HORTEXTREME - Protected **HORT**iculture in inflatable facilities, resistant to **EXTREME** conditions, for the production of high nutritional value plants: a field experiment in the AMADEE-18 mission

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Introduction

In February 2018, the Austrian Space Forum, in cooperation with the Oman Astronomical Society have conducted an integrated Mars analog field simulation in the Dhofar region, Sultanate of Oman, named AMADEE-18. Directed by a Mission Support Center in Austria, a small field crew have performed experiments in different research fields, paving the way to future human Mars missions.
The Italian Space Agency, together with ENEA and the University of Milan, proposed, in the Bioregenerative Life Support Systems field, the experiment "Hortextreme", which aims to develop novel cultivation methods dedicated to future Mars exploration missions.
We have focused our project on the production of microgreens that are leafy vegetables harvested as seedlings 7-15 days after germination, highly acceptable by consumers as Ready To Eat (RTE) food because tender, tasty, and visually attractive. They are promoted by scientific reports as an highly nutritious and healthy food product, being an eccellent source of vitamins and antioxidants in concentrations from 4 to 40 times higher than in mature plants. Microgreens are best suited for the production of leafy vegetables in that they are: i) short in height (7-12 cm), adaptable to multitier cultivation racks; ii) fast growing (7-21 days); iii) performing well under low light intensity and at a high plant density; iv) high added-value product because fresh, clean, nutritious, and pesticide free; v) amenable to quality improvement by environmental control and led light. The microgreen species Mustard Ruby Streaks (*Brassica Juncea* L.*)*, Red Cabbage (*Brassica Oleracea var. capitata)*, Radish Red Rambo (*Raphanus sativus)* Amaranth Red Army (*Amaranthus cruentus)* were selected for their high content of vitamins, carotenoids, anthocyanins and organoleptic characteristics (sowseeds.co.uk).
Thanks to the environmental conditions of the Kepler Station in Oman desert, the experimental site have been useful for evolving the knowledge on human behavior in a restricted and extreme environment, mimicking life conditions typical of spaceflight or orbiting stations. The challenge of this proposal was to realize a portable fully automated hydroponic system equipped with LED light in a climatically controlled inflatable plant growth facility, designed by means of the TRNSYS computer code, for the production of high quality microgreens to study the effects of two LED light photoperiod regimes on the growth, morphology and nutritional characteristics and also to support the diet of the crew members of the mission. In the facility assembly, robust commercial components have been privileged in order to minimize the total cost of the project and to guarantee, at the same time , ease in handling, high reliability and availability of spare parts. All the facilities, the scientific instruments and the experimental procedures were selected to reduce the number of man/hours necessary for handling, installation and testing. For biometric measurements portable lightweight multiparameter scientific instruments were selected that can perform real-time non destructive analysis. It is clear that atmospheric and environmental conditions of the test site are far from being similar to those of Mars habitat. Nevertheless, we firmly believe that the technology tested will help to reduce the resources used, reduced need for consumable resupply, enhanced diet (fresh highly nutritious food, with best organoleptic characteristic) gained psychological/physiological benefits of having plants integrated in the habitat.

The mission at a glance

Test site

Kepler Station

Amadee 18 Timeline

Hortextreme project

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.

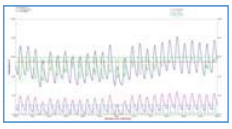
Objective:
Quantify the effects of sole source LED lighting providing different photoperiod regimes on the growth, morphology and nutritional content of microgreens

The experiment

Facility set-up

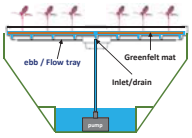
The TAG 42 external inflatable tent ready in 15 minutes with a solar screen on the roof

TRNSYS simulation of the plant growth facility



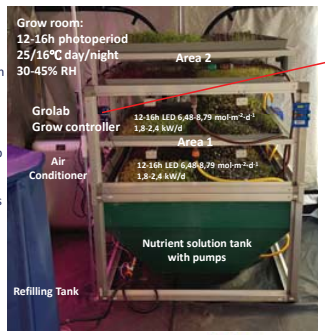
The experiment

- Ebb & Flow closed loop hydroponics
- Nutrient solution containment & recirculation
- Highly modular and customisable
- Easily removable tray
- Flat and vertical version
- Lightweight and robust (35Kg-tank in HDLPE+aluminum frame)
- Multilevel (4 x 1 m^2)
- Footprint area (1 m^2)
- Productivity improvement 4x
- Fully automatic with sensors (Grolab Opengrow system)
- Total area of cultivation 4 m^2
- Microgreens yield 0,5-10 Kg/15 days



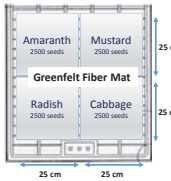
Ebb and Flow system:
Diagram shows feed cycle at «flood»

Prototype characteristics



Grolab Grow Controller

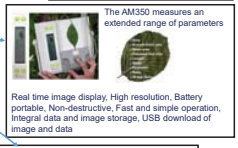
Stal and Plast Ebb and Flow tray:

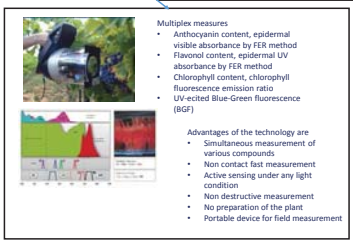


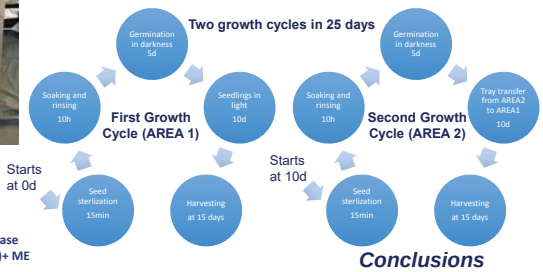
Scientific protocol

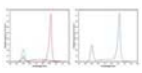
Data collected on 10 randomly selected plants every 5 days for biometric measurements:

- Hypocotyl length
- Leaf area (Cotyledons)
- Fresh weight
- Anthocyanins index
- Flavonols index
- Chlorophyll index
- NBI Nitrogen Balance Index









Heliospectra LED lightbar

Fertilizer 25% Idrofill Base NPK 10 5 23 (8Ca-2Mg)+ ME

Plant Material

Mustard Ruby Streak

Green leaves with red veins
LATIN NAME: *Brassica Juncea*
DAYS TO MATURITY: 10-15
LIFE CYCLE: Annual
1000 SEEDS WEIGHT: 2,9 g
SEED DENSITY: 1 plant/cm^2
YIELDS at 15 days (kg/m^2): 0,81 (12h) - 0,87 (16h)
YIELDS at 15 days g/g seed: 27,9 (12h) - 30 (16h)
TASTE: mildly spicy
DIFFICULTY: easy
PRODUCT FEATURES: Hydroponic Performer

Red Cabbage

Dark green leaves with purple vein and leaf margin.
LATIN NAME: *Brassica Oleracea var. capitata*
DAYS TO MATURITY: 10-15
LIFE CYCLE: Annual
1000 SEEDS WEIGHT: 2,3 g
SEED DENSITY: 1 plant/cm^2
YIELDS at 15 days (kg/m^2): 1,32 (12h) – 1,68 (16h)
YIELDS at 15 days g/g seed: 57,4 (12h) - 73 (16h)
TASTE: distinctive mild cabbage flavor
DIFFICULTY: easy
PRODUCT FEATURES: Hydroponic Performer

Amaranth Red Army

Attractive fuschia stems and leaves
LATIN NAME: *Amaranthus cruentus*
DAYS TO MATURITY: 15-20
LIFE CYCLE: Annual
1000 SEEDS WEIGHT: 0,3059 g
SEED DENSITY: 1 plant/cm^2
YIELDS at 15 days (kg/m^2): 0,24 (12h) - 0,27 (16h)
YIELDS at 15 days g/g seed: 78,9 (12h) -88,8 (16h)
TASTE: Slightly earthy
DIFFICULTY: medium to difficult

Radish Red Rambo

Dark purple stems and leaves
LATIN NAME: *Raphanus sativus*
DAYS TO MATURITY: 10-15
LIFE CYCLE: Annual
1000 SEEDS WEIGHT: 12 g
SEED DENSITY: 1 plant/cm^2
YIELDS at 15 days (kg/m^2): 4,29 (12h) – 5,29 (16h)
YIELDS at 15 days g/g seed: 35,7 (12h) - 44,1 (16h)
TASTE: mildly spicy flavor
DIFFICULTY: easy
PRODUCT FEATURES: Hydroponic Performer

Conclusions

The Hortextreme project has reached all the design requirements as indicated by the initial research proposal for AMADEE-18 call for experiments:

1) Realization of an inflatable shelter with proper thermal insulation and temperature control;
2) fully automated hybrid Ebb & Flow and NFT hydroponic system prototype, multilevel equipped with LED light;
3) The harvested microgreens have been effectively used by the Amadee 18 mission crew as supplementary Ready to Eat fresh food integrator;

The Control and management of all the relevant cultivation parameters resulted satisfactory. The preliminary experimental results show a variation of the main parameters evaluated vs the photoperiod increase (12-16h LED 6,48-8,79 mol·m^{-2}·d^{-1} 1,8-2,4 kW/d) strongly species dependent as shown in the following table:

	Mustard Ruby Streak	Amaranth Red Army	Red Cabbage	Radish Red Rambo
Fresh weight Δ %	7,4	12,5	27,3	23,3
Hypocotyl length Δ %	+67,5	-13,3	-0,5	-6,4
Cotyledon area Δ %	-19,2	-5,3	+49,3	+82,9

For instance, as it is possible to evince from the shown data, a 33% photoperiod increase results only in a reduced increase for the fresh weight , making questionable the extra energy spent in most cases.