_R}{RF\_R}$$

- NBI: Nitrogen Balance Index

$$NBI\_G = \frac{FRF\_UV}{RF\_G}$$



FLUOROMETRIC RESULTS

Mustard	Green Frills				Red Carpet			
	ANOVA	L1	L2	L3	ANOVA	L1	L2	L3
Wet weight (g)	ns	0,0865	0,0800	**0,0931**	***	0,0390	**0,0579**	0,0222
Dry weight (g)	ns	0,0045	**0,0049**	0,0034	*	0,0028	**0,0029**	0,0013
Hypocotyl height (mm)	*	63,4	**74,3**	66,1	***	28,9	**43,6**	18,5
Cotyledons area (mm²)	**	125,0	**169,7**	104,9	***	112,3	**151,5**	73,3
SFR_G	ns	**0,8577**	0,8432	0,7425	**	0,7555	**0,8305**	0,7278
FLAV	ns	-0,0001	0,0240	**0,0249**	ns	**-0,0005**	-0,0211	-0,0259
ANTH_RG	ns	-0,0395	**-0,0279**	-0,0334	*	**0,0527**	0,0240	-0,0203

Radish	Green Daikon				Rioja Improved			
	ANOVA	L1	L2	L3	ANOVA	L1	L2	L3
Wet weight (g)	*	0,3226	**0,3529**	0,2621	****	0,1870	**0,2118**	0,1461
Dry weight (g)	*	0,0150	**0,0174**	0,0141	*	0,0092	**0,0110**	0,0079
Hypocotyl height (mm)	ns	**74,4**	68,3	57,6	*	**61,6**	54,2	48,4
Cotyledons area (mm²)	**	471,9	**584,0**	419,6	**	453,0	**574,0**	413,0
SFR_G	***	1,1250	1,0200	**1,2320**	ns	0,8404	0,8020	**0,8889**
FLAV	**	0,0210	0,0315	**0,1071**	**	0,1552	0,1133	**0,1914**
ANTH_RG	*	-0,0490	-0,0348	**-0,0330**	**	0,2330	0,2056	**0,2557**

Statistical analysis (one-way ANOVA) of the effect of LED light on morphometric and fluorometric parameters in red and green genotypes of mustard and radish.
SFR_G: clorophyll content
FLAV: Flavonols content
ANTH_RG: antochyanins content

WORKING GROUP

The SOLE project: a plant greenhouse demonstrator for fresh food production in space – FISV congress 14-16 September 2022

E. Bennici[1], E. Benvenuto[1], M. Crisconio[2], A. Desiderio[1], E. Di Mascio[3], Francesca Ferranti[2], M. Garegnani[1,4], L. Giuliani[1], L. Nardi[1], C. Pacelli[2], G. Pontetti[2], M. E. Villani[1]

[1]Dept for Sustainability, ENEA, Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Casaccia Research Center, Rome, Italy

[2] Human Spaceflight and Scientific Research Unit, Italian Space Agency, Rome, Italy

[3] G & A Engineering S.r.l, Oricola, AQ, Italy – now EltHub S.r.l. Oricola, AQ, Italy

[4] Dept of Aerospace Science and Technology (DAER), Politecnico of Milano, Milan, Italy

XVI FISV Congress

3R: Research, Resilience, Reprise

Reggia di Portici (Naples), Italy

14-16 September 2022

CONCLUSIONS

SOLE demonstrator allows to monitor and analyze data on plant growth and on the accumulation of bioactive metabolites in real time and remotely.

SOLE demonstrator can be easily adapted for space applications as growing plant on-board the International Space Station or in mini/micro satellites.

This biotechnological innovation ensures an improvement of the nutritional quality of the ready-to-eat product in future space missions.

EltHUB
ELETTRONICA GROUP

G & A ENGINEERING - ENEA BIOAG - ASI
SOLE

G & A
Engineering®

asi
Agenzia Spaziale Italiana

ENEA
Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile

REGIONE
LAZIO

MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

THANK YOU.

www.melissafoundation.org

Follow us

Giorgia Pontetti
EltHub S.r.l.
giorgia@pontetti.com

MELISSA

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

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

MELISSA

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

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