2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR FUTURE

How abiotic factors change the requirements for plants cultivation in Space systems

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REQUIREMENTS

- Deep knowledge on the **micro-environment** and how it affects crop growth in terms of morpho-functional traits in CEA (Controlled Environment Agriculture).

- Study of the **extra-terrestrial constraints**, mostly ionizing radiation and microgravity and their effects on plants.

- **Implement** agricultural practices with the support of **technological solution**, in the direction of sustainability and automation.

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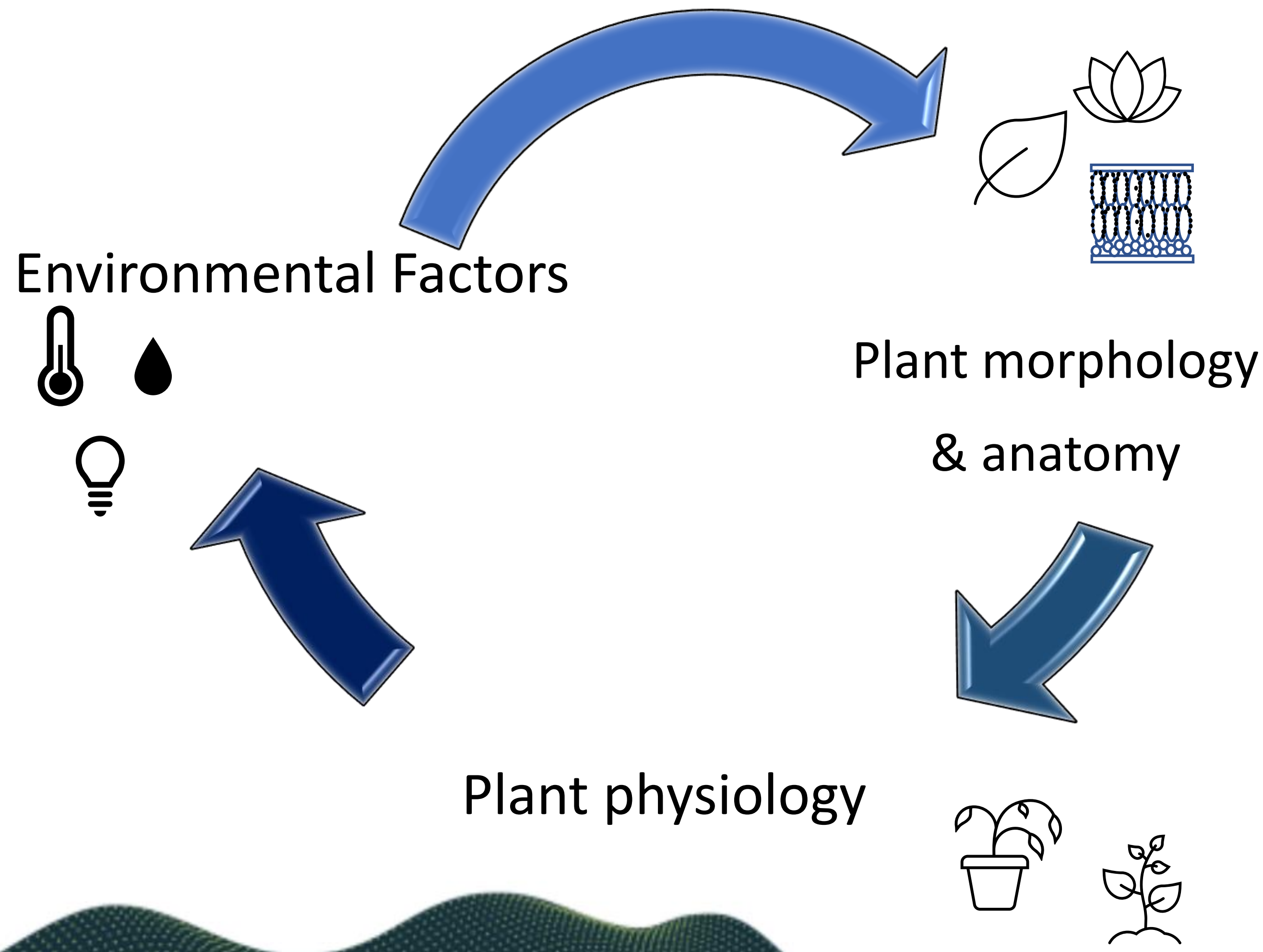
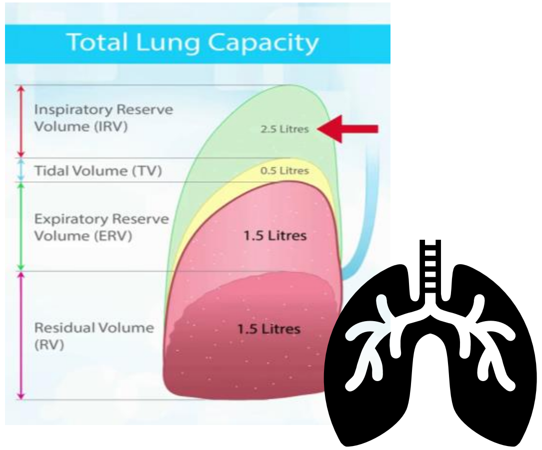
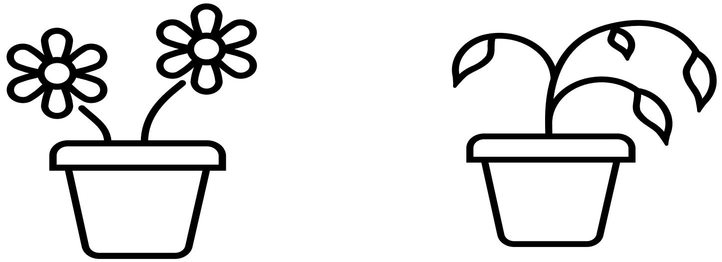
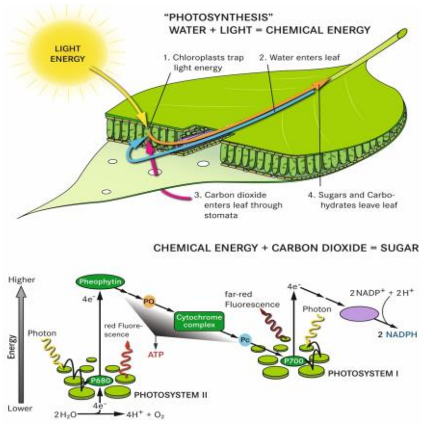
THE ENVIRONMENT



ANATOMY ESTABLISH THE LIMITS OF FUNCTIONING







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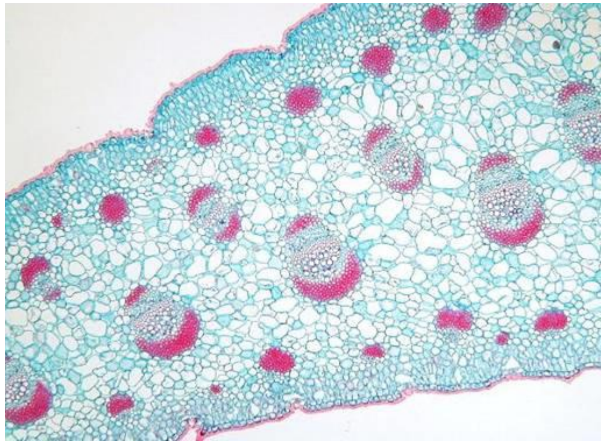
PLANT ANATOMY IS INFLUENCED BY THE ENVIRONMENT

Morpho-anatomical adaptations

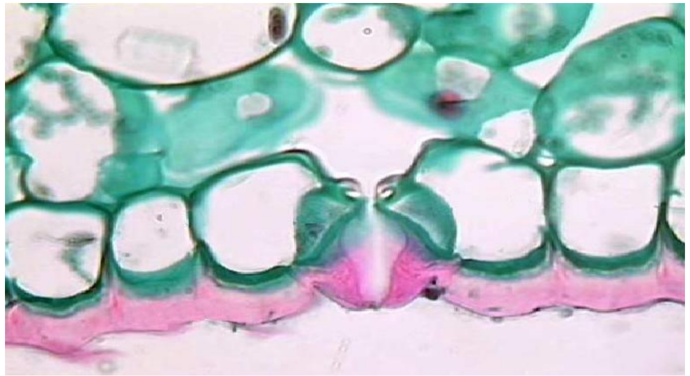
- Leaf morphology
- Tissue thickness
- Number and dimensions of stomata
- Number and dimensions of veins

Environmental factors

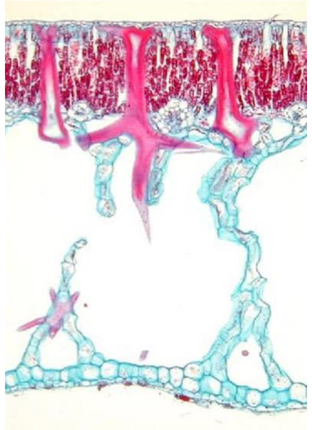
- Temperature
- Relative Humidity (RH%)
- Water availability
- CO_2 , wind



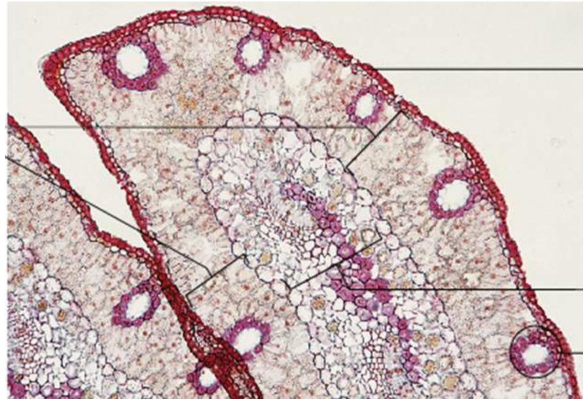
Succulent plant - aquifer parenchyma



Leaf with cuticular thickening



Aquatic plant

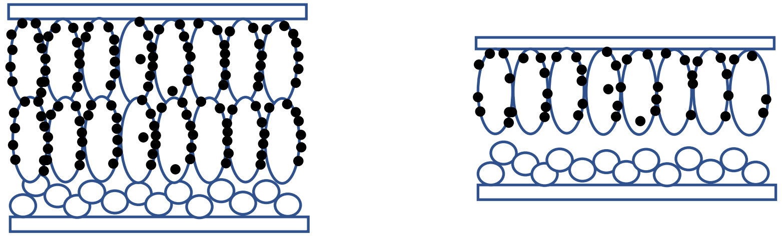


Needle-like leaf

PLANT ANATOMY IS INFLUENCED BY THE ENVIRONMENT

1. Morphology

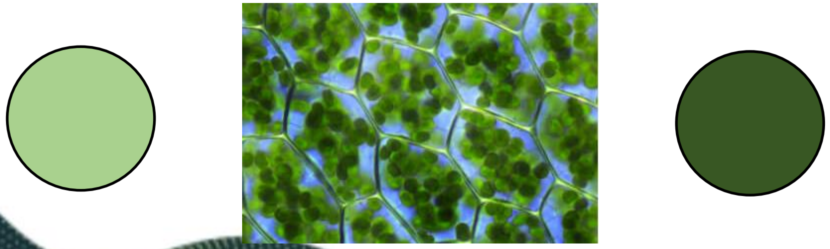
2. Tissues’ anatomical organization



Sun leaves

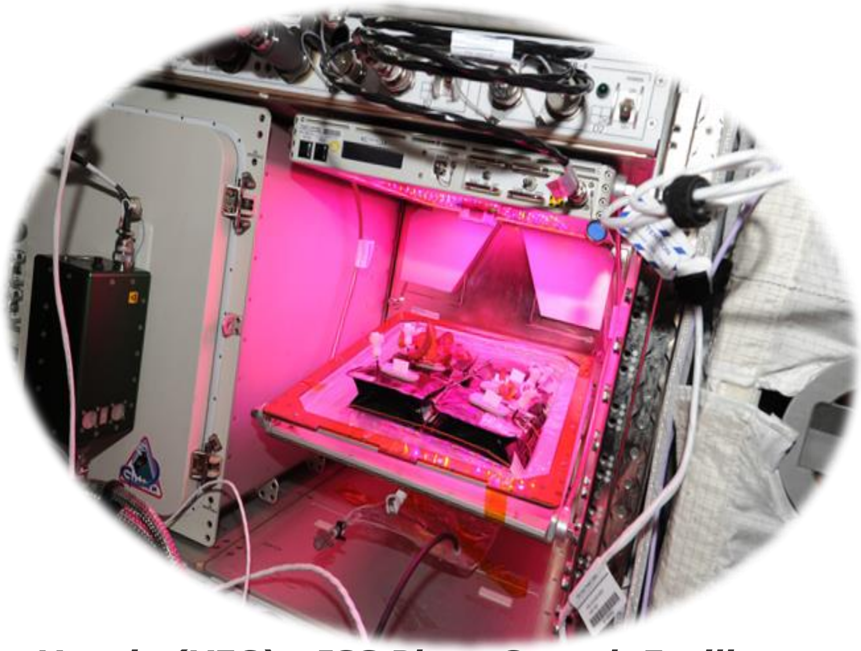
Shade leaves

3. Pigmentation

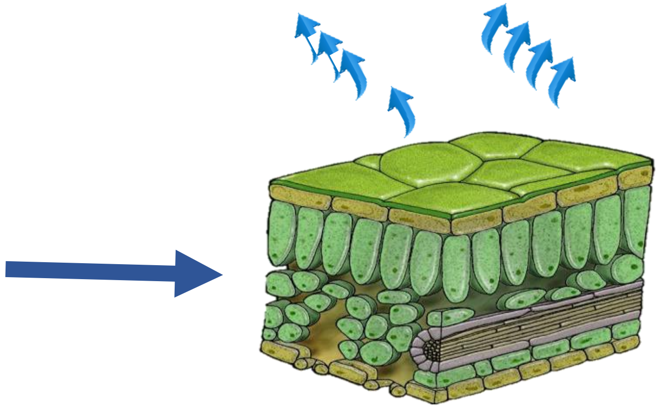


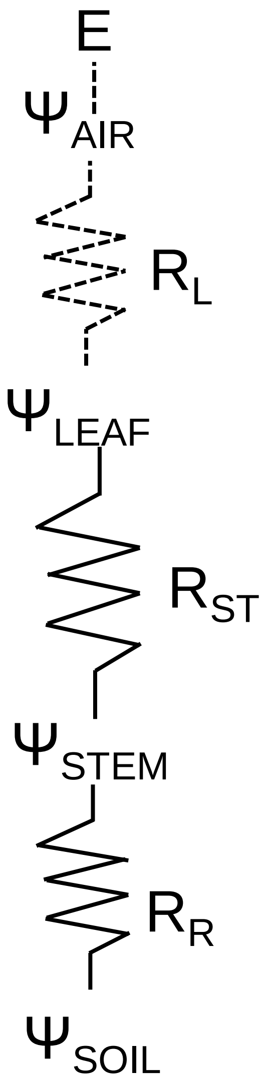
THE VAPOUR PRESSURE DEFICIT (VPD)

$$VPD = e - e_s \quad (kPa)$$



Veggie (VEG) - ISS Plant-Growth Facility





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MINOR REVIEW

Annals of Applied Biology WILEY

Vapour pressure deficit: The hidden driver behind plant morphofunctional traits in controlled environments

Chiara Amitrano[1] | Carmen Arena[2] | Youssef Rouphael[1] | Stefania De Pascale[1] | Veronica De Micco[1]

THE MICROGREENS x MICROGRAVITY PROJECT

Objective:

The definition of the
scientific requirements for
the **realization of a flight apparatus**
aimed at the realization of a system
for the **in-orbit production**
of **micro-vegetables**
for the integration of the **astronauts' diet**
with fresh products
rich in substances with nutritional and
nutraceutical value.

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EXPERIMENTAL DESIGN

We used a multidisciplinary approach to understand **the best combination of environmental factors** and **agricultural practices** on the biomass, morpho-functional and biochemical traits of two microgreens species: *1) Brassica oleracea* cv. **Vertus** and 2) *Raphanus raphanistrum* cv. **Saxa**

2 substrates → Coconut fiber / Sponge

2 nutrient solutions → Half strength / Quarter strength

2 light intensities → 150 ppfd / 300 ppfd

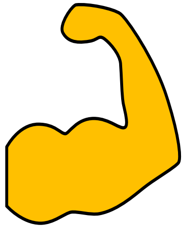
2 Vapour Pressure Deificits → 0.3 kPa (L) / 1.2 kPa (H)

Other conditions: Temperature: 24/18 ±2 ºC , Light Spectrum: LED RGB R45% W10% B 45%, Cultivation Cycle: 10 days Saxa, 11 days Vertus

RESULTS: GROWTH step 1

2 substrates <

2 nutrient solutior

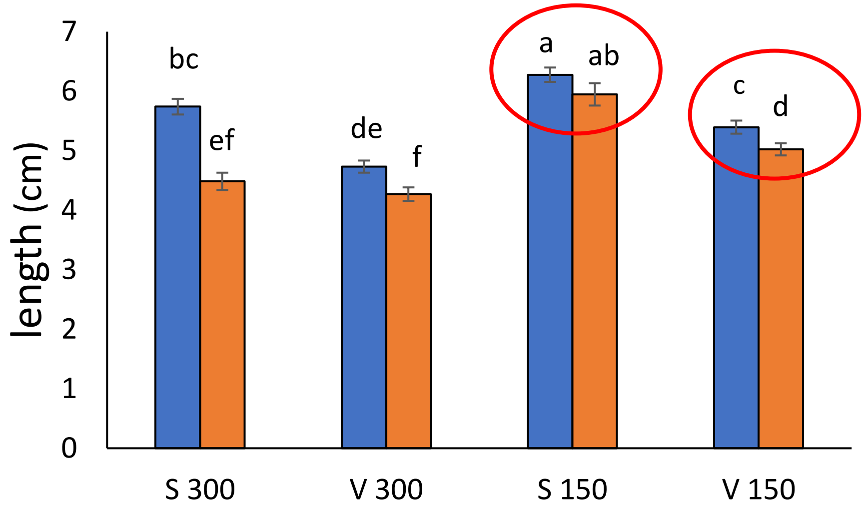


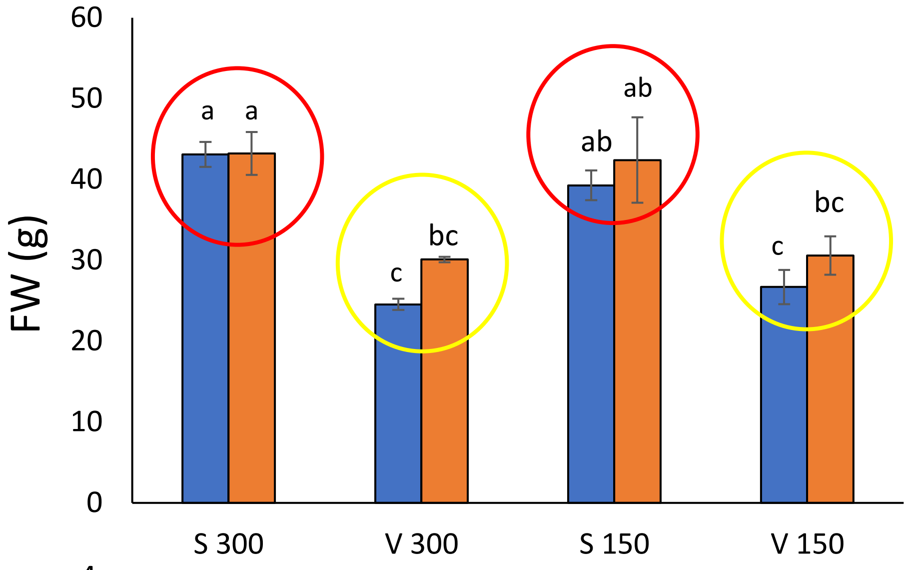
	Saxa	Vertus
	(kg FW m^{-2})	(kg FW m^{-2})
	b	1.27 ± 0.03 b
	a	1.99 ± 0.02 a
		***
		1.59 ± 0.17
		1.67 ± 0.15
		ns
	c	1.21 ± 0.01
	b	1.34 ± 0.02
	a	1.98 ± 0.03
Coconut fiber x QS	2.95 ± 0.05 a	2.01 ± 0.03
	*	ns

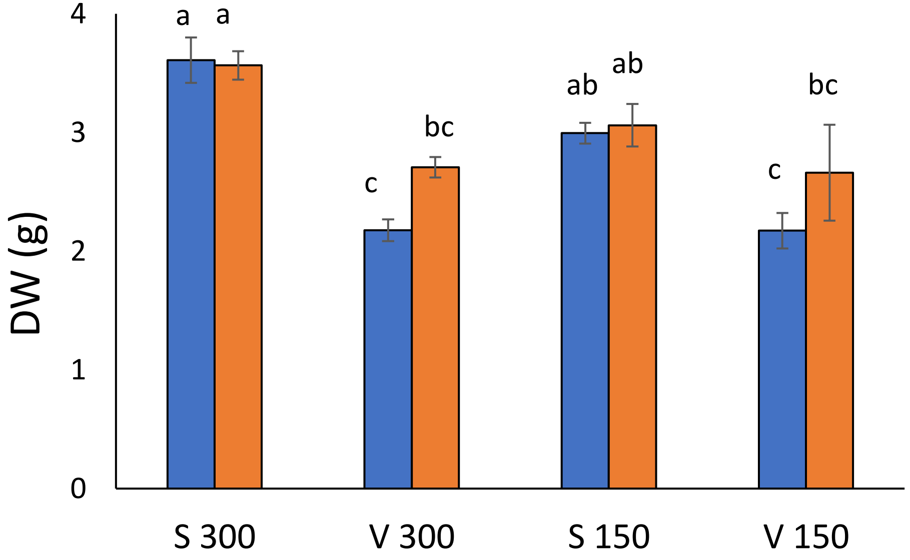
RESULTS: GROWTH step 2

2 light intensities → 150 ppfd / 300 ppfd

2 Vapour Pressure Deificits → 0.3 kPa (L) / 1.2 kPa (H)







L= low VPD

H= High VPD

S= Saxa

V= Vertus

300 = 300ppfd

150 = 150ppfd

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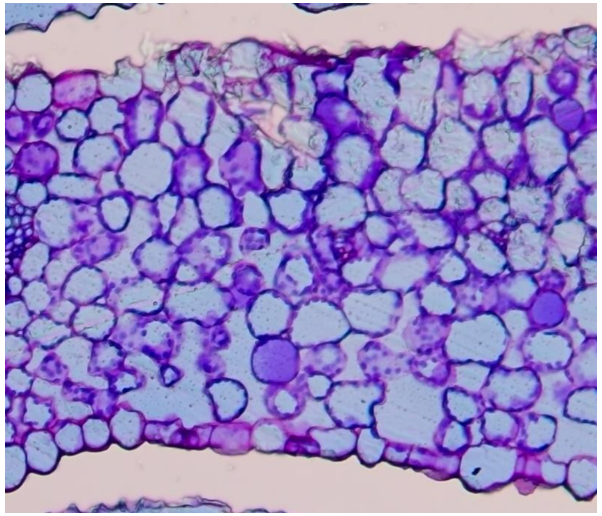
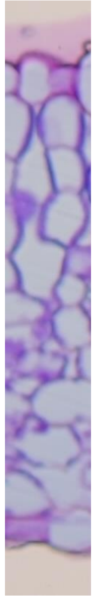
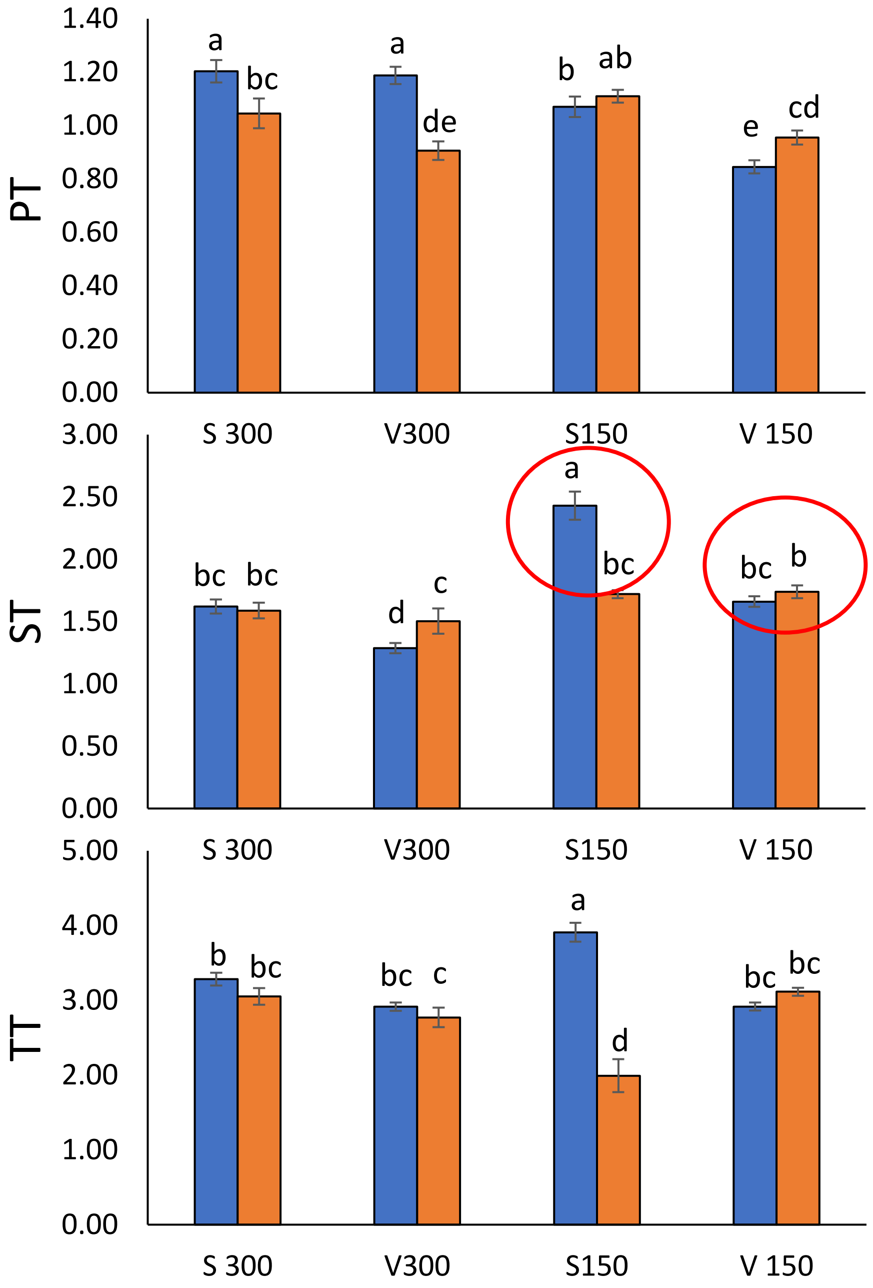
RESU

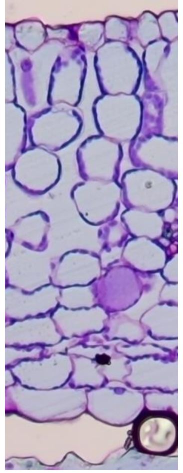


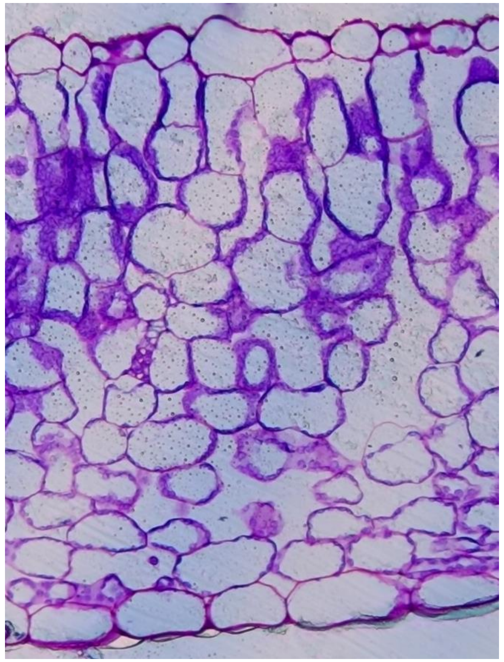
300





HIGH VP





150

LOW VPD

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RESULTS: BIOCHEMISTRY

		DHAs	Asc Tot	DHAs/TotAscA (%)	Neo	Chl b	Chl a	β-Car
Species	Saxa	16.65	29.70	55.31	1.40	16.93	47.34	3.64
	Vertus	37.22	61.60	60.84	1.69	22.84	59.81	4.60
		***	***	ns	*	**	*	**
Light	150	25.98	40.38	60.62	1.58	20.50	54.92	4.20
	300	27.89	50.92	55.54	1.51	19.27	52.23	4.05
		ns	***	ns	ns	ns	ns	ns
VPD	L	31.45	47.12	65.80	1.80	21.47	57.55	4.44
	H	22.42	44.17	50.36	1.28	18.30	49.60	3.80
		**	ns	*	***	ns	ns	*

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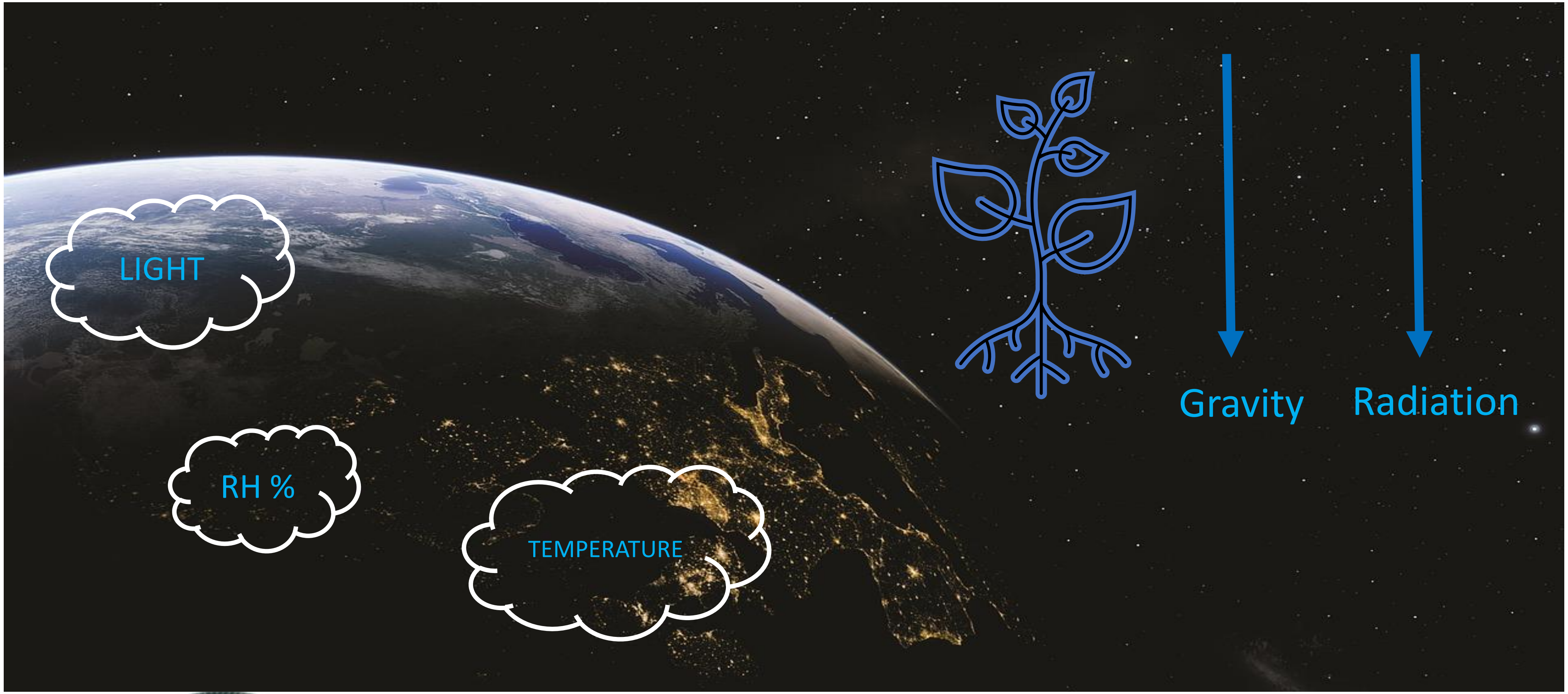
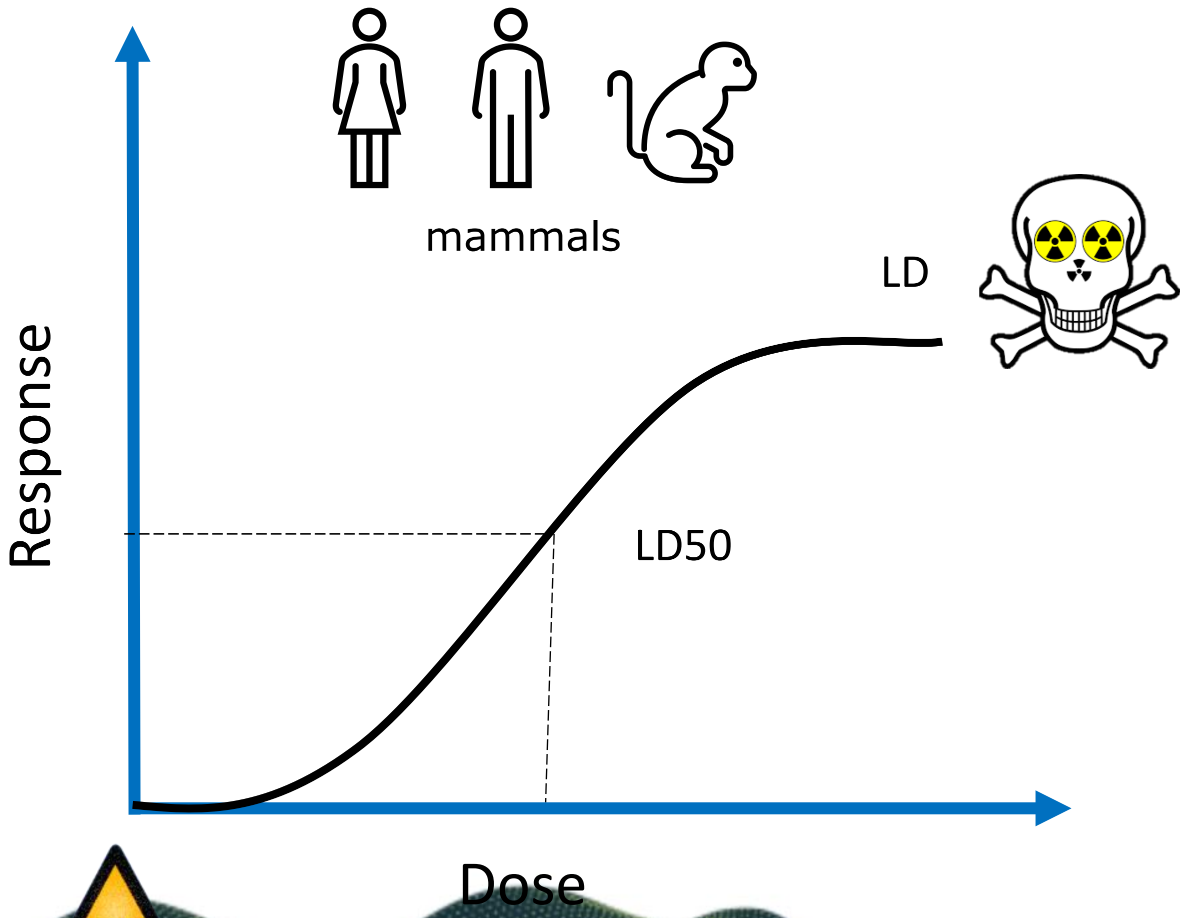
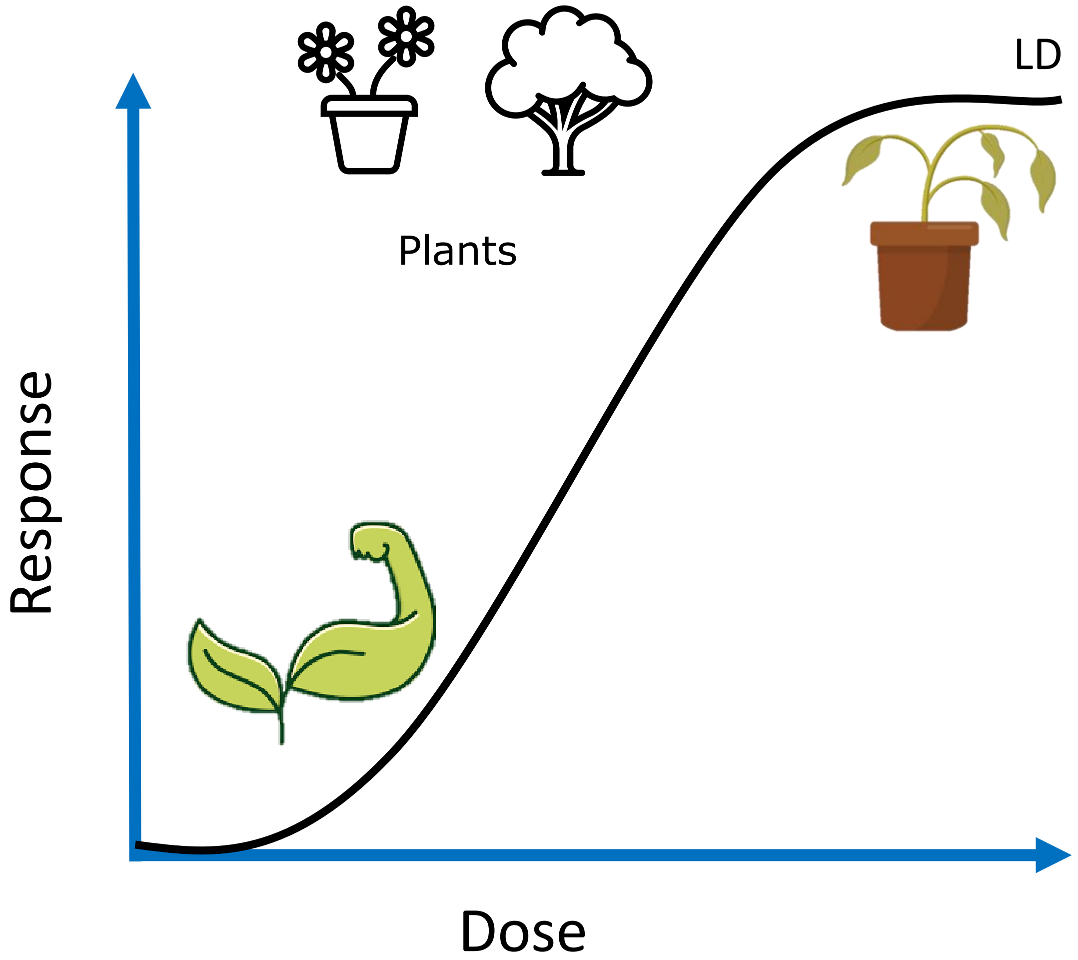
SPACE FACTORS

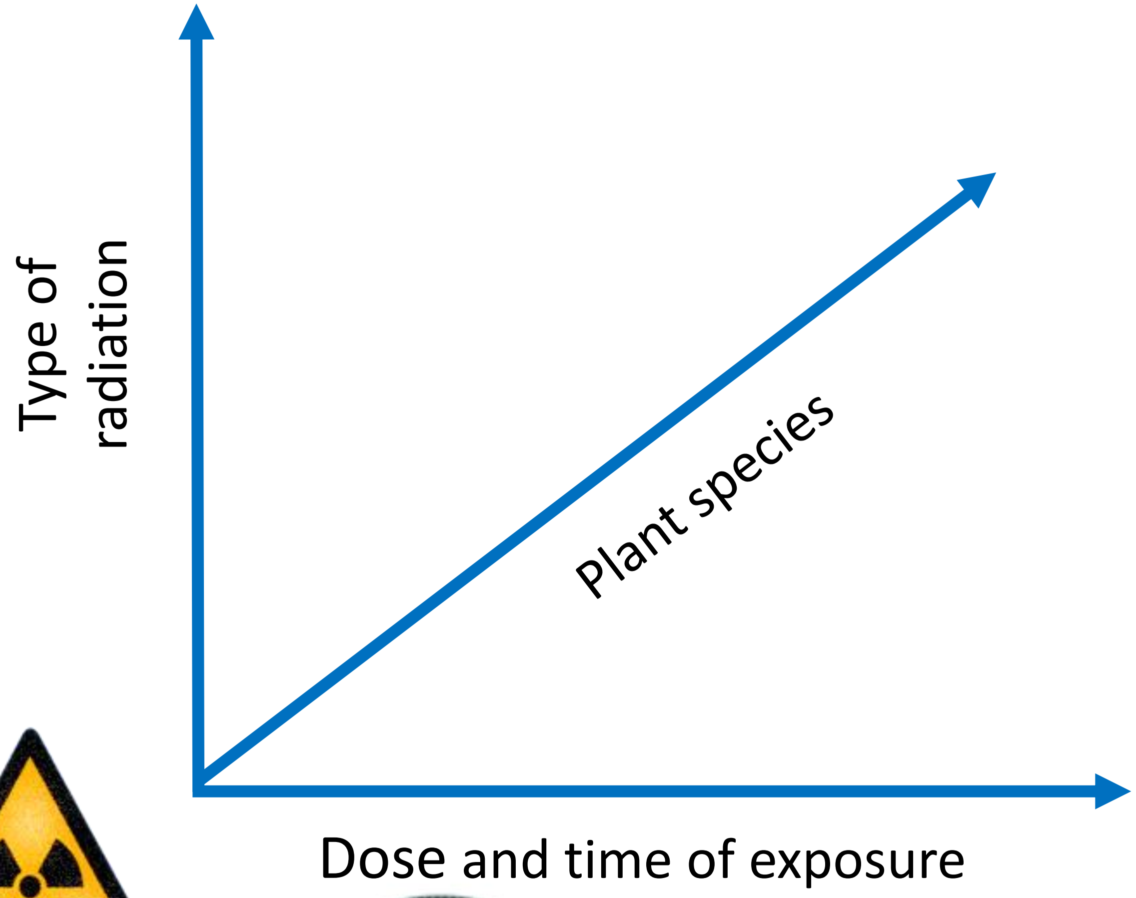


RADIATION

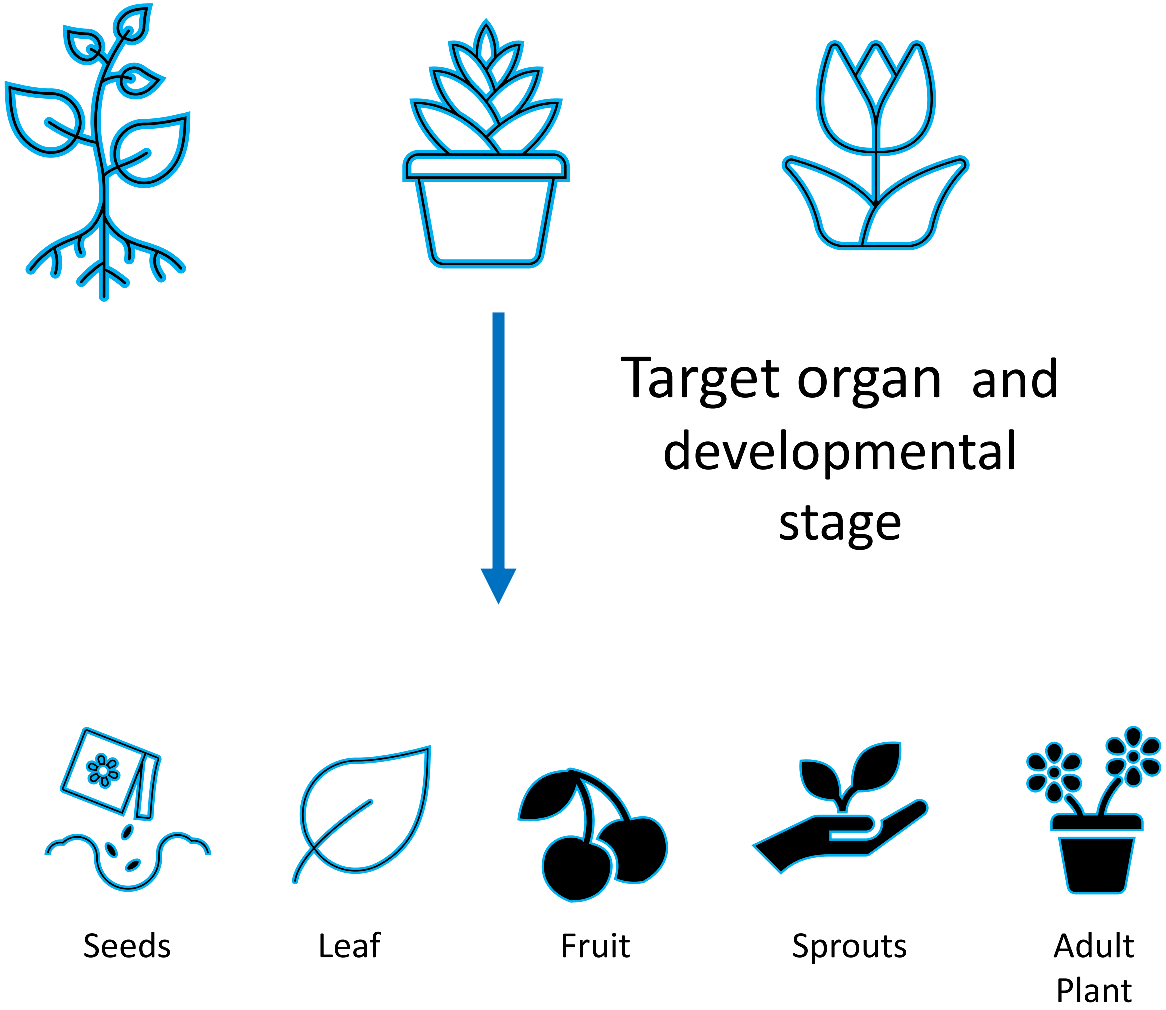




RADIATION



Type of radiation
Plant species
Dose and time of exposure



Target organ and developmental stage
Seeds
Leaf
Fruit
Sprouts
Adult Plant

RADIATION

Species:

- Dwarf bean
- Azuki bean
- Soybean
- Tomato
- Lettuces

Radiation type:

- X-rays
- C-ions
- Ti-ions
- Ca-ions

Approaches:

- Molecular
- Structural
- Physiological
- Nutritional

Main objectives:

- To explore radio-sensitivity and radio-resistance mechanisms;
- To understand if the effect of radiation change with phenological and developmental stage;
- To understand the combined effect of radiation and other environmental factor;
- To assess possible stimulatory effect at low doses

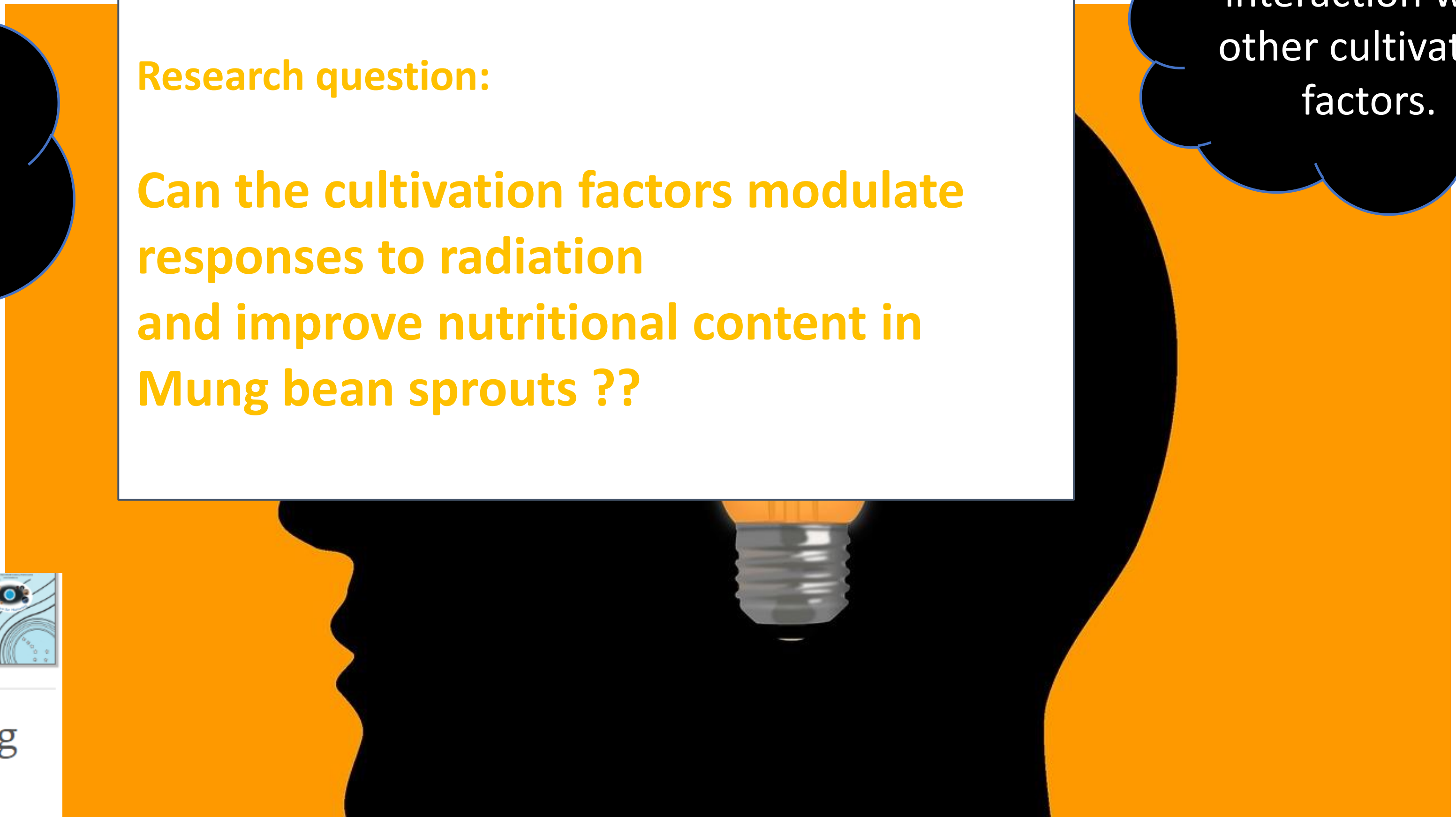
REQUIREMENTS

Irradiate Plants at the developmental stage of germinated seed, characterized by the lowest radio-resistence

Research question:

Can the cultivation factors modulate responses to radiation and improve nutritional content in Mung bean sprouts ??

Test the interaction with other cultivation factors.



Acta Astronautica
Volume 185, August 2021, Pages 188-197

Effect of light quality and ionising radiation on morphological and nutraceutical traits of sprouts for astronauts' diet

V. De Micco [a], C. Amitrano [a], P. Vitaglione [a], R. Ferracane [a], M. Pugliese [b], C. Arena [c]

EXPERIMENTAL DESIGN

X-rays generator

(Siemens, Forcheim, Germany)

Petri dishes with germinated seeds

0.3 Gy

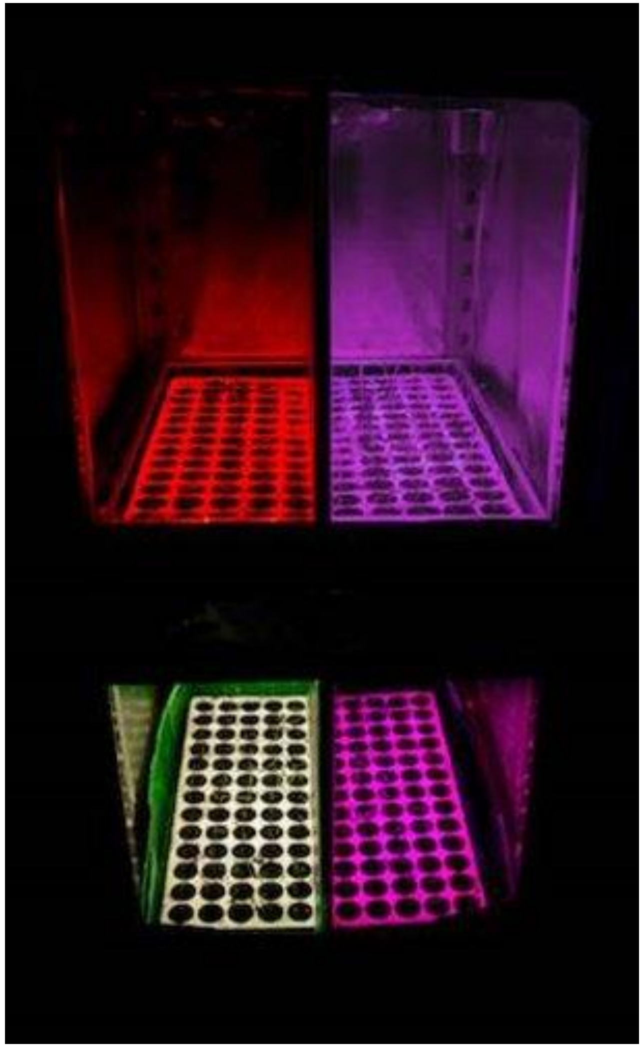
10 Gy

20 Gy

Control

Why x-rays?

- Easy to deliver
- Reference-response range to explore plant sensitivity, based on previous experiments
- Their effectiveness is similar to low-energy protons that contribute to space radiation



Incubated in a growth chamber under White, Red, Red-Blue lights.

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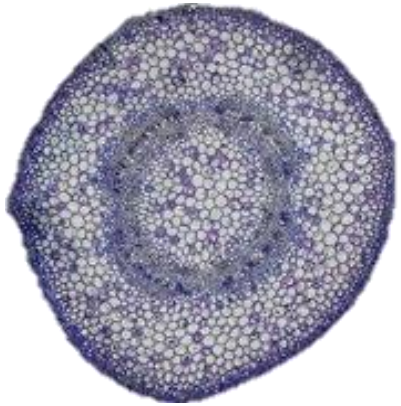
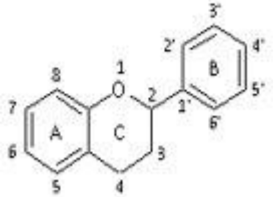
ANALYSES



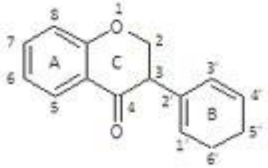
Flavonoids:

- Kaempferol-rutinoside
- Rutin
- Quercitrin
- Naringenin
- Naringin



Isoflavonoids:

- Daidzin
- Malonyldaidzin
- Glycitin
- Genistin
- Daidzein
- Glycitein
- Genistein



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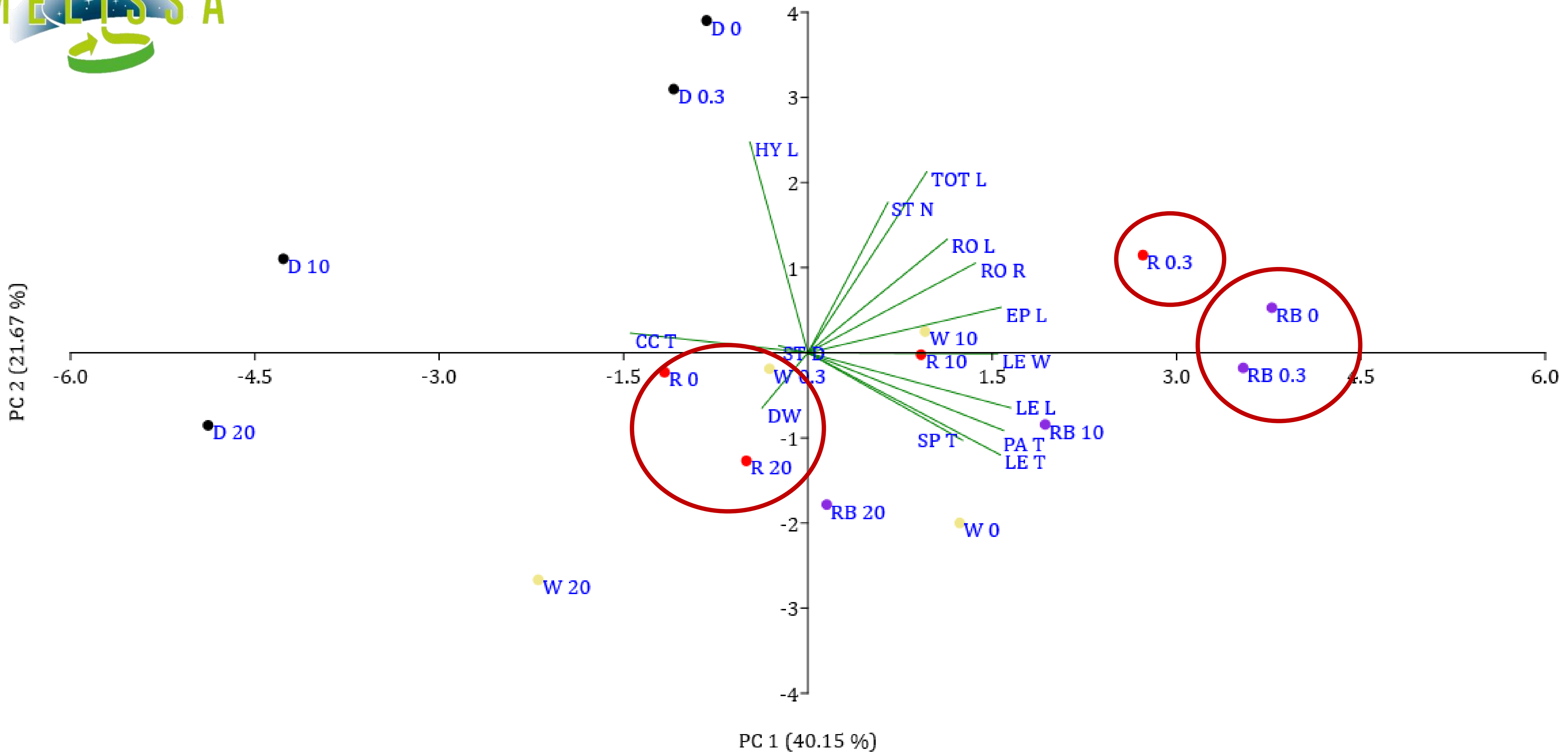
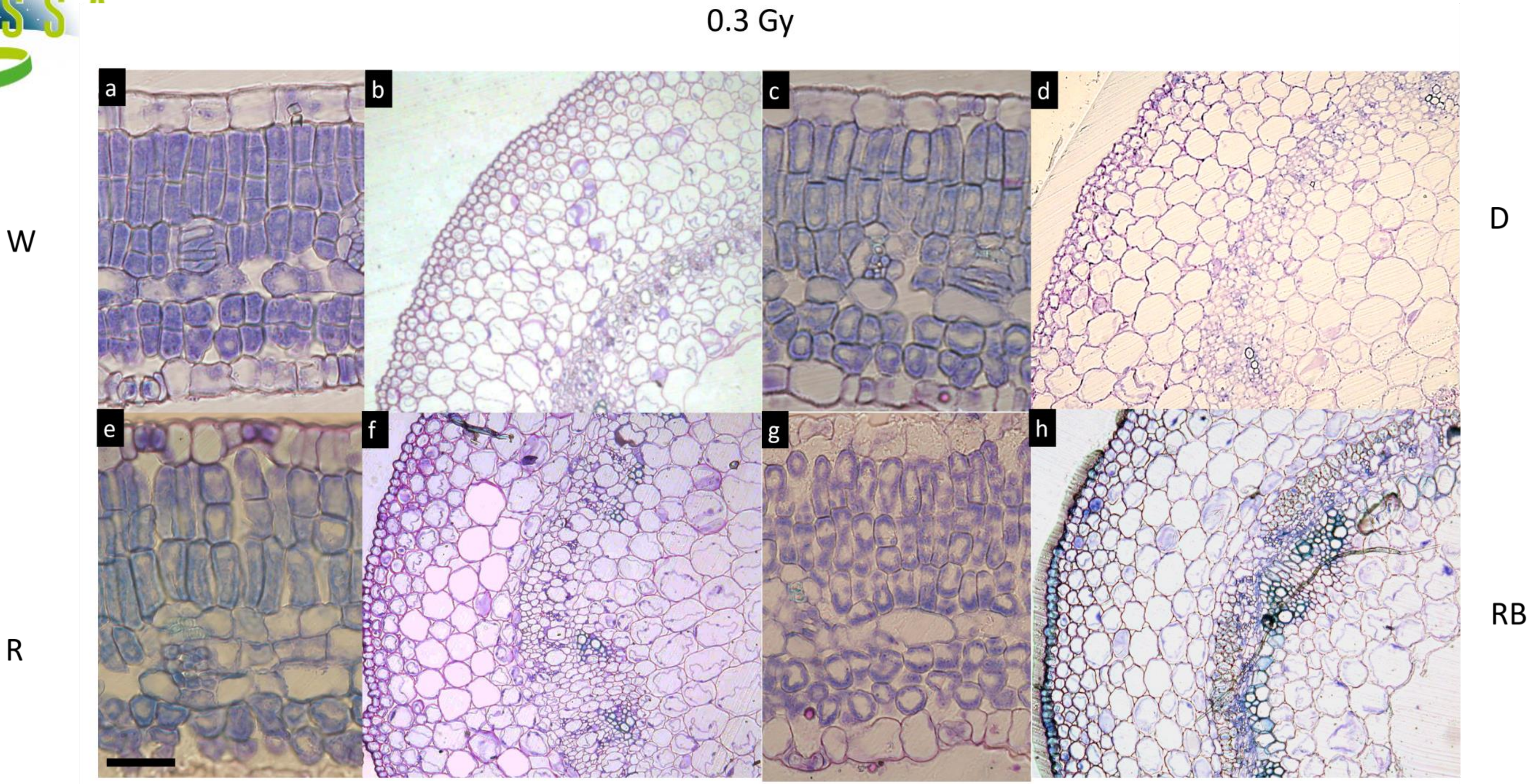
RESULTS: GROWTH



RESULTS: ANATOMY



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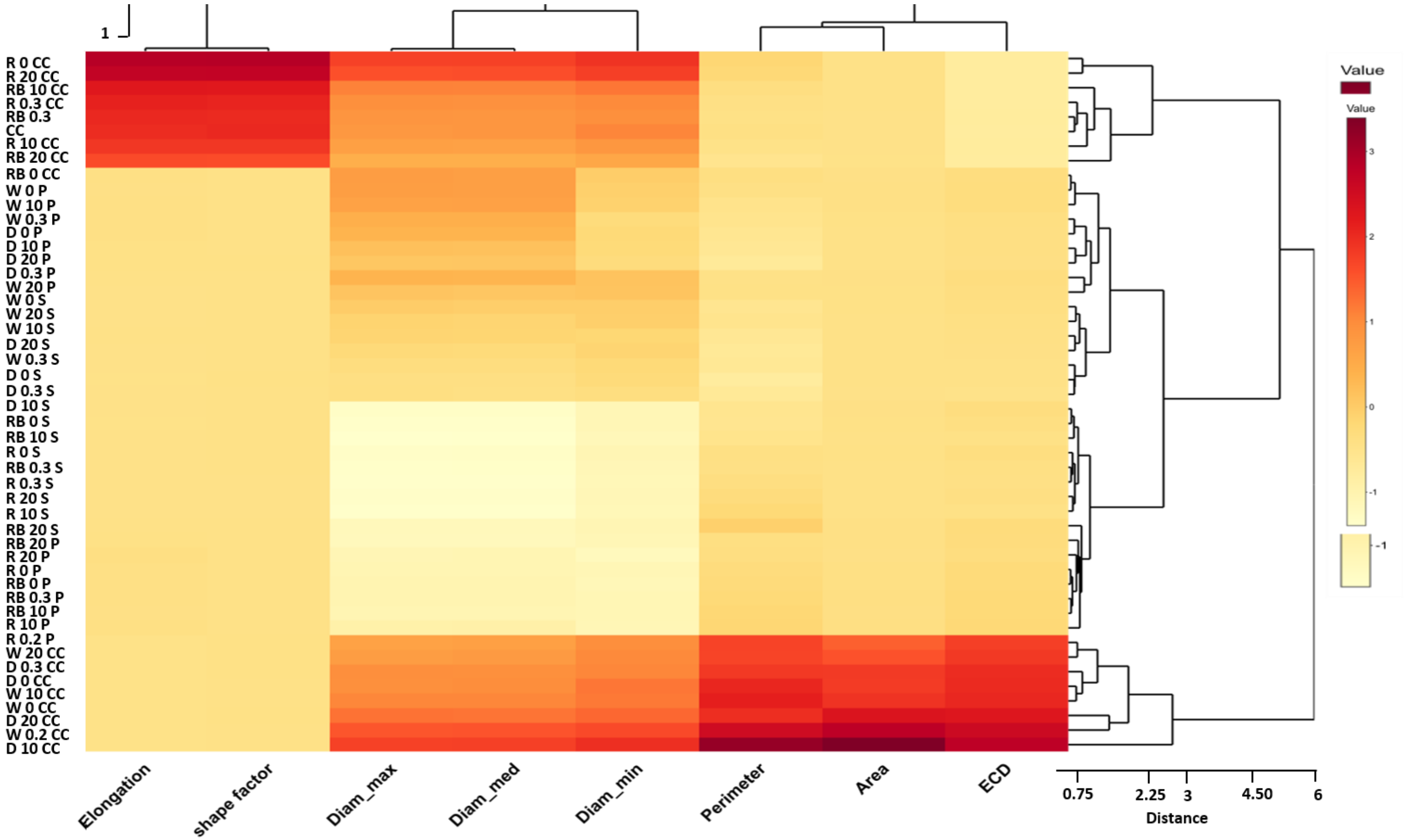
RESULTS: ANATOMY



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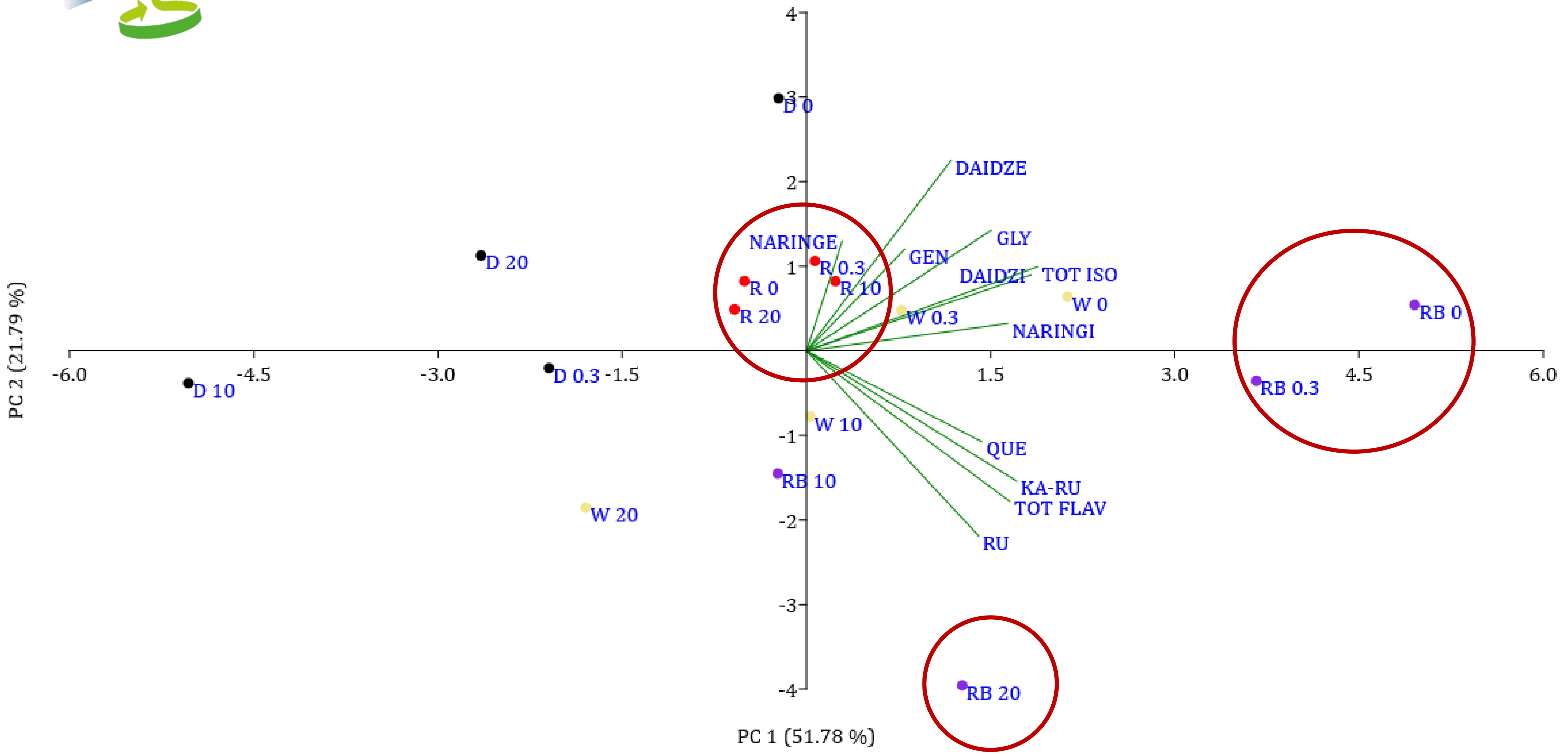
RESULTS: BIOCHEMISTRY



CONCLUSIONS

The **interaction** between **ionizing radiation** and all the other **environmental conditions** should be taken into account in the **design of plant-based modules,** also considering the nutritional compounds production of the species to cultivate on board or on planet outposts.

Include other environmental factors in the investigations

Trials with cronic exposure to radiation

Apply for Space experiments

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Thanks to Dr. Battistelli and Dr. Proietti for the biochemical analyses of the microx2 experiment
And to Prof. Pugliese for irradiation procedures and Prof. Vitaglione for HPLC analyses

THANK YOU.

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How abiotic factors change the requirements for plants cultivation in Space systems.

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MICROx2 GENERAL CONCLUSION

- **Environmental parameters** (alone and in interaction) differently and severely **influenced** microgreens **growth** and **development**.

- Such a phenomenon should be **taken into account** in the **design of plant-based modules** for crop production in Space.

- The outcomes of this study will also be **helpful to optimize microgreens production** in controlled environment agriculture systems on Earth.

CONCLUSIONS

A diet rich in polyphenols is desirable for astronauts engaged in long-manned missions, because it helps to counteract the diseases due to chronic ionising radiation exposure.

Ionising radiation and light quality can be modulated not only to induce specific traits in sprouts for astronauts' nutrition in Space, but also for indoor production, oriented towards the increasing market demand for "superfoods".

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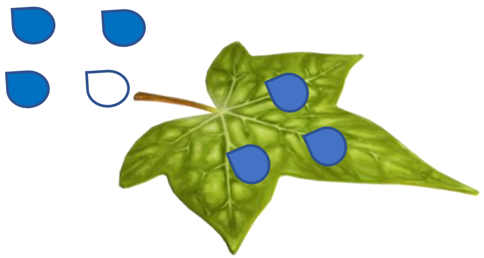
PRODUCTIVITY vs SURVIVABILITY TRADE-OFF

LOW VPD

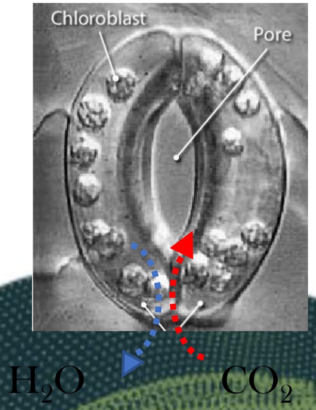
↙ **Low T°**

↖ **High RH %**



Low Transpiration:

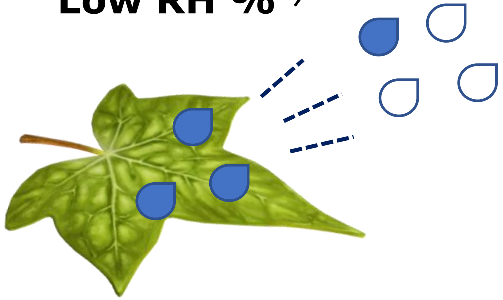
- ➢ Open stomata ⬆
- ➢ Enhanced conductance ⬆
- ➢ Plants may be more vulnerable to diseases ⬇



High T° ↘

Low RH % ↗

HIGH VPD



= Dry Air

= Water Vapour

High Transpiration:

- ➢ Closed stomata ⬇
- ➢ Reduced conductance ⬇
- ➢ Plants may dry/wilt ⬇