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# Space Mutagenesis: Cultivating the Cosmos for Next-Generation Crop Innovation

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In the quest for superior crop varieties, pioneering research in space environments has revealed promising avenues for innovation. Exposing seeds to cosmic radiation and microgravity has sparked the emergence of diverse genotypes and phenotypes, stemming from profound cellular and genomic transformations. The genetic polymorphism induced by DNA damage and chromosomal aberrations offers a fertile ground for generating crops endowed with modified genetic repertoires. These changes can be used to produce next-generation crop varieties capable of surviving diverse environmental conditions.

## But why space breeding required?

The answer lies in their remarkable versatility and importance to life as we know it. Plants not only provide sustenance but also play a crucial role in generating oxygen, recycling carbon dioxide and maintaining the delicate balance of ecosystems. In the harsh environment of space, where resources are limited and every breath is precious, harnessing the power of plants becomes imperative for our survival.

## What happens when seed sent to space?

**Microgravity Effects:** In microgravity, seeds may germinate differently compared to those on Earth. The absence of gravity alters the orientation of plant growth, affecting root development and overall plant morphology.

**Cosmic Radiation:** Seeds in space are exposed to cosmic radiation, which can induce DNA damage and chromosomal aberrations. This radiation can lead to genetic mutations, potentially resulting in new traits or genetic diversity in the resulting plants.

**Gene Expression Changes:** Space conditions can influence gene expression patterns in seeds and plants. Certain genes related to stress responses, growth and development may be upregulated or downregulated in response to the space environment.

**Altered Metabolism:** Space-grown plants may exhibit changes in metabolic pathways and biochemical processes compared to their terrestrial counterparts. These metabolic alterations could affect plant growth, nutrient uptake and the production of secondary metabolites.

**Adaptation to Stress:** Seeds exposed to space conditions may develop adaptations to cope with the stressors present in that environment. This could potentially result in the generation of plants with improved stress tolerance and resilience to harsh environmental conditions.

## Space-breeding platform

The international space station is well-known for its role in space biology research. Fig 1. Shows the space breeding platform. When the plant seeds can be exposed to microgravity and cosmic radiation in space and brought back to the earth and sow for germination. The phenotypic and genotypic parameters can be measured to find the superior trait. The superior trait can be subjected to next-generation sequencing to find potential gene associated with the space environment. Once the gene will be identified, it can be used for molecular breeding to generate crops with the superior trait. The seeds can also be germinated in the space environment itself and grown plants can be brought back to the earth to check for chromosomal aberration, changes in cell shape and size and alteration in the cell division.

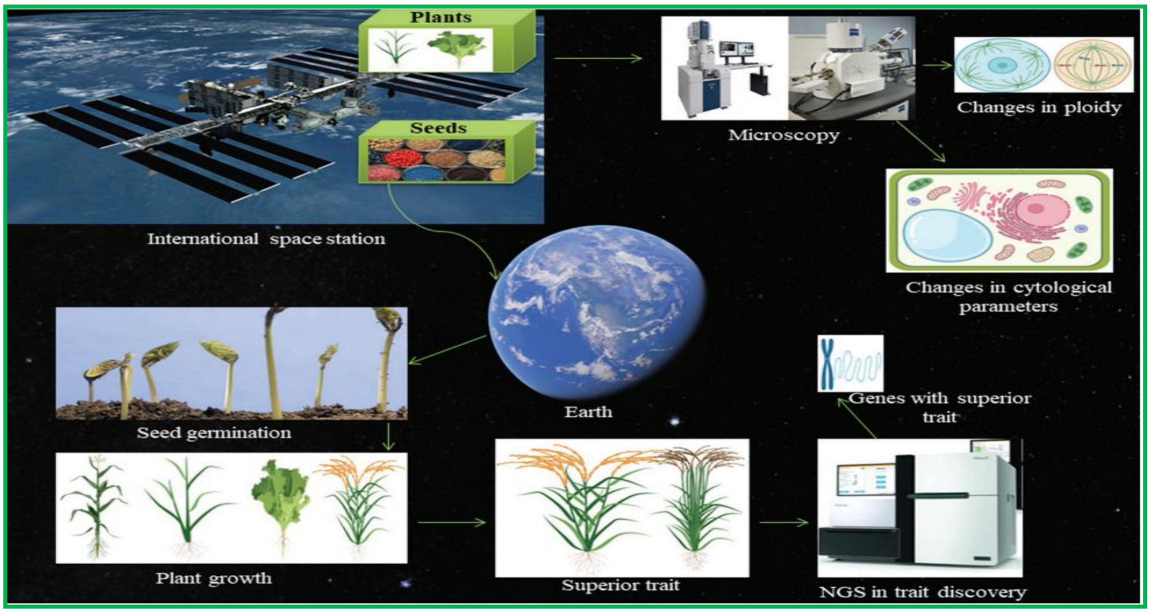


**Fig 1.** Schematic presentation of the space-breeding platform (https://doi.org/10.3389/fpls.2021.771985)

## Development of Mutant Varieties through Space Breeding

Since 1987, China has been actively involved in space breeding missions, resulting in around 200 plant varieties influenced by space radiation. Using high-altitude balloons, they conduct experiments with seeds in space. The first space breeding satellite, Shiijian-8, launched in 2006 with 2,000 plant accessions from 133 species (Zhihao, 2020). Seed germination of cotton, maize, sunflower, cucumber, tomato, wheat, barley and soybean noticeably increased after space flight but rice, millet, pea, sweet pepper, tobacco and lettuce failed to show any differences .The seed germination potential of eggplant, radish, watermelon and sorghum was reduced, whereas that of wheat, barley and triticale was significantly higher than that of ground control and gamma-irradiated seeds .The activities of both esterase and peroxidase enzymes in these species were also increased during flight. At least 66 mutant crop varieties, including lucerne, cotton, pepper, sesame, rapeseed, rice, tomato and wheat, have been released in China through space breeding programmes (Liu *et al*., 2009).

## Challenges in space mutation

From engineering specialized growth chambers to navigating the complexities of genetic modification, scientists face formidable hurdles on the path to cultivating life beyond Earth. Yet, with each experiment, each breakthrough, they inch closer to realizing humanity's dream of becoming a multiplanetary species.

The journey of space breeding is one of collaboration and innovation, drawing upon the expertise of botanists, engineers and astronauts alike. It's a testament to humanity's insatiable curiosity and our capacity to adapt and thrive in even the most inhospitable environments.

## Conclusion and future prospects

Space mutation research offers a fascinating avenue for advancing crop breeding and genetic innovation. The unique environment of space, characterized by microgravity and cosmic radiation, triggers genetic variations in seeds that can lead to the development of novel crop varieties with improved traits. However, understand the effects of cosmic radiation on its genome, scientists need to sequence its DNA and RNA. They should also study how proteins and metabolites change. Identifying genetic markers through SNP analysis and genome-wide studies can help apply findings to other crops. Simulation models can predict how mutations affect different crops so that it ultimately contributing to sustainable agriculture and global food security.

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