It’s Alive! (Or is it?): Life Science Experiments for High-Altitude Ballooning

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DePaul’s HAB Program

46 flights since March 2009.

- undergraduate summer research (11)
- environmental science senior thesis projects (13)
- atmospheric chemistry course (2)
- Society of Physics Students (4)

- community college faculty workshops (2)

- general education courses (6)

- high school and middle school outreach (8)
K-12 Curriculum

Student investigations of the effects of radiation on microbes and seeds during balloon flights address central ideas in the K-12 curriculum.

NGSS LS3 Heredity: Inheritance and variation of traits

NGSS LS4 Biological evolution: Unity and diversity

- Effects on structure and function.
- Survival and reproduction.
- Natural selection.
- Genetic engineering.
- Environmental factors.
- Evolution.
- Statistical analysis of populations.
Space Microbiology
Gerda Hornok,1 David M. Klaus,2 and Roccol L. Mancinelli2
1German Aerospace Center, Institute of Aerospace Medicine, Radiation Biology Division, 31276 Cologne, Germany; 2BioServe Space Technologies, Division of Aerospace Engineering Sciences, University of Colorado, Boulder, Colorado 80309-0429; and Carl Sagan Center for the Study of Life in the Universe, SETI Institute, 355 N. Whittier Rd., Mountain View, California 94043

Available online at www.sciencedirect.com

Spaceflight effects on consecutive generations of peas grown onboard the Russian segment of the International Space Station
Vladimir N. Sychev1,*, Margarita A. Levinshskkah, Sergey A. Gostimsky3, Gail E. Bingham, Igor G. Podolsky4
1RF SRC—Institute for Biomedical Problems, Russian Academy of Sciences, 794 Krasnodonskaya str., Moscow 117997, Russia
2Genetics and Selection Department, Biology, School, Moscow State University, Vernadsky Gory, MGU, Moscow 119899, Russia
3Space Dynamics Laboratory, Utah State University, 1801 North Research Park Way, Logan, UT 84321-1942, USA

Summary of Biological Spaceflight Experiments with Cells
KATHERINE J. DICKSON
Science Communication Studies, George Washington University, Washington, DC 20052


Mutation effect of high altitude balloon flight on rice and green pepper seeds.
Li Y, Wang P, Han D, Chen F, Deng J

NASA/TM-2009-214768

Roadmaps and Strategies for Crop Research for Bioregenerative Life Support Systems
A Compilation of Findings from NASA's Advanced Life Support Meetings

Advances in Crop Improvement by Space Mutagenesis in China
Lu-xiang Liu1, Hui-jun Guo, Linshu Zhao, Jiayu Gu and Shiron Zhao
1The National Key Facility for Crop Gene Resources and Genetic Improvement, National Center of Crop Space Mutation Breeding, Institute of Crop Science, Chinese Academy of Agricultural Sciences, Email: luxiang@263.net.cn

Achievements and Perspectives of Crop Space Breeding in China

Crop Production for Advanced Life Support Systems – Observations From the Kennedy Space Center Breadboard Project

J. X. Liu, H. J. Guo, L. S. Zhao, J. Wang, J. Y. Gu & S. R. Zhao

GROWTH PROTOCOLS FOR ETIOLATED SOYBEANS GERMINATED WITHIN BRIC-60 CANISTERS UNDER SPACEFLIGHT CONDITIONS
H. G. Levine1, J. A. Shurek2, K. M. Johnson2, E. C. Styjewski2, V. I. Prima2, O. I. Martynenko3, and W. C. Fiascati1
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2Inst. for Molecular Biology and Genetics, National Academy of Sciences, Ukraine

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"FUNDAMENTALS OF SPACE BIOLOGY"
Research on Cells, Animals, and Plants in Space
Gilles-Clement Klaus gramme

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"ADVANCES IN CROP IMPROVEMENT BY SPACE MUTAGENESIS IN CHINA"
Lu-xiang Liu, Hui-jun Guo, Linshu Zhao, Jiayu Gu and Shiron Zhao

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"ACHIEVEMENTS AND PERSPECTIVES OF CROP SPACE BREEDING IN CHINA"
J. X. Liu, H. J. Guo, L. S. Zhao, J. Wang, J. Y. Gu & S. R. Zhao

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"CROP PRODUCTION FOR ADVANCED LIFE SUPPORT SYSTEMS - OBSERVATIONS FROM THE KENNEDY SPACE CENTER BREADBOARD PROJECT"
NASA Kennedy Space Center Biological Sciences Office
Dynmac Corporation, Kennedy Space Center, Florida
W.L. Berry
University of California, Los Angeles, California
Microbe research

- Model organisms for evaluating biological responses.
- Detecting life on other planets.
- Avoid contamination of other planets.
- Origin and spread of life.
Plant seed research

- Plants for long-duration space travel.
- Mental well-being of astronauts.
- Plant breeding.
- Spread of life.
No need to start from scratch!

Existing curricula use

- ultraviolet light from germicidal light sources and the sun to irradiate yeast and other microbes.
- seeds that were irradiated with gamma rays from cobalt-60 sources, which are available from science supply companies
- seeds that were irradiated with cosmic rays during orbital flights.

Examples:
- NASA Radiation Biology Educator Guide
- A Classroom Guide to Yeast Experiments
- Tomatosphere project
- NASA’s Lunar Plant Growth Chamber
Yeast strains

Baking and Brewing Yeast (Saccharomyces cerevisiae)

- HA1 and HA2 strains contain mutations that cause cells to turn red. Back-mutations to the white wild type are easy to spot.

Simple procedures

Pre-flight

- Transfer small sample into sterile water.
- Pack 1-2 ml of yeast suspension into 5 cm square zip lock bags.
- Tape bags to the inside and/or outside of payload containers.
Post-flight

- Spread yeast suspension with sterile swab evenly on sterile media plate.
- Incubate for three days at 30°C. (Can also be done at room temperature if incubator is not available.)
- Determine survival and mutation rates by examining plates visually for colony number, color, size and shape.
ABSTRACT

We often hear theories about how radiation affects humans and DNA. This experiment observes the intensity of cosmic radiation and UVA/UVB rays in space on earth, which is an essential source for humans. By observing the difference in levels of radiation and UVA/UVB rays on Earth to the edge of space, we determine whether exposure is dangerous for humans. According to our findings, the levels of radiation are not extreme enough to cause any negative side effects, however, the UVA/UVB rays could be a contributor to most cancerous growth patterns of yeast and also human DNA.

BACKGROUND

NASA has done multiple studies on the effects of radiation on living organisms. In order to keep astronauts and create healthy living conditions in space, scientists must gather as much information as possible on the probable side effects of radiation exposure. The risks are described in the "NASA Biosatellite Critical Path Roadmap" and include carcinogenesis, acute and late central nervous system risks, chronic and degenerative tissue risks, and acute radiation risks." NASA, in order to protect the astronauts during long duration space travel we need to further understand how the radiation affects the human body. It is not yet possible to avoid the radiation completely, however, studying the results of experiments such as this one can allow NASA to adequately develop protective space suits.

Microbiologists often use yeast as a model organism because yeast. The DNA strands are similar to the yeast, if they're done or can be extrapolated and utilized in studying the effects on human DNA. Radiation studies conducted at Kansas State University, were specifically designed to test the growth of mutations in the yeast composed of yeast strains, created at Kansas State University. The aim was to understand the radiation resistance mechanisms in yeast strains. A radiation-resistant yeast strain with a frequency of 22 mutations per cell per 10^6 cells was analyzed. The radiation dose was 500 rad of gamma radiation, which is a single mutation per cell.

METHOD

In preparation for the flight, we observed the growth of yeast in four different tests. By doing this, we were able to see what the normal growth of yeast and mutant colonies. Yeast turns into a red-pinkish color once it is at its full growth and no longer obtains nutrients from the medium. Mutants within the yeast turn a white color and can continue to grow without the medium. Out of the four tests, the first test and the last (post-flight) were the most successful. The yeast turned into a pink color and showed visible growth as well as the mutant colonies. It appears that the mutation rate did not change in the same way for the mutants in the same tests.

For the flight, we prepared the yeast into tiny bags. We made a total of six bags: two were taped inside the pod; two were taped on the outside of the pod; and the last two were taped and used as controls. We made two bags each because we were aware of the time that the yeast is in the vial was still alive, so we used yeast from the first successful growth and yeast from the vials to be thorough.

As for the collection of data, we use sensors to collect data every six seconds during the duration of the flight. We did this in order to get an abundant amount of data to make our data more precise. Once we returned from the flight, we switched the yeast onto the Petri dishes and inserted them into the incubator at body temperatures (37°C).

RESULTS

We have various results to examine. First, the UVB and UVA sensors showed that the intensity of these rays are exponentially higher than on Earth. The same pattern existed with the radiation exposure. As for the post-flight, we noticed a few strange growths that didn't align with the previous petri dishes. The growth of the pink yeast, which need nutrients to grow turned out far bigger than the white mutations. Usually, the white mutant colonies would appear bigger than the pink colonies as they do not need nutrients to grow. In all the petri dishes, including the control groups, there were significantly more white mutations compared to red yeast growth. This lead us to believe that there was not an impact from the cosmic radiation in space to the normal growth of yeast and that the white mutations might be due to something that had developed in the original strain of yeast. There was a significant difference in the number of mutations in comparison to the control groups. This could be due to the fact that our experiment was only capable of reaching the edge of space rather than deep space.

In addition, the samples that were sent into space on the outside of the box showed no sign of growth whereas which could indicate multiple findings.

PURPOSE

The experiment was designed to observe the effects of radiation on life forms similar to that of humans. The data can be extrapolated in order to further our knowledge on the effects of cosmic radiation on organisms. Due to the fact that we could not bring up a human or animal into space, we used yeast as it closely resembles the human DNA. We wanted to see what would happen in the yeast if brought to space and what negative or altered effects would occur in altering the growth, shape, or color of the yeast. Furthermore, we wanted to compare the radiation differences within the edge of space and Earth. This will allow us to infer what kinds of mutations could be caused by cosmic rays that are not as common on Earth because of the lower levels of radiation and UVA/UVB that we humans experience on a daily basis.

Above every square inch of body, there is 14 and a half pounds of air above the atmosphere. This is the amount of mass that a spacecraft would need to be constructed with in order to protect astronaut from being exposed to the high levels of radiation present in space. This experiment aims to compare the levels of radiation and UVA/UVB recorded on Earth with the data collected during the flight to determine whether the exposure is harmful enough to cause negative side effects.

CONCLUSIONS

The flight, and project in whole, has helped us better understand the impact cosmic radiation and UVA/UVB rays have on life form. While there could have been confounding variables that existed throughout this process such as human error, data collection error, or contamination, the rates of white to red growths on the Petri dishes did not differ significantly from control to the samples that were in space. We conclude that the radiation levels were not high enough at the edge of space to cause any visibly noticeable side effects to the yeast. However, due to the fact that the samples exposed directly to UVA & UVB showed no sign of life at all, it is possible that the levels were high enough to kill the strain.

REFERENCES

Results from our students

- Yeast flown on the outside does not survive.
- Yeast flown on the inside have variable survival rates.
- When survival rates are high mutation rates are low and vice versa.
- Many interesting questions for students to investigate.
Seeds for balloon flights

Garden radish (Raphanus sativus)
- Germinate quickly.
- Allows you to quickly make quantitative measurements (germination rate, root length, etc.).
- Ideal for younger kids.

Wisconsin Fast Plants (Brassica rapa)
- Short life cycle (40 days).
- Allows for multigenerational studies to look for heritable mutations.
- Ideal for high school and beyond.
Results from our students

- Near 100% survival rates
- Seeds exposed to cosmic rays and ultraviolet radiation on the outside have lowest reproductive rates. (Number of flowers and seed pods.)
- Larger variation for every measured trait. (plant height, weight, etc.)
Reproductive rates and phenotypic traits of Brassica plants.

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Simple statistics:
• ANOVA
• Coefficient of variation = standard deviation / mean
Questions?