

11. Resistant plants

Some plants are tolerant to freezing temperatures, but others can hardly survive low temperatures.
Perform experiments to investigate what plants can survive freezing temperatures.

The theoretical part

- The Hypothesis
- The Theory Behind the Hypothesis
- Species Selection

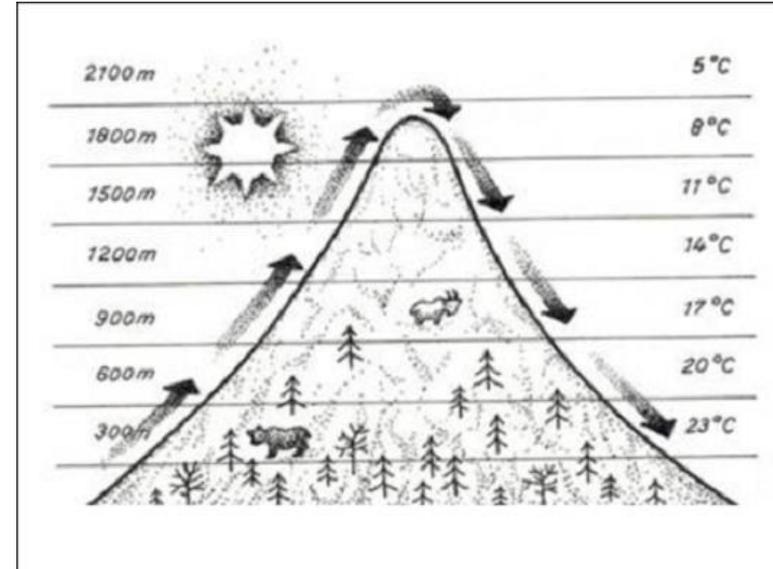
The theory behind the hypothesis

- **Evolution** determines **features**
- **The higher** the altitude **the colder** the climate.
- **High altitude natural habitats** results in **better low temperatures** resistance.



Research Hypothesis

- *The higher the natural habitat the better the resistance to freezing temperatures is.*



Species selection 1 - Mountain Region (>800 m)



Spruce tree (*picea*)



15°C



-30°C

1. The **needle-like** leaves **coated in wax**



2. The **rough** bark

3. Produces **cones** rather than flowers



4. The **cone-like** shape of the tree

Species selection 2 - Hill region (400 - 600 m)



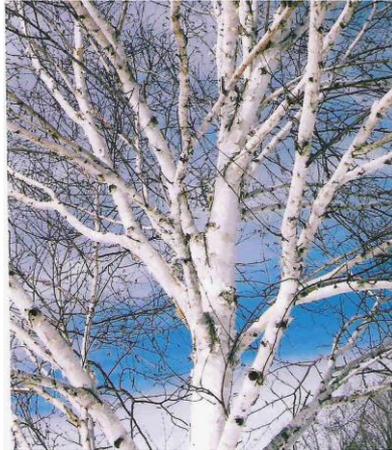
Oak (*Quercus Robur*) and **Birch** (*Betula Pendula*)



1. The **rough** bark



2. The **hibernation** state



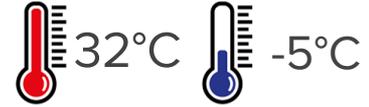
3. **Flexible** branches
(birch)



Species selection 3 - Plains (100 - 400 meters)



Plains oak (*Quercus frainetto* and *Quercus Cerris*)



1. The **hibernation** state



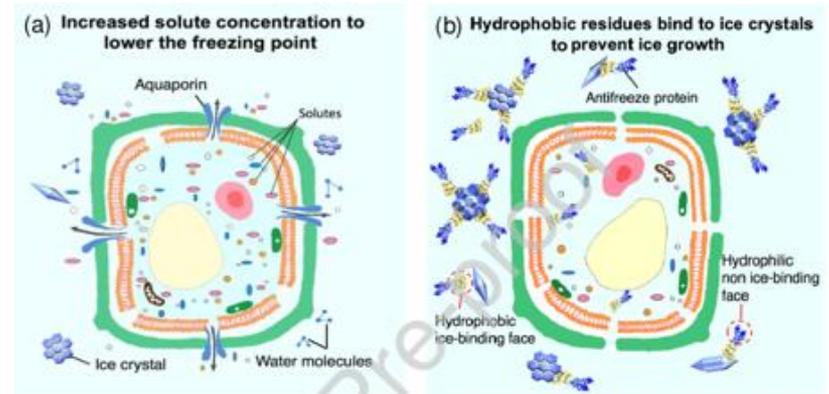
These trees have no other adaptations for cold environments.

How does frost affect plants

- There are two ways a plant can freeze:
 - Intracellular freezing
 - Extracellular freezing
- This phenomenon affects the **water circulation system** of the plant (The intracellular freezing) and the **structure of the cells** (The extracellular freezing)
- Both of the phenomena lead to **damaged or dead cells**

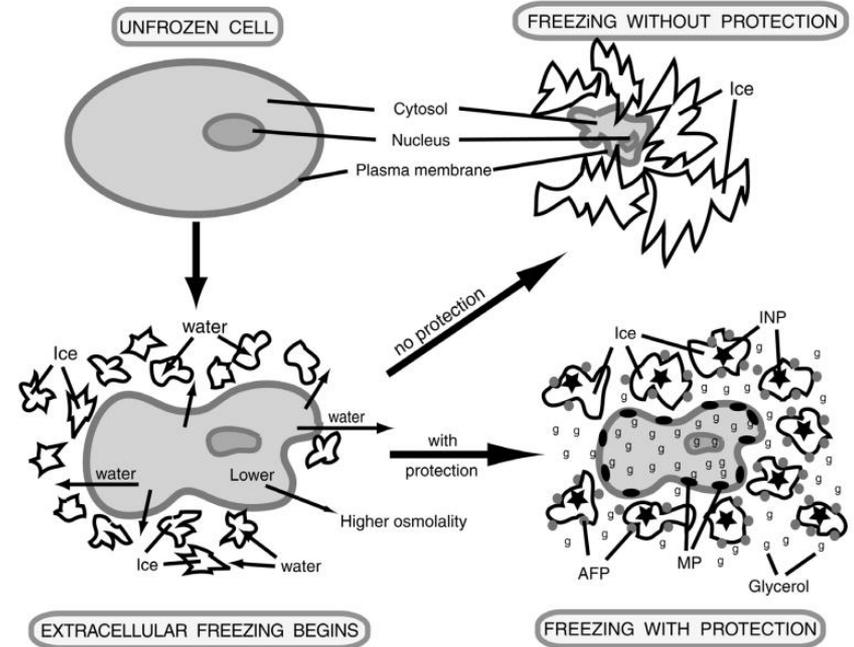
The intracellular freezing

- **Ice crystals** form first in the protoplasm and then in the vacuole.
- Intracellular freezing is **fatal** to all cells by visible mechanical **disruption** of the protoplasm and vacuole.
- Its facilitated by rapid freezing and occurs less easily in hard tissues
- It tends to be prevented by an increased permeability.



The extracellular freezing

- Ice forms outside the cells from water in the cells.
- The water in the cells tries to eliminate the frost from outside but it also freezes
- The resulting dehydration of the cell causes its malfunction, the opposite walls are squeezing it to collapse
- If the plant freezes slowly, it is fatal to all unhardy cells
- Some **proteins** can **protect** the cell from freezing (AFP, MP, Glycerol)



The Methodology

- Materials
- Experiment
- The Raspberry Pi program

Methodology - Materials

- **Three months to 1 year** old seedlings
- **5 piece** / species / experiment
- From **Tree Nursery**
- **Same** soil; **same** pots



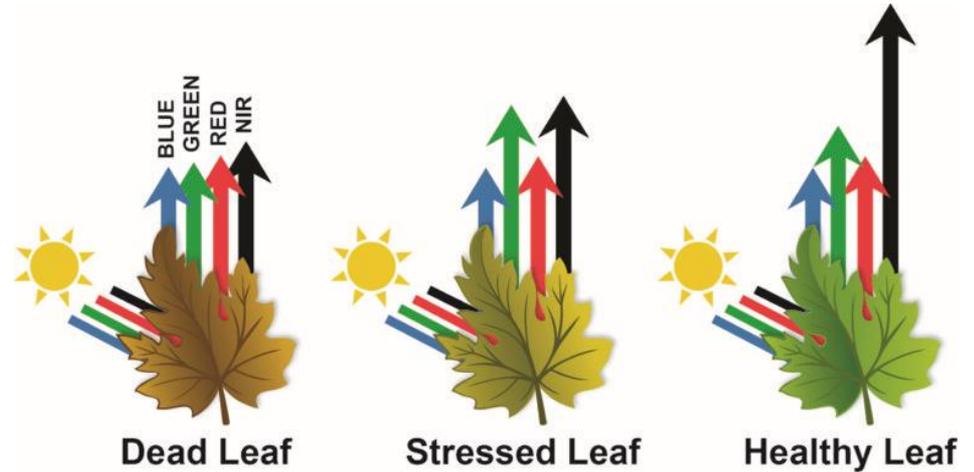
Methodology - Experiment

- **Meat processing & cooling room**
- **Continuous** light
- 24, 48 & 72 hours at -24°C for every species
- 3-4 weeks **normal temperatures**
- Analyze the state of the plant with the **Raspberry Pi system**



Analyzing health of leaves with NDVI* index

- Chlorophyll **reflects green** light during photosynthesis → this is why plants look green;
- Plants **reflect** most of the **infrared light**;
- The healthier the plant, the more near-infrared light is reflected;
- Use of a Raspberry Pi NoIR camera with a **blue filter**.



*NDVI = Normalised Difference Vegetation Index

Formula for calculating NDVI

$$NDVI = \frac{NIR - Blue}{NIR + Blue}$$

- the NDVI values varies between -1 and +1
 - NDVI: **blue** pixels → **brighter**
 - NDVI: **red** pixels → **darker**
- } image in black and white
- **brightest** pixels → **healthy** plants
 - **darkest** pixels → **unhealthy** plants / **absence** of plants



Steps for calculating the NDVI



1. Unprocessed image



2. Increasing the contrast



3. Calculating NDVI



4. Colour mapping

*colour of the brightest pixel $\rightarrow 255$
colour of the lowest pixel $\rightarrow 0$*

```
def calc_ndvi(image):  
    b, g, r = cv2.split(image)  
    bottom = (r.astype(float) + b.astype(float))  
    bottom[bottom==0] = 0.01  
    ndvi = (b.astype(float) - r) / bottom  
    return ndvi
```

red = healthy
green = unhealthy
grey = dead

The Experiment

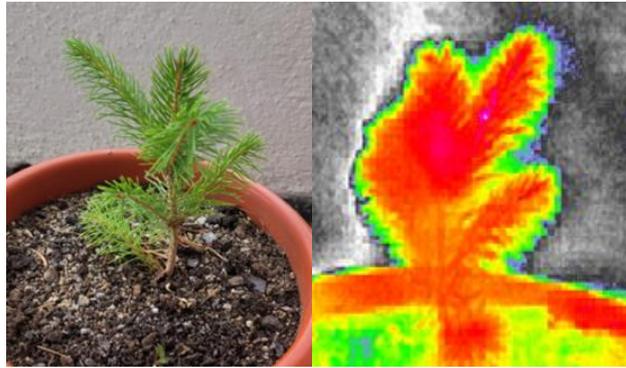
- Analyzation of the data from the experiments

Results of the experiment 1 - The mountain region



Spruce tree (*picea*)

24 hours



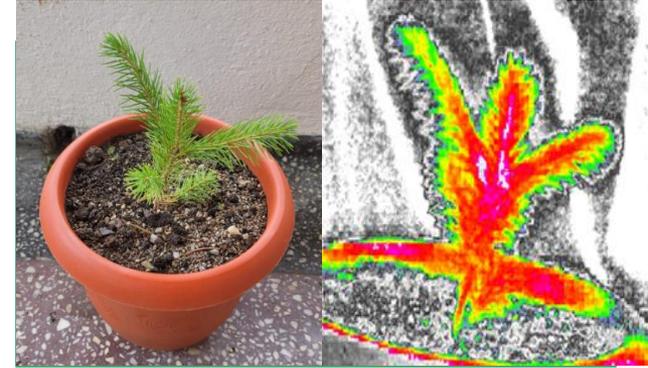
All of the exemplars survived

48 hours



All of the exemplars survived

72 hours



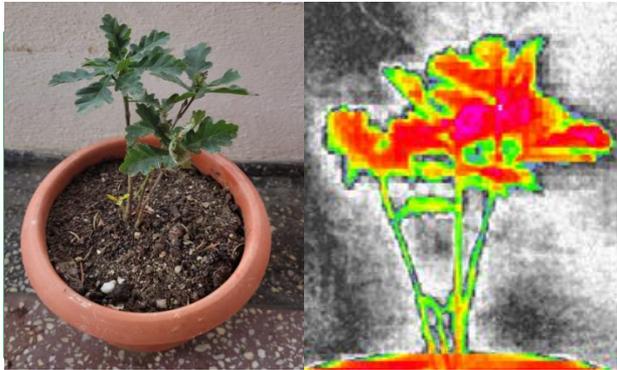
All of the exemplars survived

Results of the experiment 2 - The hill region



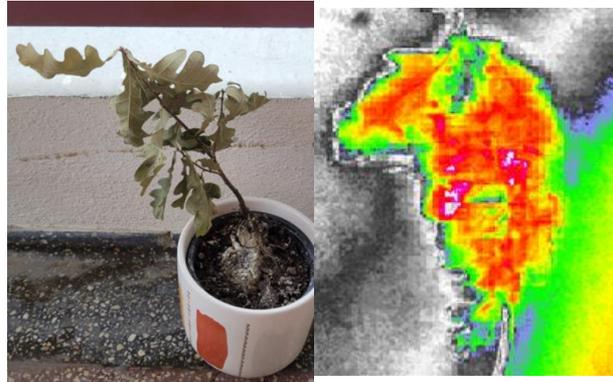
Oak (*Quercus Robur*)

24 hours



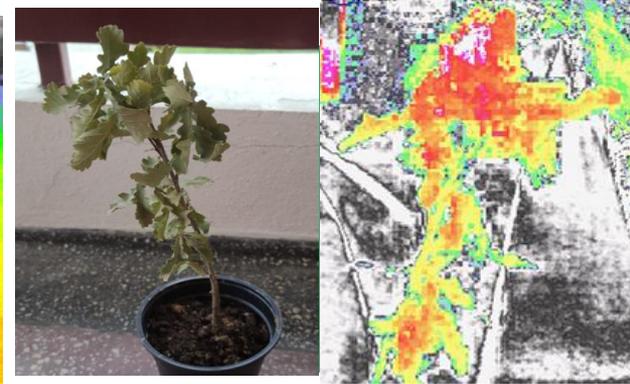
All of the exemplars survived

48 hours



All of the exemplars survived

72 hours



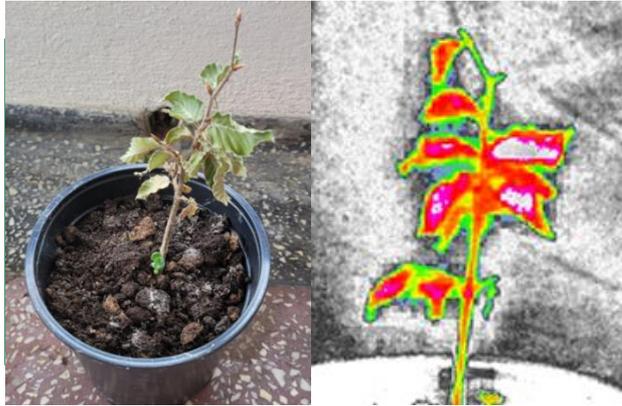
All of the exemplars survived

Results of the experiment 2 - The hill region



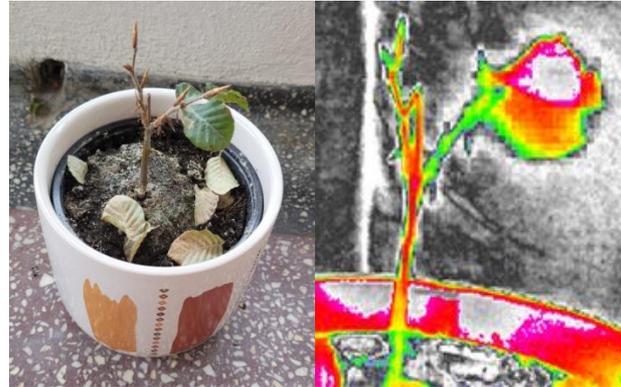
Birch (*Betula Pendula*)

24 hours



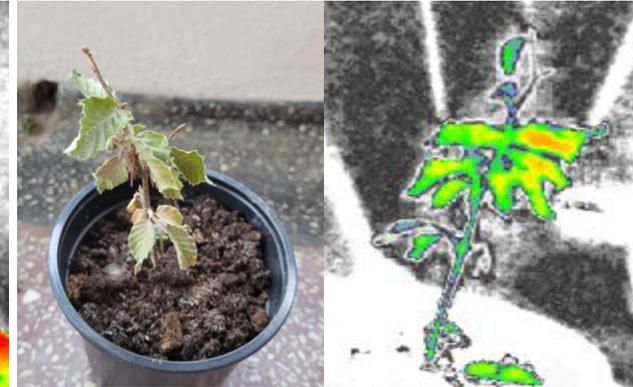
All of the exemplars survived

48 hours



4 exemplars survived

72 hours



Only 3 exemplars survived

Results of the experiment 2 - The plains region

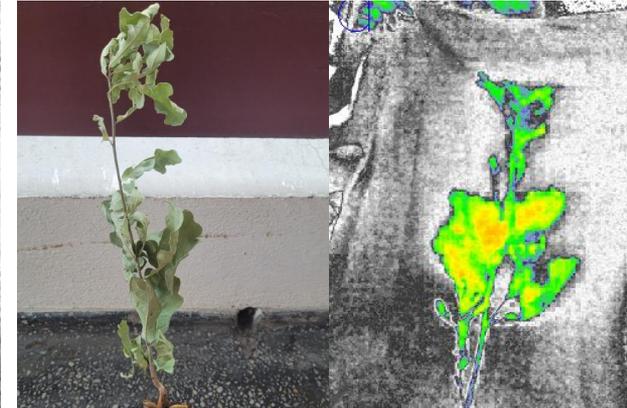
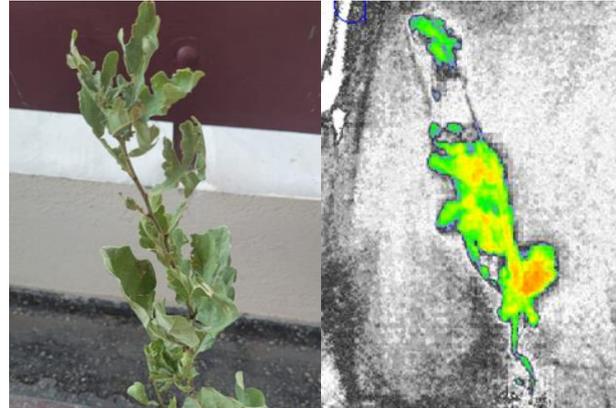


Hungarian oak (*Quercus frainetto*)

24 hours

48 hours

72 hours



4 of the exemplars survived

None of them survived

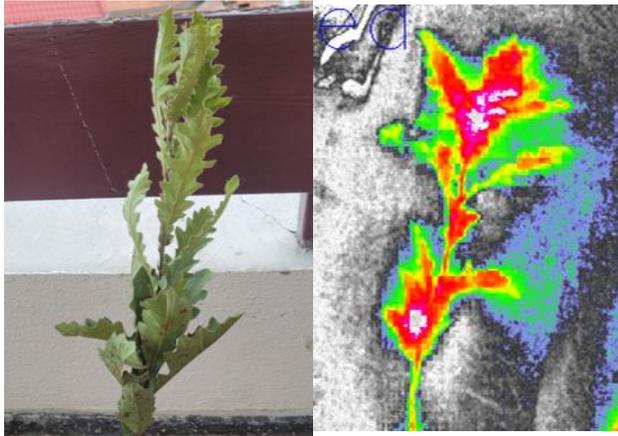
None of them survived

Results of the experiment 2 - The plains region



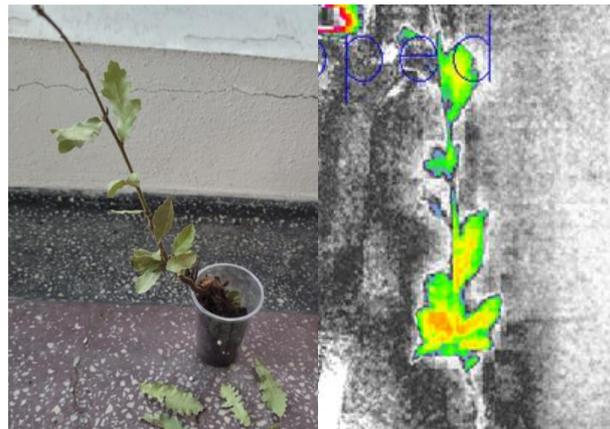
Plains oak (*Quercus cerris*)

24 hours



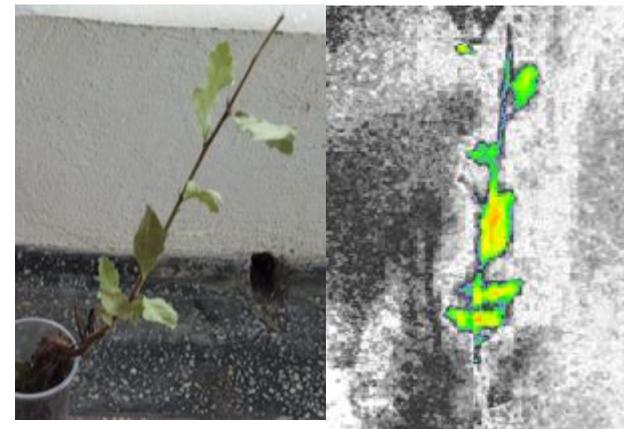
4 of the exemplars survived

48 hours



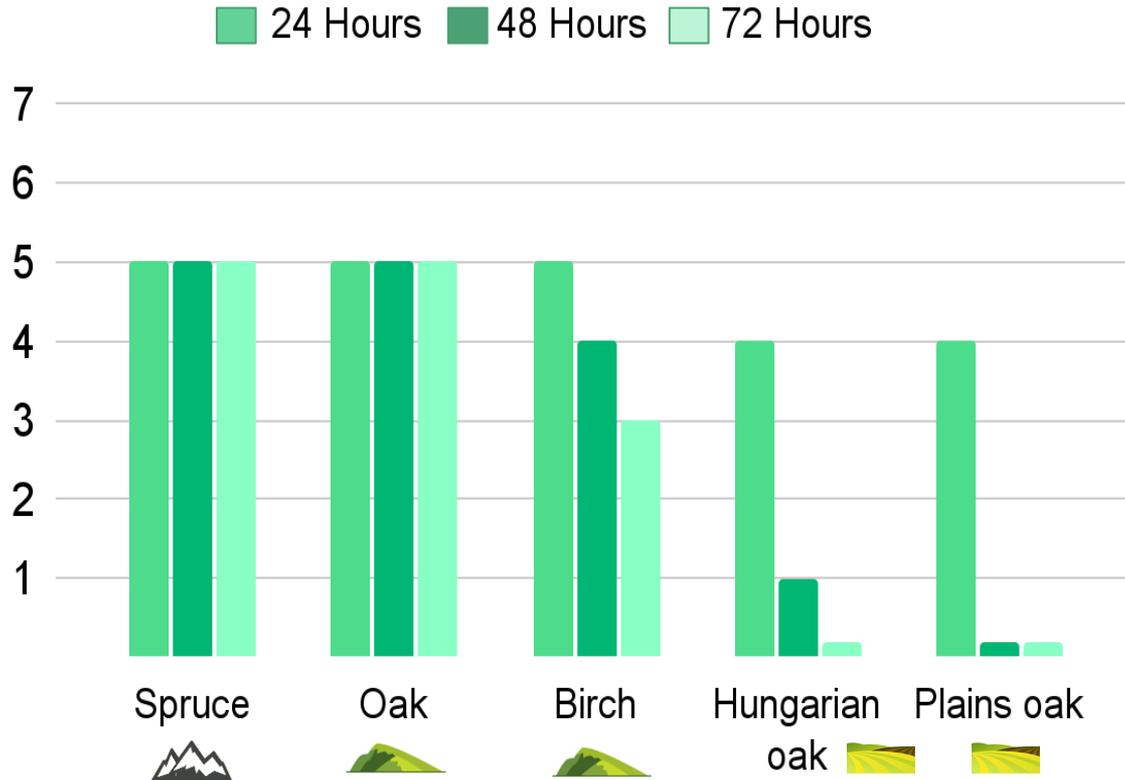
None of them survived

72 hours



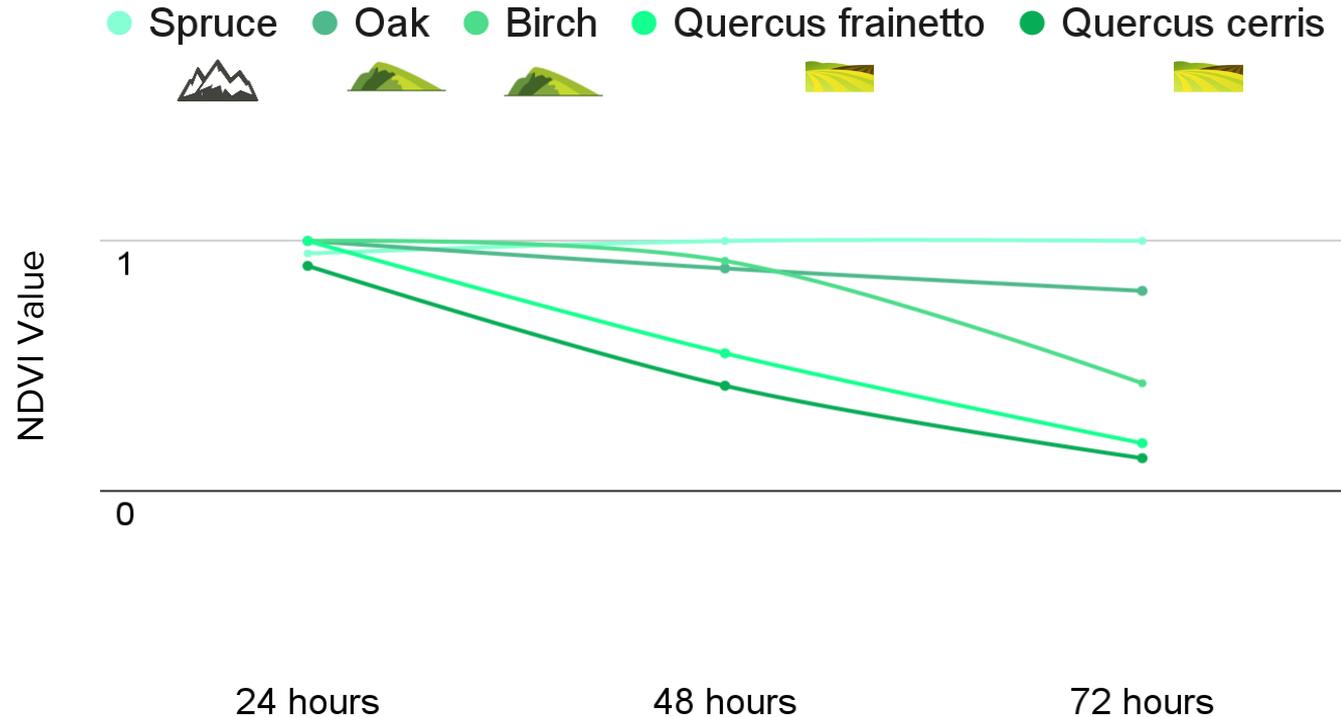
None of them survived

Comparison of the number of exemplars that survived



Plants that lived in **lower altitude** had a **lower number** of exemplars that survived. → **H1 true**²³

Comparison of the NDVI values



The bigger the time spent in the refrigerator **the lower** the **NDVI value**.
Plants that lived in **lower altitude** had a lower **NDVI value**. → **H1 is true**

What does the NDVI value mean

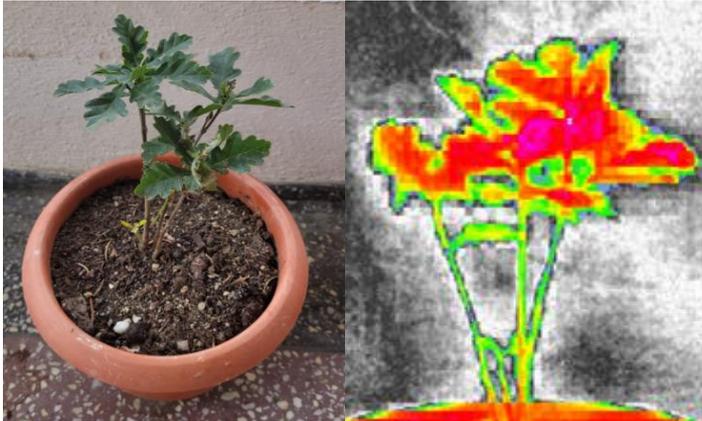


Conclusions and possible errors

Conclusions

H1: The higher the natural habitat the better the resistance to freezing temperatures is.

- **Plants** that lived in **lower altitude** had a **lower number** of exemplars that survived.
- **The bigger** the time spent in the refrigerator **the lower** the **NDVI value**.

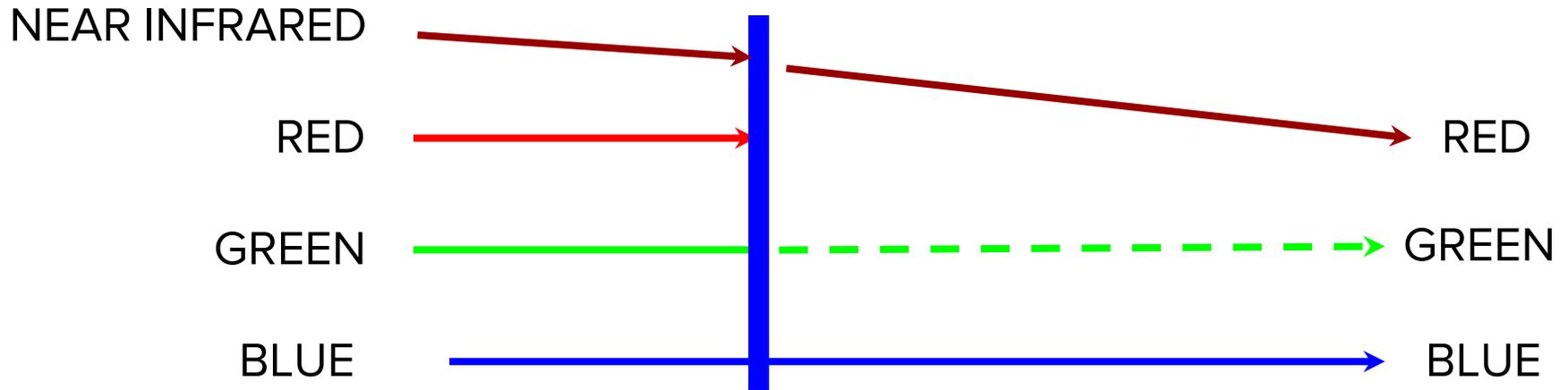


Possible errors

- White spots on the plants in the NDVI processed pictures = ~100% healthy
- The small number of species and exemplars used;
- A +/-30 mins error when the trees were taken out of the cooling room;
- The conditions in which the trees were preserved after taken out;
- The plants could not be taken from the same tree nursery

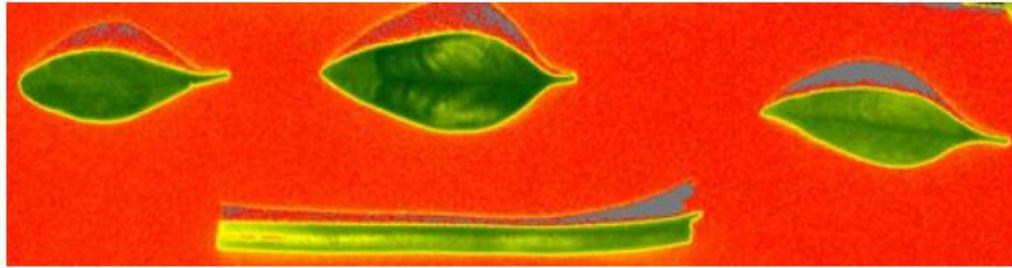
Thank you for your attention

Appendix 1 - Filtering red light with a blue filter



Appendix 2. Blue vs Red Filter

Event38 NGB VIS blue NIR red



MidOpt DB660/850 VIS red NIR blue

