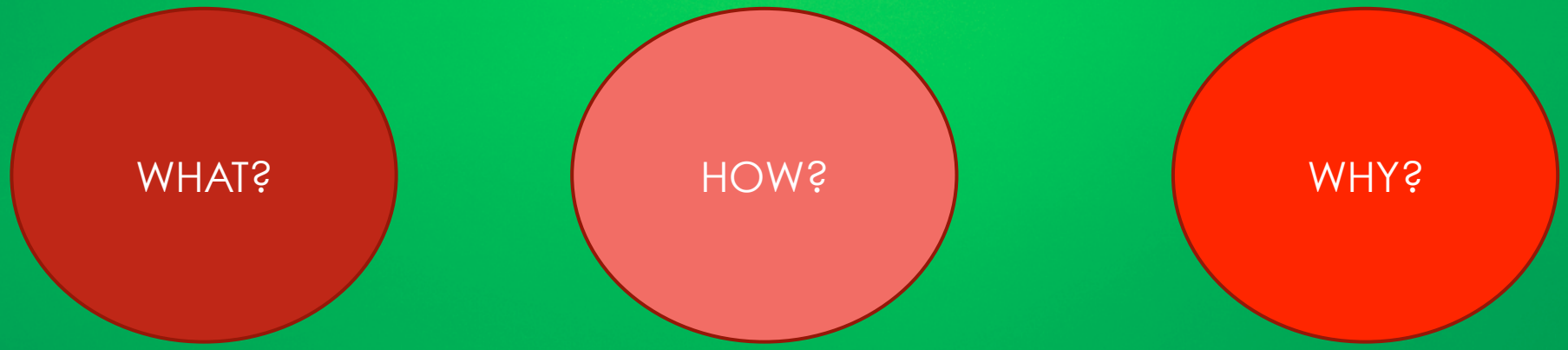
ASTROPLANTS

AN ODYSSEUS EUROPEAN YOUTH SPACE CONTEST ENTRY

esa

Our mission

- to study the phenomenon of plant growth in space and the factors that influence it
- to determine which environmental factors are optimal and what are the best alternatives for light and soil on a space farm
- to project an artificial habitat and a monitoring device that can be used for **space colonies**
- to create a viable ecosystem on an unpopulated planet



Conditions for agriculture

Earth agriculture

- Protection from radiation assured by Earth's magnetic field
- Soil contains all the necessary composition and amount of nutrients
- Optimal temperature and humidity for life
- Natural light
- Low level of carbon dioxide

Space agriculture

- Low or no magnetic field assuring protection
- Soil doesn't match the necessary conditions for plants to grow optimally
- Temperatures or humidity levels are too low or too high for life
- Natural light ?
- High level of carbon dioxide

Scientific premises and questions

PREMISES

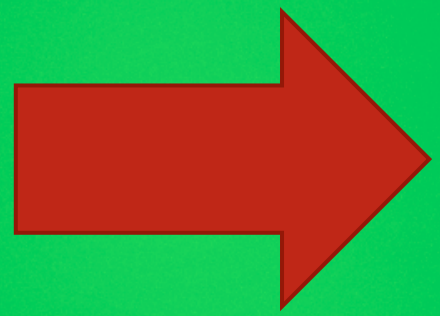
- The optimal parameters for plants to grow in are the ones on Earth
- Light is useful for photosynthesis only with its red and blue wavelengths
- Earth's soil has the perfect composition for plants to grow
- Magnetic fields influences the growth of plants
- CO_2 is vital for plants
- A space colony requires agriculture

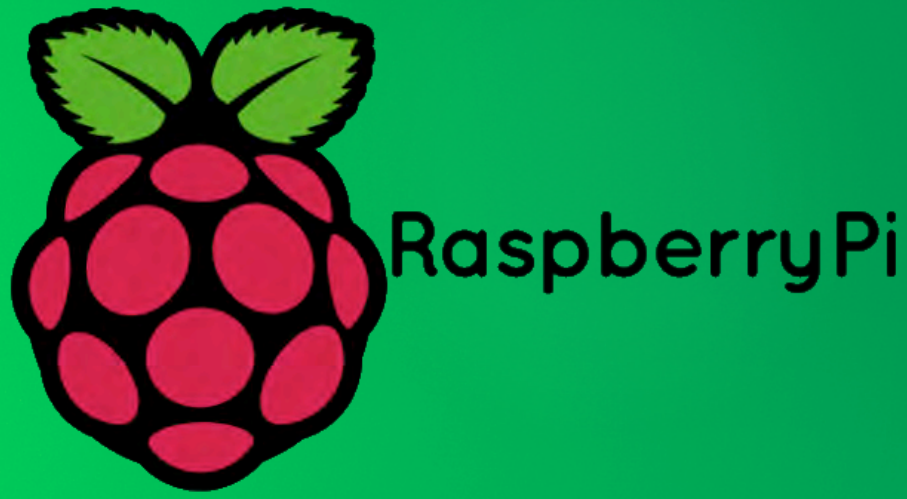
QUESTIONS

- How to reach the numerical values for these parameters?
- What is the minimal and optimal composition of light for plants to develop at their maximum potential?
- What is the best alternative for soil to grow plants in?
- What is the effect of an external magnetic field on plants?
- How much CO_2 can plants use?
- What does a space agricultural module look like?

Parameters that influence the growth of plants

- Temperature
- Pressure
- Relative humidity
- Magnetic field intensity
- Light radiation intensity
- Chlorophyll distribution





The device – Raspberry Pi

Advantages

- Its sensors measure all the necessary **parameters** we have to monitor and study
- It supports cameras and filters that allow us to study the **distribution of chlorophyll** inside the plants, as well as to monitor their growth at anytime
- It **doesn't affect** the measurements, nor the growth of the plants

Code Snippets from the Scripts

```python
#gets data from sensors and appends them to sense_data
def getSenseData():
    senseData=[]
    sense.set_imu_config(True, False, False)
    t = round(sense.get_temperature(), 2)
    h = round(sense.get_humidity(), 2)
    p = round(sense.get_pressure(), 2)
    comp = sense.get_compass()
    rawComp = sense.get_compass_raw()

    senseData.append(datetime.now())
    senseData.append(t)
    senseData.append(h)
    senseData.append(p)
    senseData.append(comp)
    senseData.append(rawComp)

    return senseData
```

Buffering data

```python
    if len(batchData) >= WRITE_FREQUENCY:
        print("Writing to file...")
        with open(filename,"a") as f:
            for line in batchData:
                f.write(line + "\n")
            batchData = []
```

Printing the buffer

```python
cnt = 1
while True:
    fileName = str (datetime.now()) + "NoIR" + str(cnt) + ".jpg"

    camera.capture (fileName)
    print ("Pic " + str(cnt) + " at " + str(datetime.now()) )
    cnt+=1
    sleep (FREQUENCY)
```

Capturing pictures

```python
if FILENAME == "":
  filename = "SenseLog-" + str(datetime.now()) + ".csv"
else:
  filename = FILENAME + "-" + str(datetime.now()) + ".csv"

fileSetup(filename)
```

Timestamping the logs

```
  GNU nano 2.2.6     File: /tmp/crontab.ACxrAN/crontab

@reboot python3 ~/Desktop/ODYSSEUS/NoIRCamera.py &
@reboot python3 ~/Desktop/ODYSSEUStest/main.py &

^G Get Help ^O WriteOut ^R Read Fil ^Y Prev Pag ^K Cut Text  ^C Cur Pos
^X Exit     ^J Justify  ^W Where Is ^V Next Pag ^U UnCut Te ^T To Spell
```

Crontab reboot commands

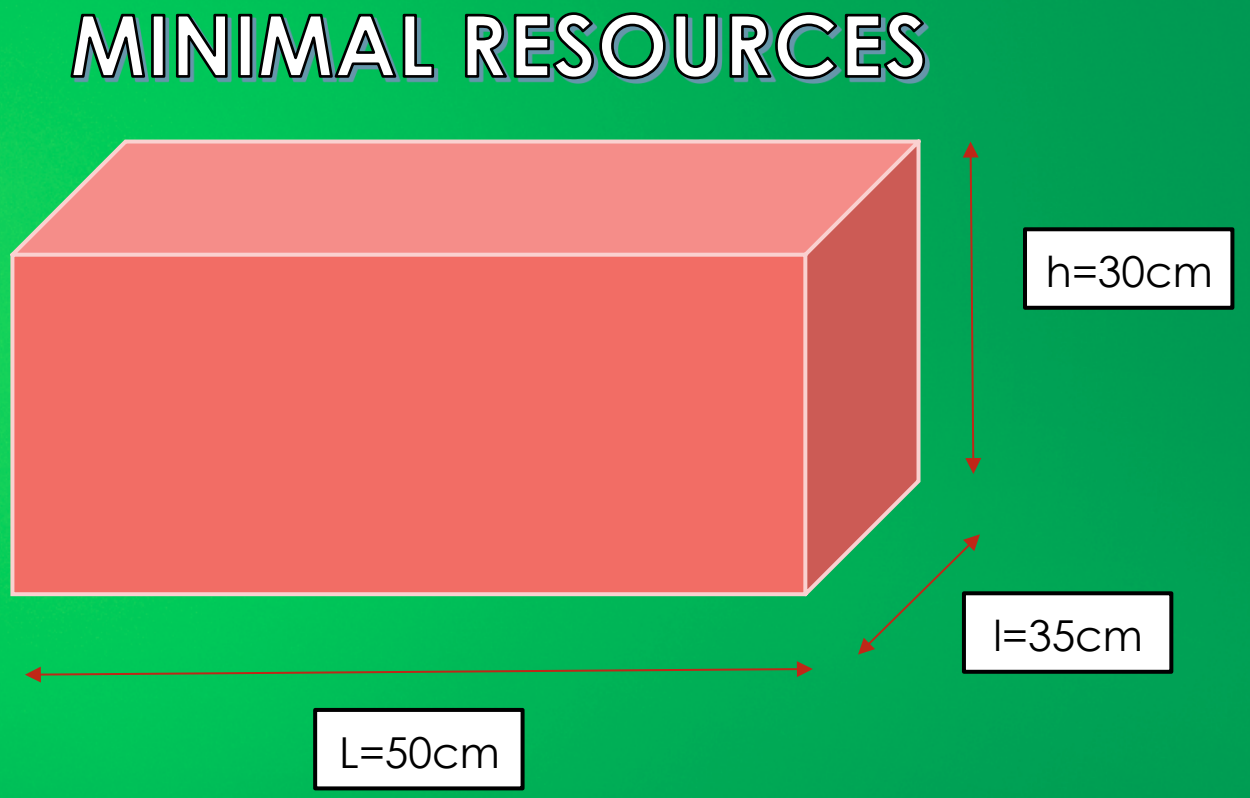
DESIGNING THE HABITABLE ENVIRONMENT

PART 1

Choosing the box

Calculations and results

- *Based on the necessary amount of **light** and **oxygen** for plants*
- $P=I\cdot S$
- $P=18W$
- $I=10285\ lx$
- $S=1750cm\hat{}2$
- $h=V/Ll$
- $\boldsymbol{h=30cm}$



Choosing the appropriate light

Theoretical considerations

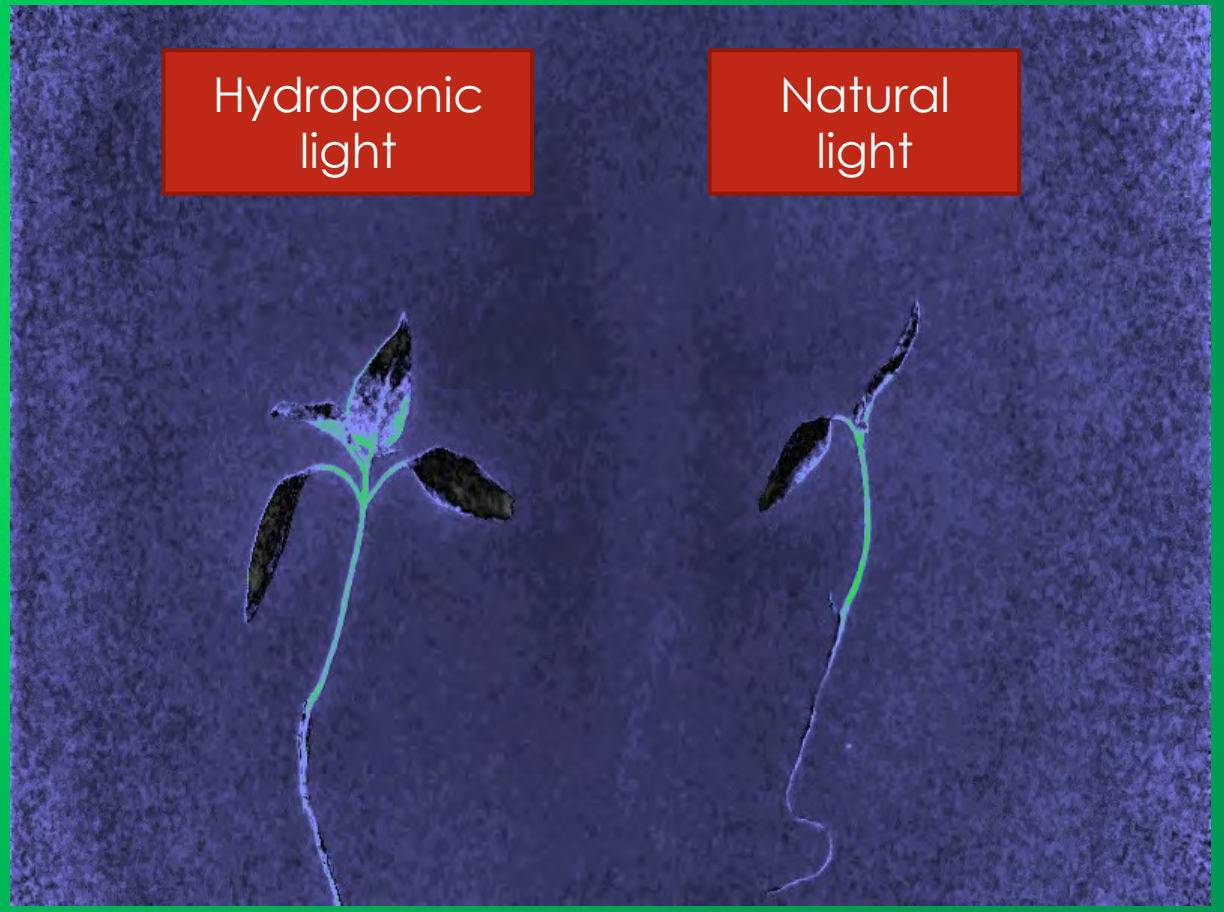
- **Red light** can be used in growing periods, when we need tall plants that grow fast
- **Blue light** is responsible for a plant's growth towards the light and even for the amount of water retained by the plan
- Blue light can be alternated with red light to produce a **better environment** for plants
- **Green light** is not a good option, because most plants reflect it rather than using it for photosynthesis

Choosing the appropriate light

Experiment

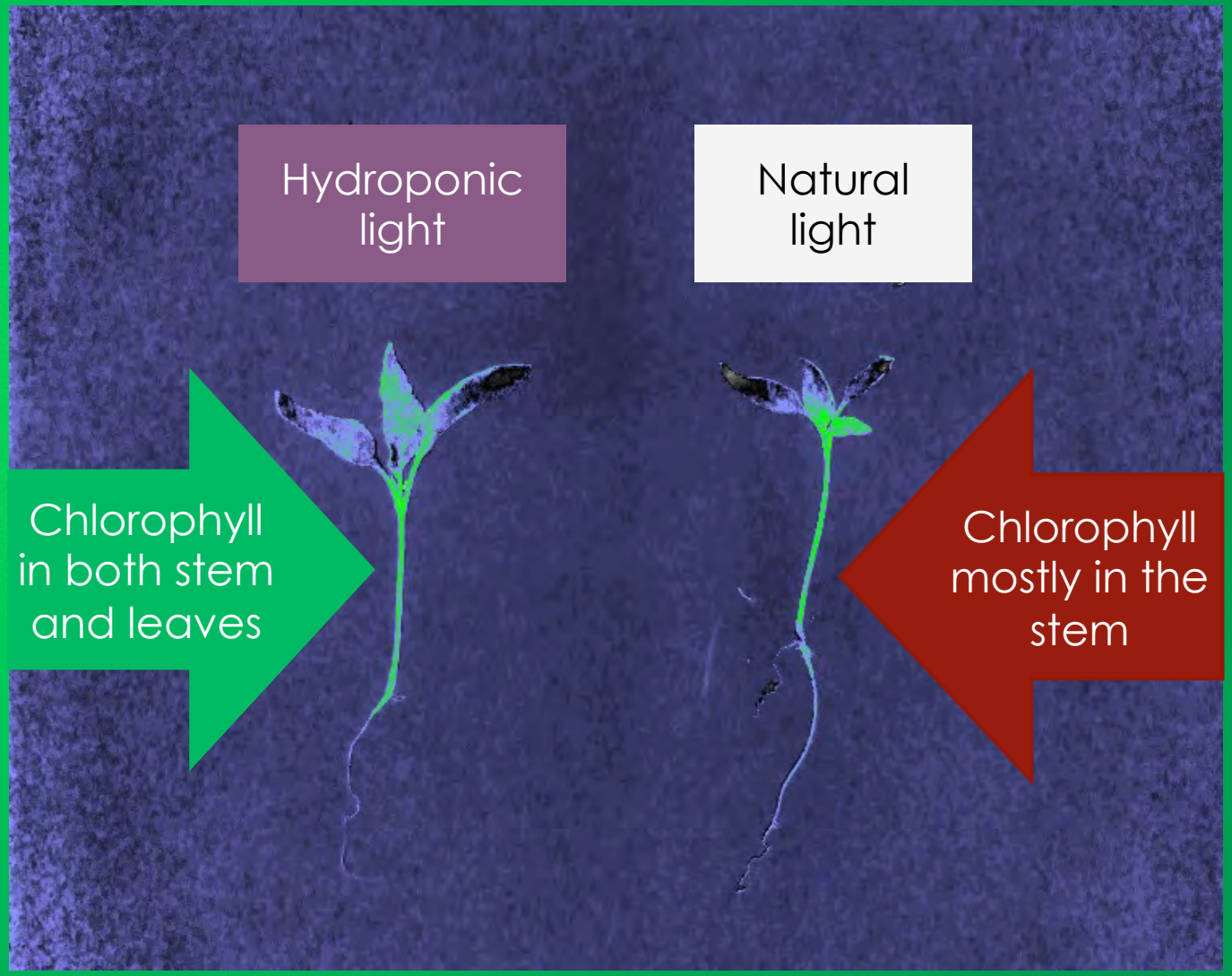
- A collection of 12 Red and 6 Blue LEDs
- Power: P=18W
- Average wavelength: $\lambda = 576.6\ \mathrm{nm}$

Green region – chlorophyll



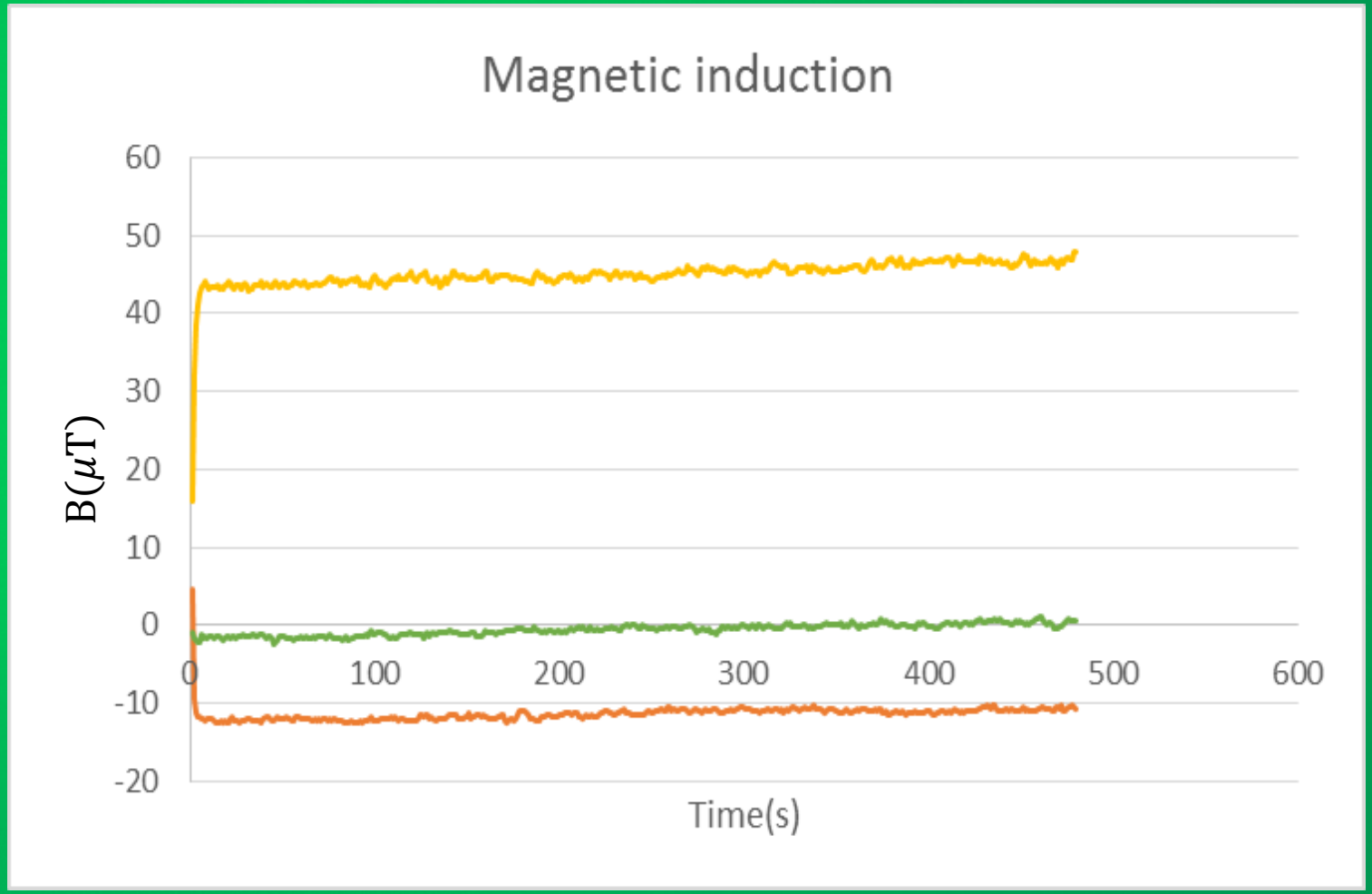
Conclusions

- The hydroponic light doesn't affect the zones where photosynthesis is done
- Plants grow in hydroponic light have a better distribution of chlorophyll



Normal parameters of the habitat

- Temperature
- Pressure
- Humidity
- Magnetic field



Accuracy of experiment

Box was closed during the day

All measurements done at night

Device not interfering with the experiment

Plants watered at the same time

SIMILAR CONDITIONS FOR A SPACE FARM

CHOOSING THE TYPE OF SOIL

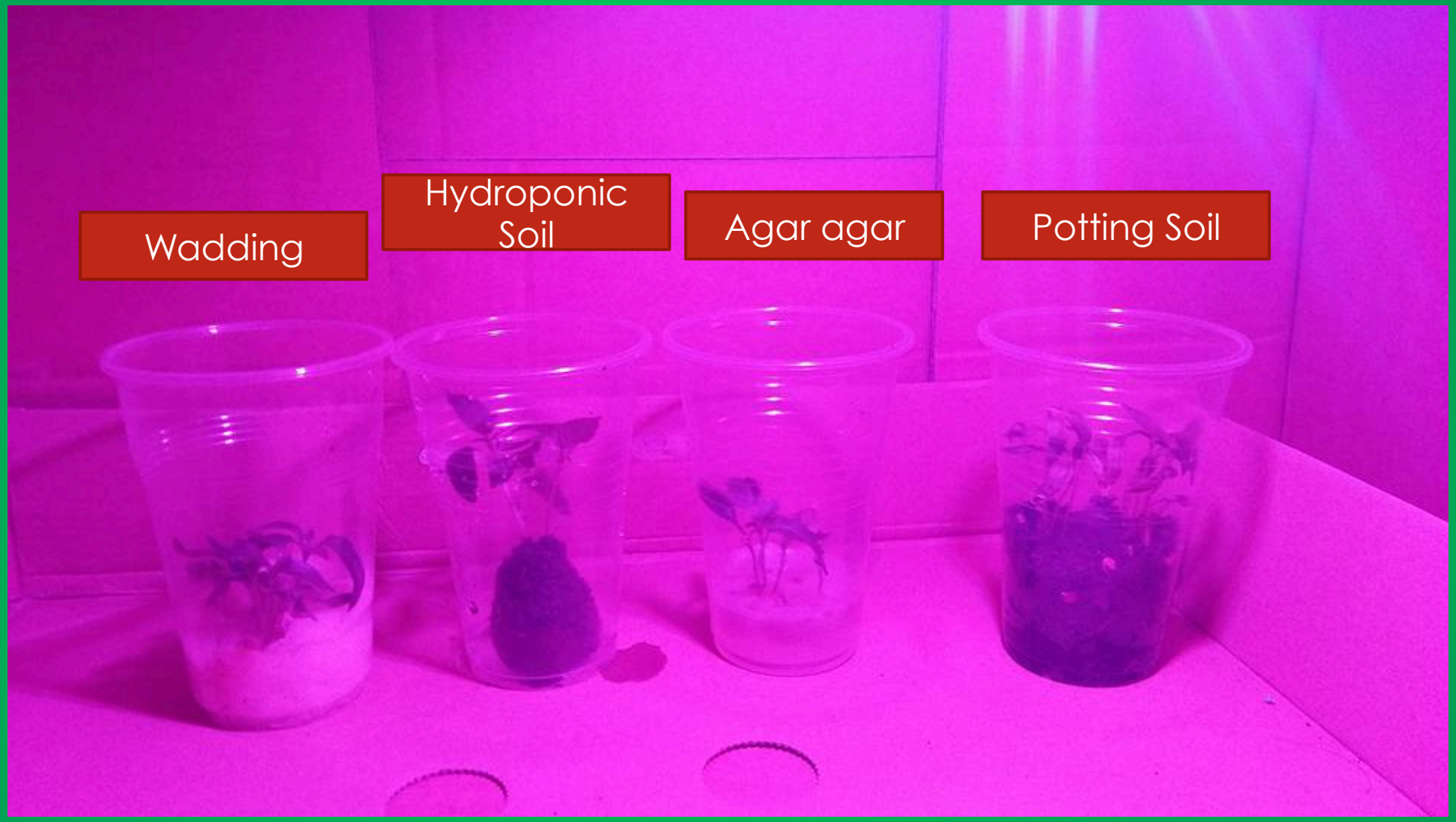
PART 2

Experimental setup & observations

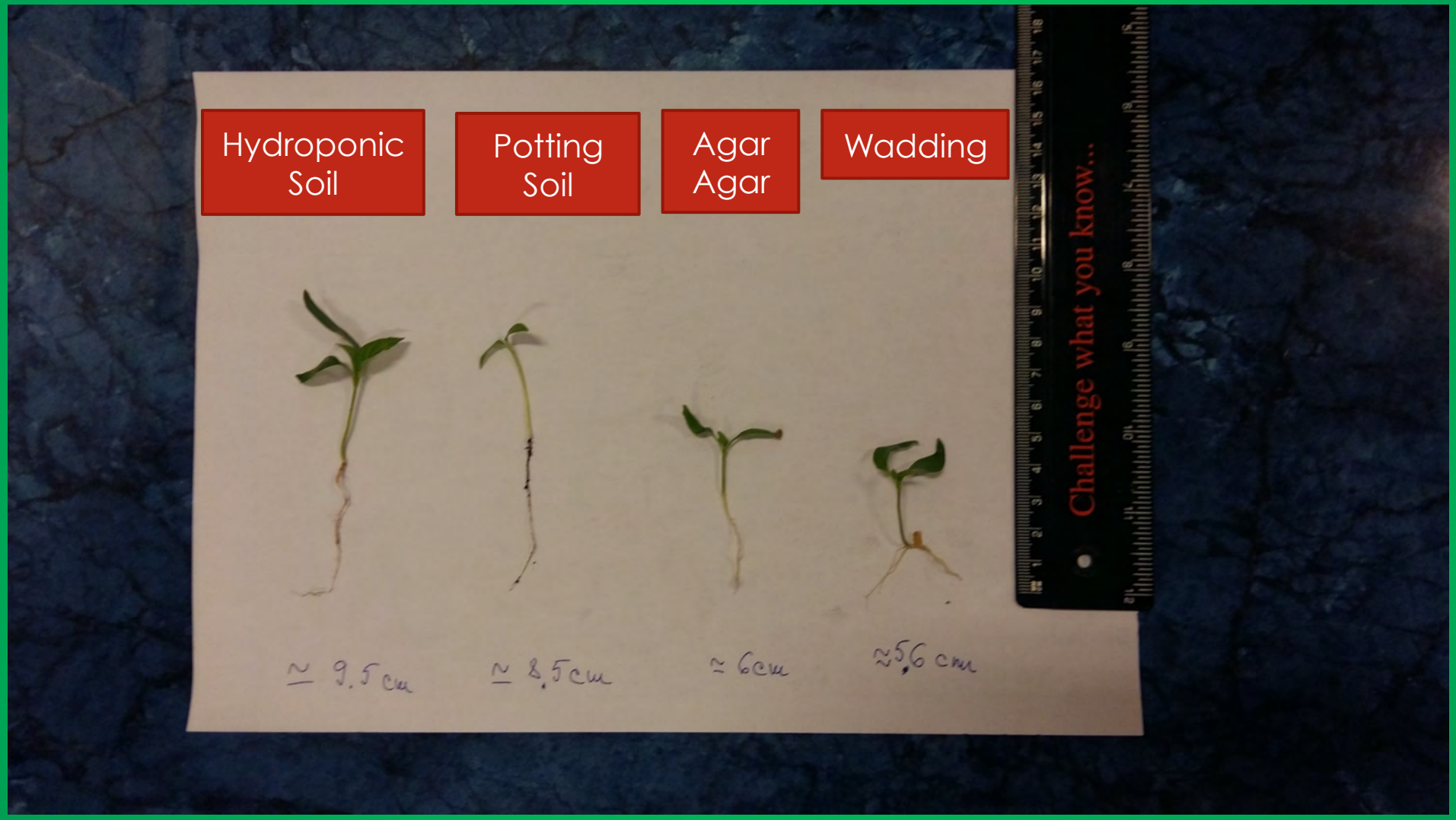
- 4 types of soil: potting soil, hydroponic soil, agar agar and hydrophilic cotton wool
- Using the camera on the device we can monitor the growth of the plants in the habitat
- The plant grown in hydroponic is the one with the largest leaves and strongest structure

VIDEO – Plants growing inside the box

Visual analysis



Measurements



Final result and conclusions

- The best soil – hydroponic
- The most similar plant to the one growing in normal soil

Hydroponic Soil

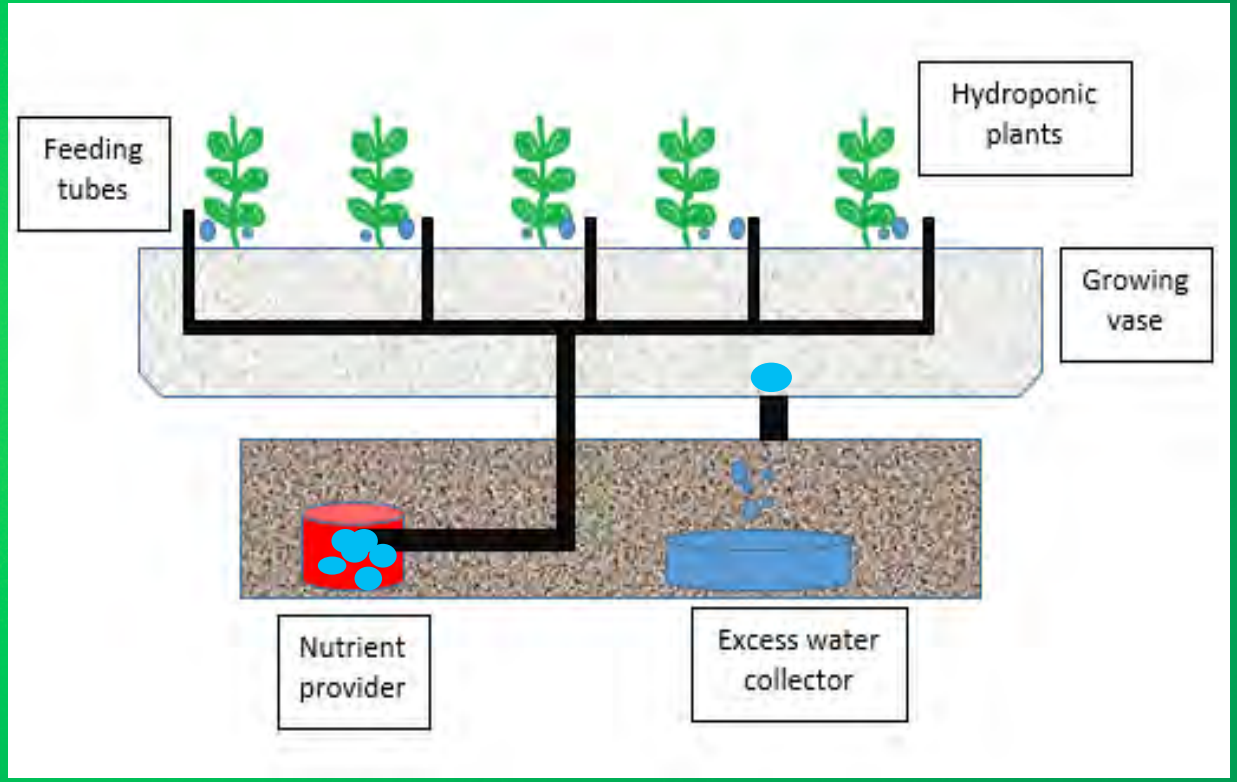
Potting Soil

- Height
- Number of leaves per stem
- Total surface of leaves
- Strength of plant

Hydroponic Garden in a Space Colony

Benefits:

- It conserves water
- It conserves the fertilizer and the energy
- The containers allow the root systems to evolve
- The root takes the nutrient solution to the plant
- The fruits and vegetables develop the same way like the ones growing in soil, sometimes even better

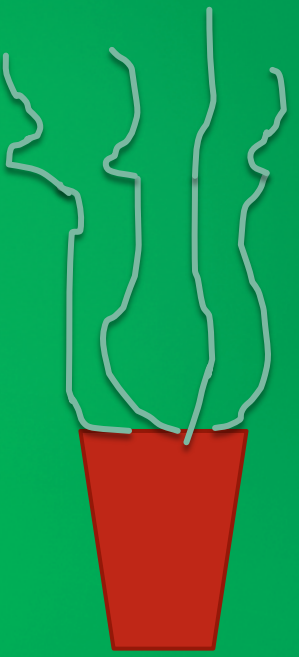


STUDYING THE EFFECTS OF THE INTENSITY OF THE MAGNETIC FIELD

PART 3

Scientific theories about plants in magnetic fields

- The principle of *MHD (Magneto-Hydro-Dynamics)*, where magnetism supposedly reduces the surface tension of water, thus increasing solubility and promoting growth.
- The subtle change in soil temperature caused by electro-magnetic fields which accelerate plant metabolism.
- The attraction of iron particles and starch grains by magnets; stimulating plant growth
- The excitement of Calcium ions (Ca^{2+}) by magnetic fields which are essential to many areas of plant growth and development.



Data analysis – Magnetic field comparison

NO extra magnetic field (μT)
32.24127
32.13787
31.83166
31.80688
31.69653
31.95607
32.84319
33.08207
32.87498
32.12421
32.28449
31.73621
31.66111
31.91085
32.35438
32.17447

NO extra magnetic field

Extra magnetic field (μT)
53.85659
55.46186
56.36745
56.69579
56.48067
56.63031
56.66847
56.24665
56.38842
56.62810
56.53345
56.52255
56.59705
57.29677
57.06620
56.92607

Extra magnetic field

Pictures taken with a normal camera

Left: NO Extra Magnetic field – no signs of leaves

Right: Extra Magnetic field – seeds already started to grow

Pictures taken with a normal camera

Left: NO Magnetic field – smaller plants, grow vertically

Right: Magnetic field – taller plants, roots slightly attracted by the magnetic field

Pictures – Raspberry Pi NoIR camera

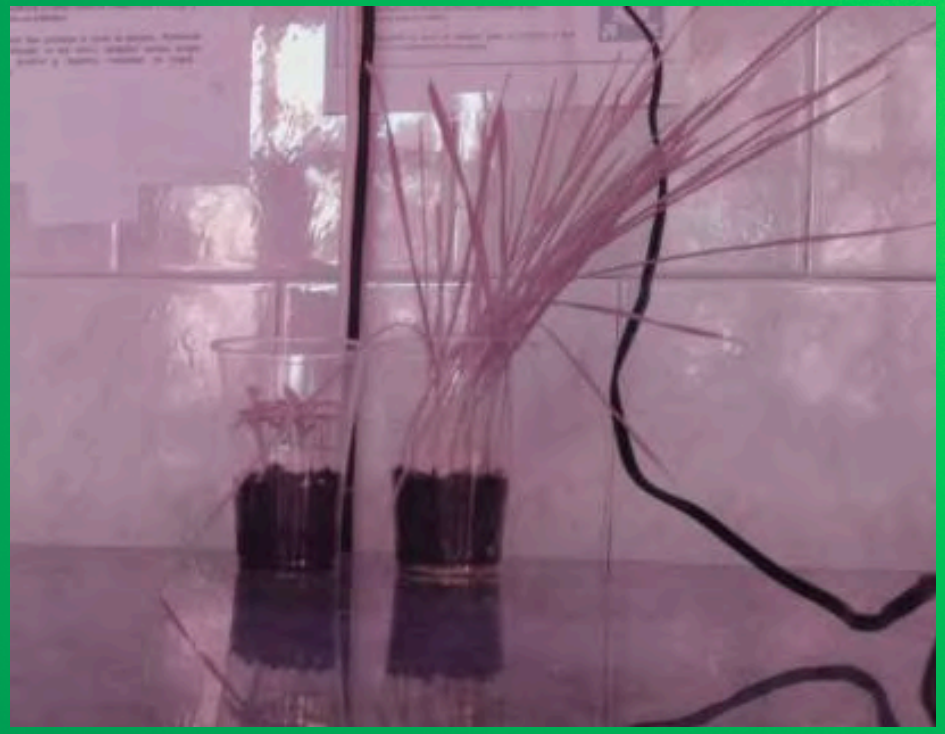
Left: NO Magnetic field –no signs of plants for chili peppers

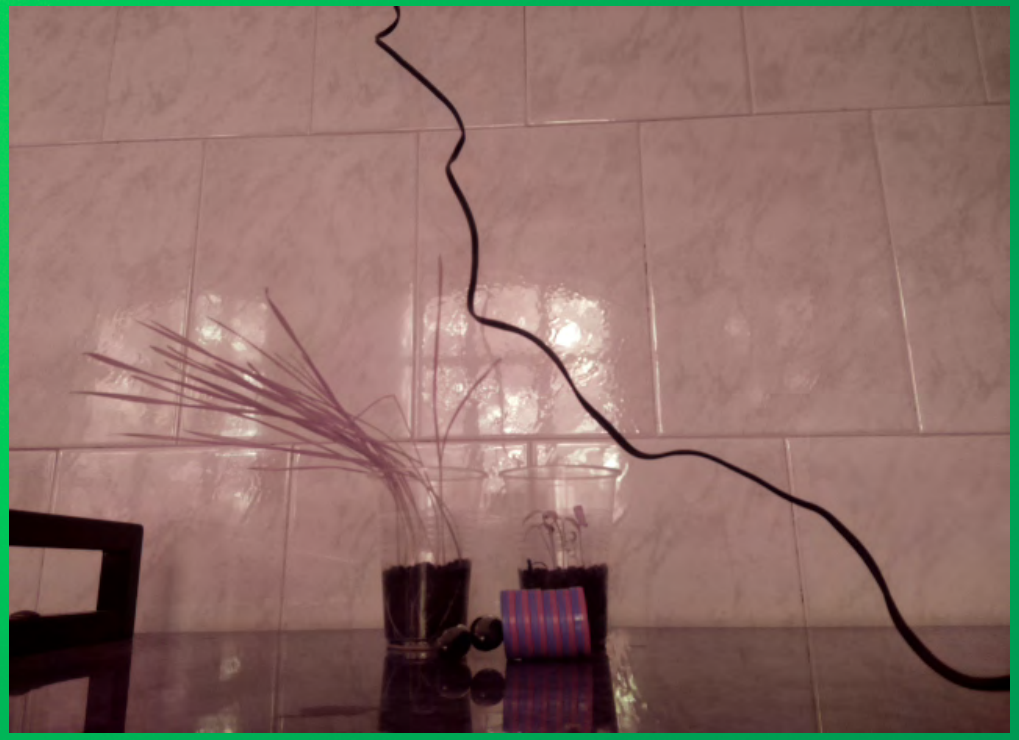
Right: Magnetic field – signs of plants for both species

Pictures – Raspberry Pi NoIR camera

Left: NO Magnetic field – smaller plants

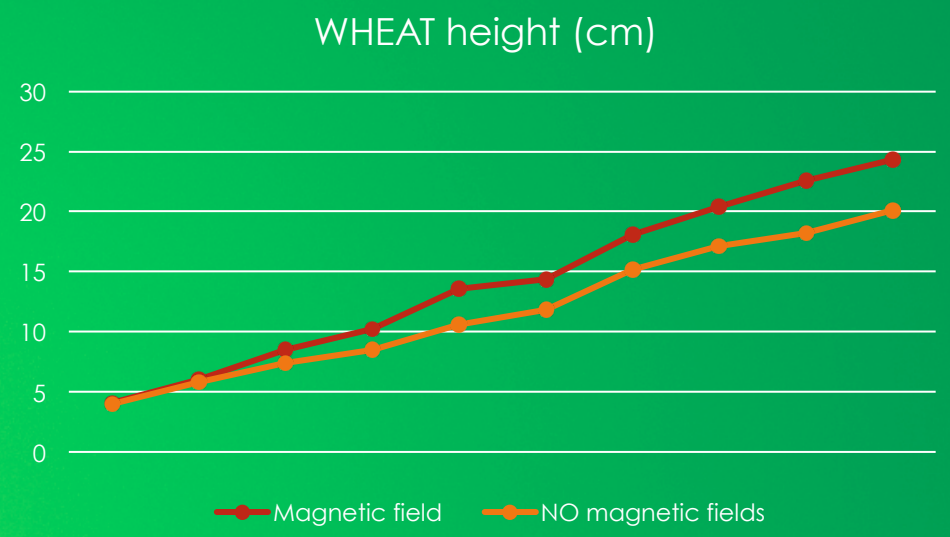
Right: Magnetic field – taller plants

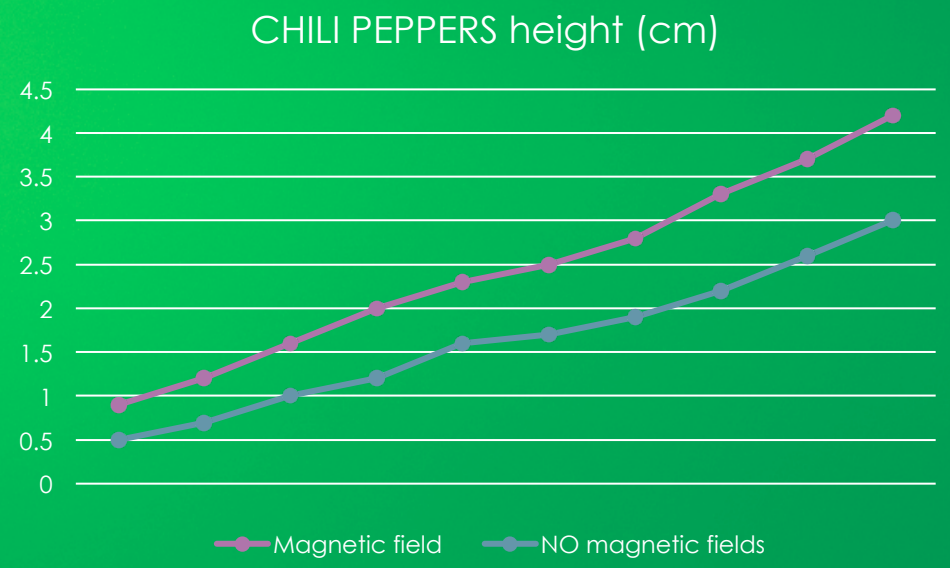




Experimental data & analysis

WHEAT		CHILI PEPPERS	
Extra magnetic field (cm)	NO extra magnetic field (cm)	Extra magnetic field (cm)	NO extra magnetic field (cm)
4.1	4.0	0.9	0.5
6.0	5.8	1.2	0.7
8.5	7.4	1.6	1.0
10.2	8.5	2.0	1.2
13.6	10.6	2.3	1.6
14.4	11.8	2.5	1.7
18.1	15.2	2.8	1.9
20.4	17.1	3.3	2.2
22.6	18.2	3.7	2.6
24.3	**20.1**	**4.2**	**3.0**





NEW!!

Changing poles of magnets

North-South direction

South-North direction

- Same magnets were used
- Same external conditions (our physics laboratory)
- Conclusions: no significant difference between the two plants

Conclusions

- static magnetic fields do have a **significant impact** on the growth of wheat and chili
- the statistical comparison demonstrates that the **difference in heights** between the control and all magnetic fields is statistically significant

- the relative growth percentage in magnetic field differs from species to species

$$(p+1)l\downarrow normal = l\downarrow magnetic\ field$$

$$p = l\downarrow magnetic\ field\ /l\downarrow normal\ -1$$

- For wheat: **p = 0.208 = 20.8%**
- For chili peppers: **p = 0.400 = 40.0%**

NEW!!

STUDYING THE EFFECTS OF A CO_2-ENRICHED ATMOSPHERE

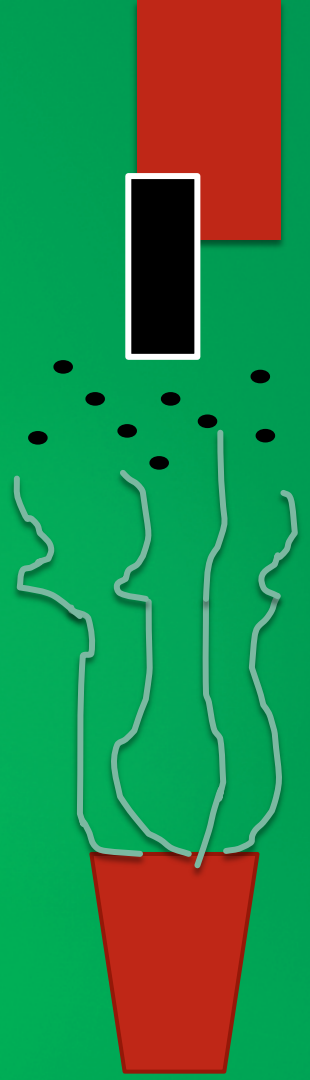
PART 4

Theoretical considerations

- Plants use carbon dioxide in photosynthesis:

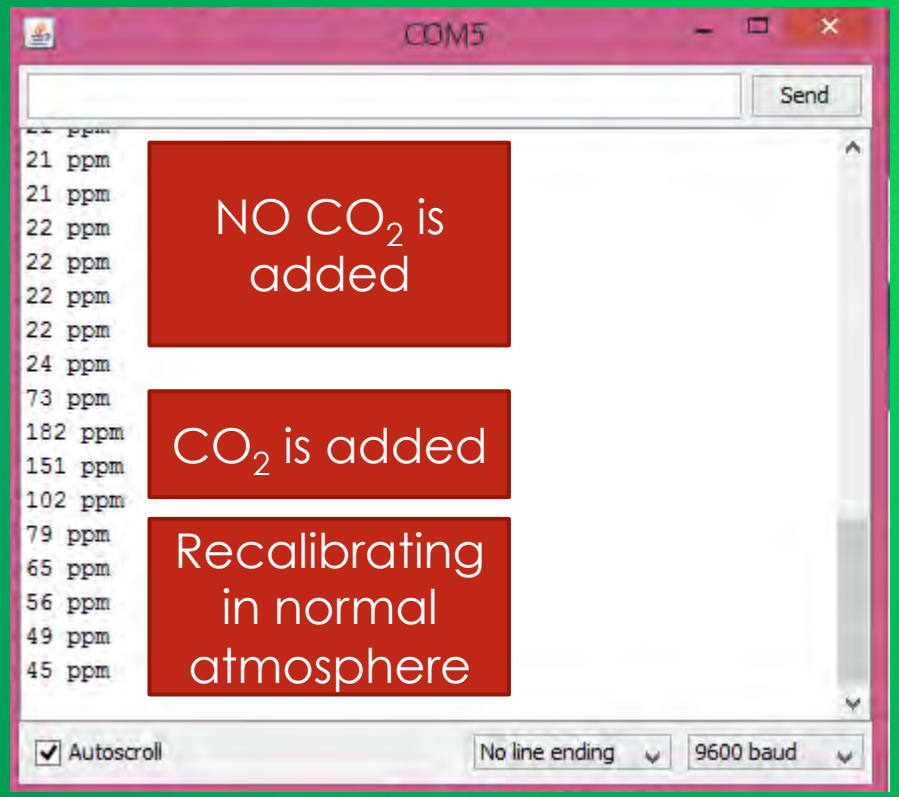
$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

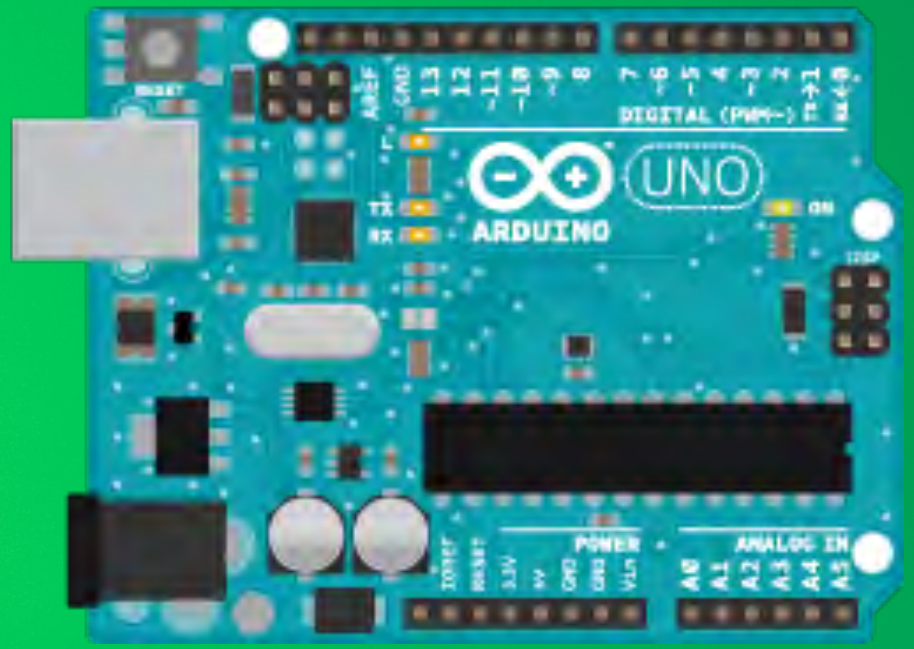
- Carbon dioxide can increase the rate of photosynthesis and benefit the growth of plants as it produces more food and, therefore, allows plants to grow taller
- Plants regulate the degree of stomatal opening as a compromise between the goals of maintaining **high rates of photosynthesis** and **low rates of water loss**.
- Leaf nonstructural carbohydrates per unit leaf area increase
- Protein and mineral concentrations decrease after a certain level of carbon dioxide is enriched



The Arduino Device & Measuring data

- MQ-135 sensor for air quality
- Adapted for measuring CO_2





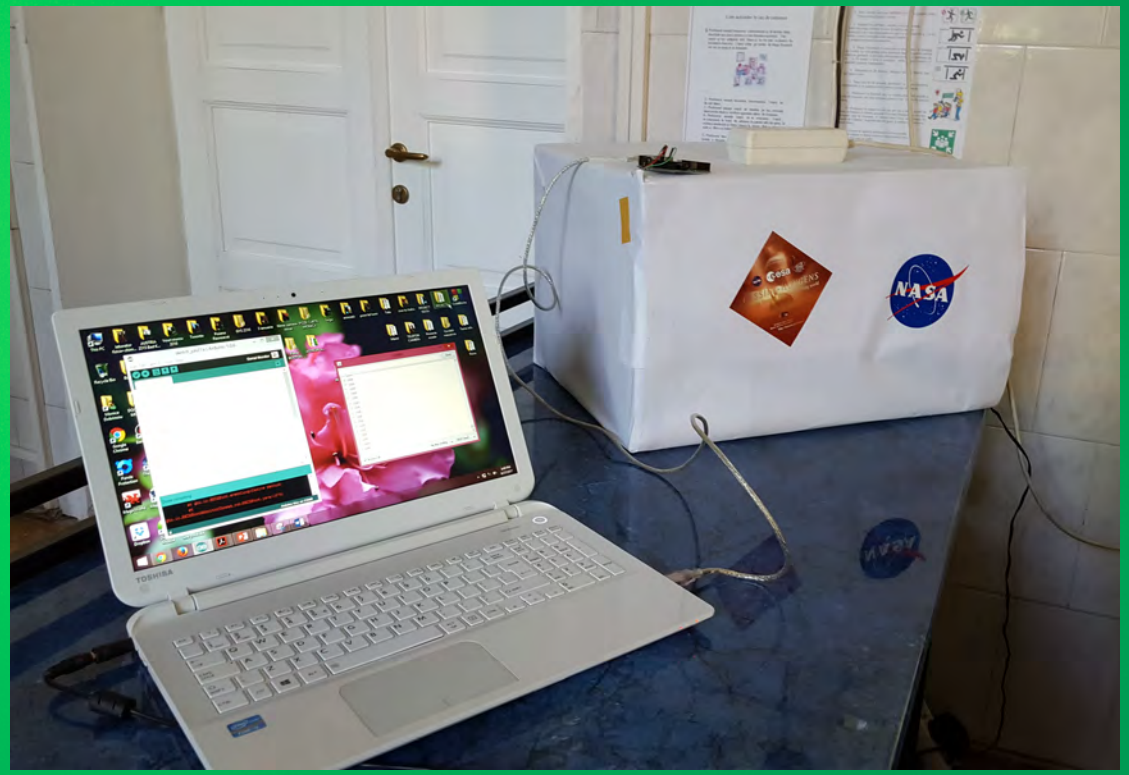
Two types of habitats with CO_2

Higher concentration

Natural light

Lower concentration

Hydroponic light



First habitat – natural light & CO_2

-Raspberry PI
-Arduino sensor & board

NO CO_2 (ppm)	CO_2 (ppm)
22	141
21	141
21	141
21	141
21	140
21	141
21	141
21	140
20	141
21	140
21	140
20	141
21	140
21	141
21	140
20	141
21	140
21	140

Second habitat – hydroponic light & CO_2

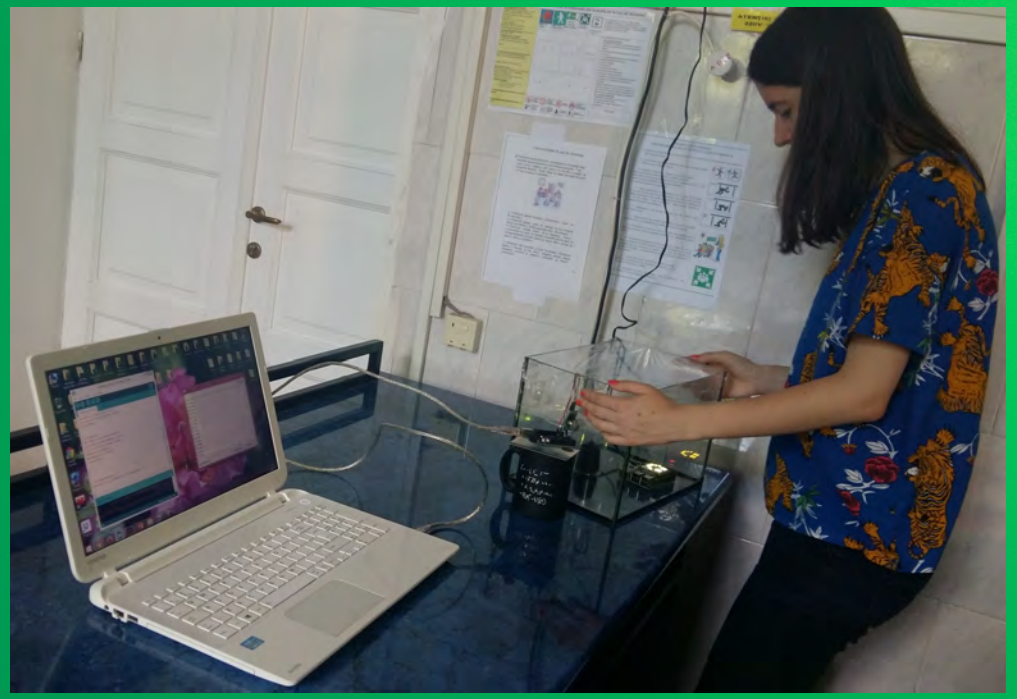
-Raspberry PI
-Arduino sensor & board
-**Hydroponic light**

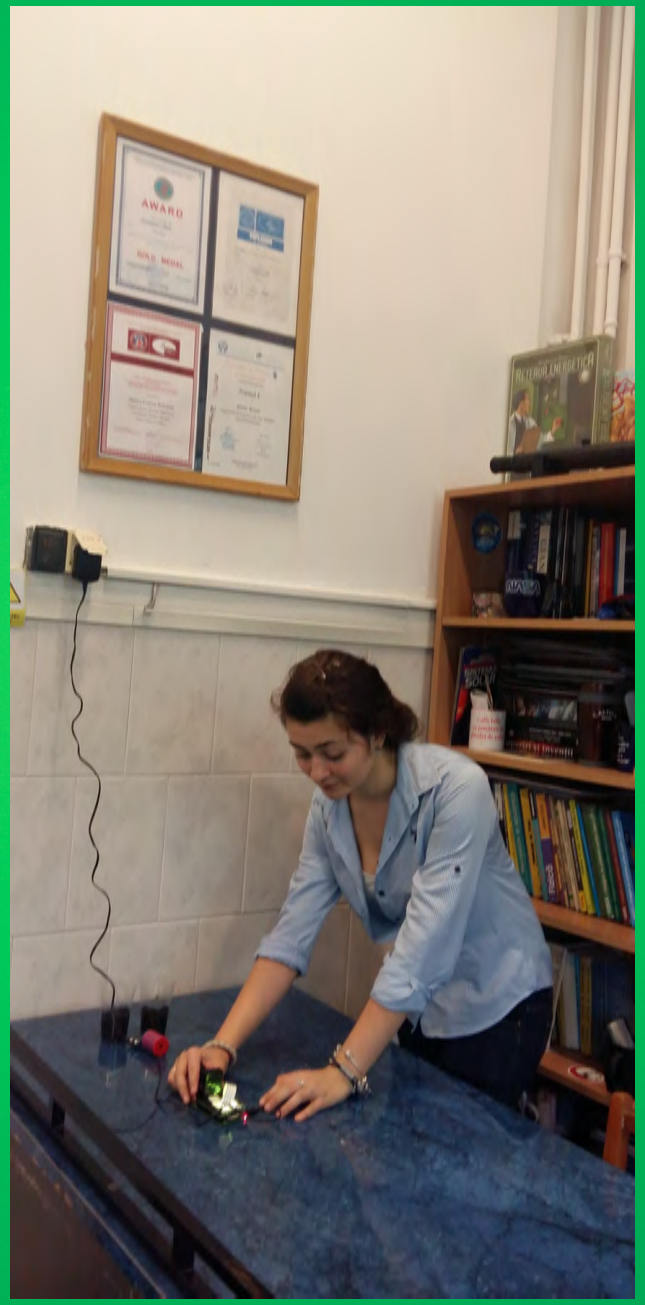
NO CO_2 (ppm)	CO_2 (ppm)
24	77
24	77
25	77
24	76
25	76
25	77
25	76
25	77
25	77
24	76
25	77
25	76
25	76
25	76
24	77
24	77
25	76
25	77

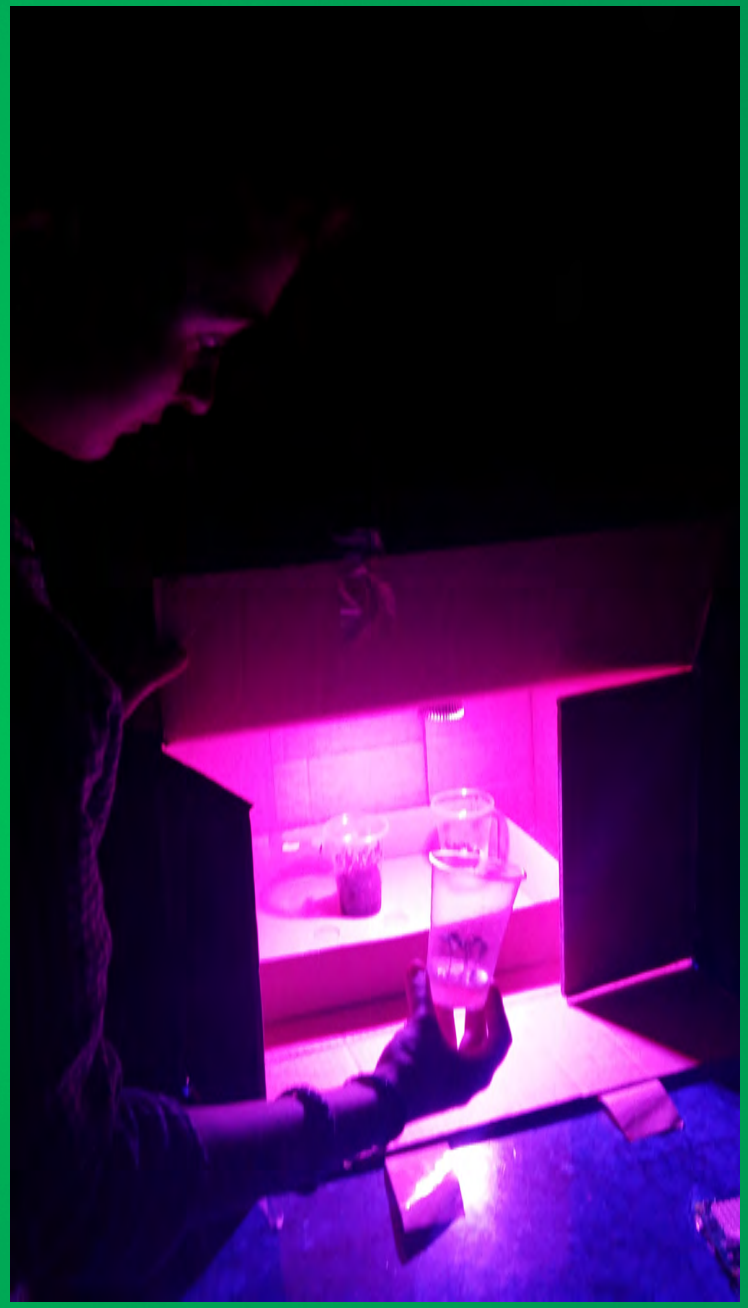
Final conclusions – the ideal space farm

- Minimal resources
- Hydroponic light
- Hydroponic soil
- An external magnetic field
- An enriched-CO_2 atmosphere

Working on the project







Further development

- Continue the measurements with the current plants
- Extend the experiment using more types of seeds
- Test the artificial selection algorithm
- Use the accelerometer function of the Raspberry Pi and study the growth of plants in several values of the gravitational field, by collaborating with other schools
- Learning by teaching – continue the studies and make relevant measurements for a future space farm

Acknowledgements

- Odysseus Contest Organizers
- Our coordinating teacher, Mrs. Ioana Stoica
- Our high school, "Tudor Vianu" National High School

Motto: "*All our dreams can come true, if we have the courage to pursue them.*" – Walt Disney

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- T.Ivanova, et al. - First Successful Space Seed-to-Seed Plant Growth Experiment in the SVET-2 Space Greenhouse

Thank you very much for your attention!

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Category: Astrobiology