4-13-2017

How the Space Environment Affects Seed Germination and Growth

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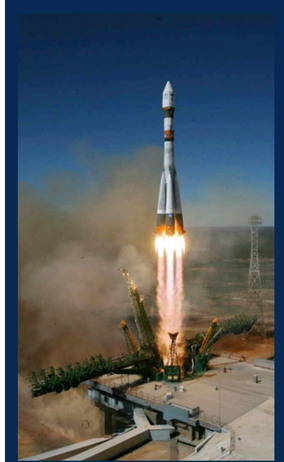
Introduction

Understanding space environment effects on biological organisms like seeds will help plan for long-duration space missions, such as those planned to Mars. The purpose of this research is to evaluate the effects of the real and simulated space environments on seed coats, germination, and growth. Logan High School and Utah State University students compared measurements of the space-exposed, vibration-exposed and radiation-exposed seeds to the ground-based control group to determine physical and biological changes resulting from space flight.



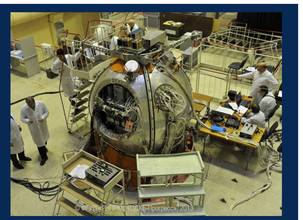
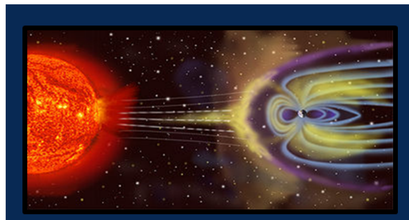


Figure 1. The "space" seeds used in our tests took an LEO/Polar orbit 30-day flight on Russia's BION-M1 Satellite in 2013. The mission studied effects of space on living organisms.

Methods

Alterations to Radish seed performance were hypothesized to be a result of radiation exposure during flight or vibrations during launch and reentry. A paint shaker is used to simulate launch vibrations, and the USU Materials Physics Group Space Survivability Test (SST) chamber, which is designed to mimic low-earth and geosynchronous orbital environments, was used to simulate the space environment. A custom biological exposure test chamber designed by University of Tsukuba students housed the seeds to ensure the vacuum would not kill the seeds and irradiation was consistent and not hindered. This was placed inside the SST for testing.



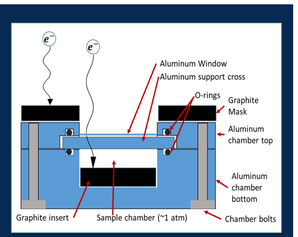


Figure 2. SST Chamber and Biological Test Chamber

Results

Preliminary tests of germination rate of the seeds have identified statistically significant differences in both the space-exposed and vibration-exposed seed coats, as shown in Figure 4.

Examination of the seed coats showed the enhanced production of surface proteins in space-exposed and vibration-exposed seeds. These proteins are presumably related to defense of the embryo from soil pathogens during seed germination.

Images show that space-exposed seeds have the most surface proteins and ground-based seeds have the least. Production of these proteins through the cell wall may weaken the seed surface, allowing for faster uptake of water and subsequent emergence of the plant embryo.

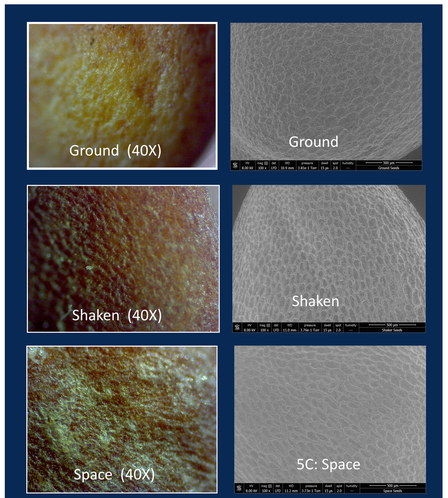
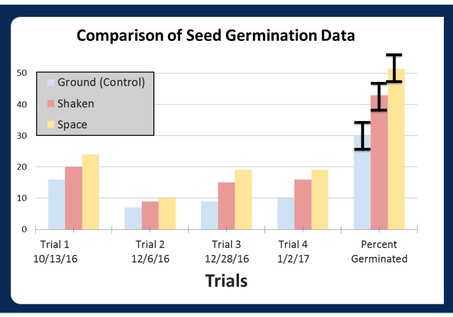


Figure 3. Seed images from light (left) and scanning electron microscopes (right) show changes on seed surfaces in response to disturbances.



Seed Germination Data Oct 2016- Jan 2017

	Trial 1 10/13/16	Trial 2 12/6/16	Trial 3 12/28/16	Trial 4 1/2/17	Total Germinated	Percent Germinated
Ground (Control)	16	7	9	10	42 of 140	30±5 %
Shaken	20	9	15	16	60 of 140	43±5 %
Space	24	10	19	19	72 of 140	51±6 %
Total	60	26	43	45	174 of 420	41±3 %

Figure 4. Space-exposed and vibration-exposed (shaken) seeds showed faster germination rates than ground-based. Space-exposed had the highest germination rates.

Conclusion

- Continued disruption of the protective seed coat during the production of proteins likely leads to micro-fissures in the seed surface. These fissures could hasten water loss and/or degrade the embryo's food source, leading to seed death.
- Germination is different from viability. Not all embryos that germinate are viable. Physiological or genetic damage to embryos during dormancy or seed formation may not manifest until plant growth. This study looked at germination, not viability, for evaluating effects of space travel on long-term storage/use of crop seeds.
- Faster germination does not always produce robust seedlings. Associated changes to enzymatic function and seedling growth should be studied if the seed crop is intended to provide food in locations far from Earth.
- Amazing experience in international and multigenerational collaboration.

Study conducted through collaboration between the USU Materials Physics Group, University of Tsukuba, and Logan High School partially funded through USU STARS! GEAR UP partnership, Japan Student Services Organization (JASSO), and University of Tsukuba. Special thanks to Space Dynamics Lab for supplying seeds.

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