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Introduction

With the advent of climate change and variation of ozone layer, it is expected that more harmful incoming radiation will reach the lower tropospheric regions. This increase in the amount of incoming radiation in the form of Ultraviolet-A (UV/A) and Ultraviolet-B (UV/B) can not only harm human health, but also affect the of seeds and plants vitality (germination success and growth). Investigating the effect of radiation on germination success and seed growth is vital in improving our knowledge in order to better adapt to climate changes.

The BalloonSAT program at Arkansas State University was used as a platform to expose vegetable seeds to lower stratospheric (~86,000 ft.) conditions and investigate the effects of high altitude conditions (Temperature, UV/A UV/B, air pressure, and humidity) on germination success and growth rates of four types of seeds: bean, carrot, corn, and radish.

Experimental Conditions

- The launches consist of a 1200 gram latex weather balloon attached to payload boxes weighing total 12 pounds.
- The payload boxes carry weather instruments that measure/record atmospheric conditions (like temperature, water-vapor (as absolute and relative humidity), pressure and light intensity) as a function of altitude.

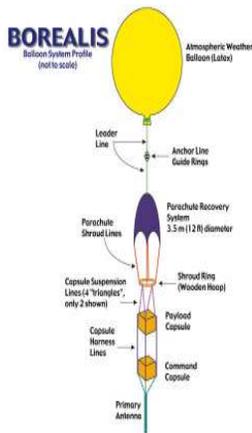


Figure 1: Schematic of a weather balloon showing the arrangement of the balloon, parachute and payload boxes.

Payload boxes :

The seeds were placed in a payload box and launched into the atmosphere using a weather balloon.

Each type of seed included three different groups :

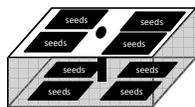
- Control** – seeds stayed on ground in laboratory at room temperature and pressure;
- Group 1** seeds were mounted outside of the box and secured to box via lid exposing seeds to UV, light, pressure, and cold temperatures; and
- Group 2** seeds mounted on the inside of the box which exposed seeds to cold temperatures and low pressures.



a.



b.



c.

Figure 2: Payload box design, with plates containing seed on the outside (a and b) and inside (not shown) of the box. Schematic representation of the plates/groups seed arrangement is shown in figure 2c.

- The payload with the seeds was then launched into space, reaching at altitude of 87, 000 ft (25 km) in the atmosphere.
- After 4 hours of flight time, the weather balloon with the payload was recovered , and seeds were retrieved and taken to the laboratory for planting.
- Seeds were germinated in 2 inches of soil and observed for germination 10 and 20 days after initial planting for seedling success and seedling growth.

Control Experiments

- Several control experiments were performed to mimic the atmospheric conditions that the seeds encountered in the atmosphere.
- The three significant conditions studied were temperature, pressure and radiation. These were done to see what effect they have on germination success (how many seeds germinated) and seed growth (how many seeds continued to grow).

i. Temperature and pressure :

- Vertical temperature measurements indicated that the lowest temperature measured by sensors outside the payload box was at -70°C and 10 Torr
- Several seeds were exposed in the laboratory to -70°C and 10 Torr temperature for an hour.
- The seeds were then planted and germination success rate was recorded.
- The germination of the seeds was not affected. Statistically, the success rate was identical to the germination rate of the controls.

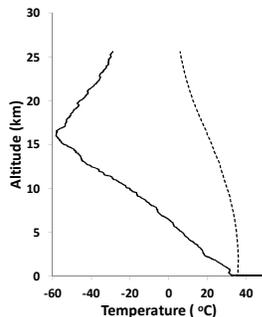


Figure 3: Vertical temperature profile. (The dashed line is the temperature inside the insulated payload box, as a comparison)

ii. Radiation:

- Several seeds were lined up on the outside and inside of payload boxes (figure 2) and exposed to variable UV/A and UV/B in the atmosphere (Figure 4)
- The seeds were then planted and germination success rate was recorded. These experiments are elaborated in the next section.

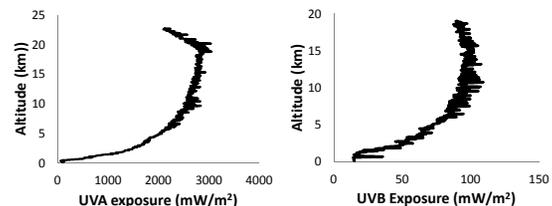


Figure 4: (Left) UVA radiation (320-390 nm) exposure as a function of altitude collected from Vernier sensors. (Right) UVB radiation (290-230 nm) exposure as a function of altitude.

Results and Discussion

Effect of radiation exposure on plant leaf and stem structure

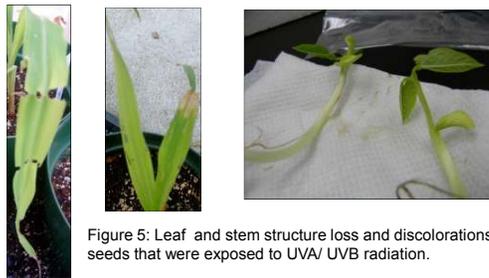


Figure 5: Leaf and stem structure loss and discolorations from seeds that were exposed to UVA/ UVB radiation.

- Seeds exposed to high altitude conditions were found to have lower germination success and stunted growth.
- Seed outside the payload box had the highest statistical difference with the control, due to max UV exposure
- The height of control seedlings to outside seedlings were statistically significant ($p < 0.05$)

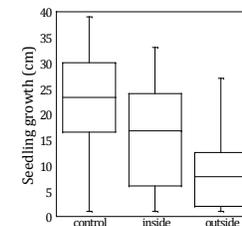
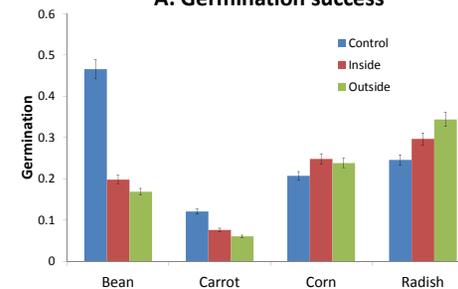


Figure 6: Box plot of garden bean seeds across different conditions.

A. Germination success



B. Seedling growth

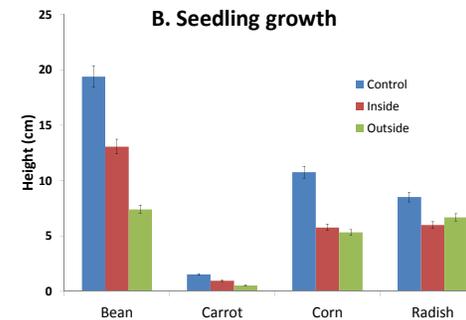


Figure 7: Graph showing A. germination success rates (how many seeds germinated, 1 being all seeds germinated) and B. seedling growth (how many seeds continued to grow) of all seed type investigated.

Summary

- Seeds exposed to radiation (group 1, outside) were found to be statistically different in their germination and growth success compared to control seeds and seeds in group 2 (inside the box)
- Some seeds (carrot) show germination success but low growth, while other show a slight increase in germination and growth with exposure to radiation.
- All seeds though, when exposed to increased amounts of unfiltered UV/A and UV/B radiation, show a significant change, compared to control, in the ability to germinate and lead to seed growth.

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