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Technology of Space Mutation Breeding in Crop Improvement

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SUMMARY

Induced mutations play a great role in creation of genetic variability and as a tool in molecular biology to study various genes. Space mutation breeding is a technology in which seeds are sent to space for inducing mutations due to genomic, chromosomal, cellular, subcellular and biochemical changes caused by unique cosmic radiation and ultra-vacuum conditions, which on bringing back to ground are tested for desired superior traits to use in further breeding programs.

INTRODUCTION

As per World Economic Forum, the world must feed two billion more people by 2050 and the demand for food is estimated to be 56% greater than it was in 2010. In past 50 years of the 21st century, genetic improvement has greatly enhanced the yields but has caused a reduction in the genetic variability due to extensive breeding of major crops. Thus, narrowing the possibilities for further genetic improvement (Jacob *et al*., 2017). Mutations, which are sudden heritable changes in the DNA of an organism not produced due to segregation or recombination provides a low-cost means to generate novel variation. The rate of spontaneous mutations which occur naturally are very low ranging between 10^{-4} – 10^{-6} in eukaryotes. Whereas, mutations produced by various physical and chemical agents are called as induced mutations. There is no difference in the nature of mutants created either by spontaneous or induced mutations. Mutation induction has proven flexible, workable, and ready to use on any crop (Shu, 2009, Liu *et al*., 2009). Mutation breeding is the purposeful application of mutations in plant breeding and has advantage of correcting a defect in an otherwise elite cultivar, without losing its agronomic and quality characteristics (Pathirana, 2011).

During the last decade, induced mutations are also gaining importance as a tool in molecular biology to identify, isolate and study the structure and function of various genes (Shu, 2009). Knowledge of genes for various yield and quality traits are important for plant breeders to use them in breeding programs. Thus, induced mutations with the potential of increasing yield potential and stability either directly or indirectly can contribute to increase in global food production.

Space mutation breeding

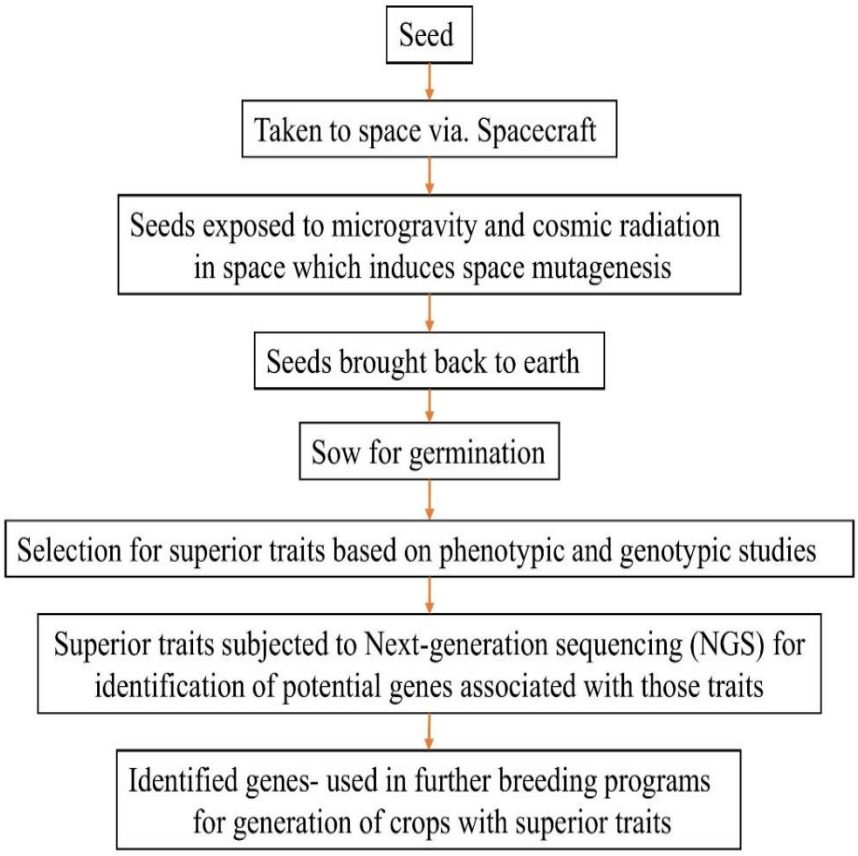
Space breeding also known as Aviation breeding or Spaceflight mutation breeding is a breeding technology in which crop seeds are carried by recoverable satellite into space where the unique environmental conditions of space such as the cosmic radiation (high-energy ion radiation), microgravity, space-magnetic field and ultra-vacuum induce mutations which on return to the ground may be beneficial for generation of crop varieties with diverse genotypes and phenotypes arising from different genomic, chromosomal, cellular, subcellular and biochemical changes (Mohanta *et al*., 2021). DNA damage and chromosomal aberrations caused by combined effects of cosmic radiation and microgravity appear to be the main causes of genetic changes in seeds from space flights. For the first time in 1987, China worked on this technology by using high-altitude balloons to carry ‘Dragon pepper 2’ variety of sweet pepper, which on recovery to ground after space mutations helped to obtain a new variety with an increase of 250g per fruit and thus increasing the yield by 120% (Jiang *et al*., 2020). After this success, this technology was applied by China for improvement of rice, cotton, wheat and other crops using recoverable satellites, Shenzhou spacecrafts and high-altitude balloons. The occurrence of mutations in seeds or seedlings in space may be occurring in order to complete a full life cycle by having either direct or indirect effects on the various metabolic activities and plant growth.

After space flight, seed germination potential, germination index, seedling height and seedling vigor index were significantly higher than those of ground controls and Gamma-ray irradiated seed in wheat, barley and triticale (Liu *et al*., 2004a). The sensitivity to space flight differs between plant species and between varieties of the same species. Space induced mutations help in obtaining rare mutants that may bring major breakthroughs in economic characters of crops like higher yield potential, better quality, resistance to biotic stresses and better

adaptation to climate change, the source for which may not be available in the germplasm present on the earth surface.

Procedure of space breeding

Select seeds of good varieties with large planting area and strong adaptability. Carry the seeds via spacecraft to space beyond the ozone layer where due to loss in gravity, magnetic field and hyper-vacuum conditions leads to receiving of large amounts of cosmic radiation causing mutations (Bagshaw, 2008; Zhang *et al*., 2014, Eichinger *et al*., 2020). The seeds are brought back to ground and sown for germination and observed phenotypically and genotypically for occurrence of any desirable traits due to mutations. The superior traits are then subjected to Next-generation sequencing (NGS) for identification of potential genes associated with them, which can be used in further breeding programs for generation of crops with superior traits (Mohanta *et al*., 2021).



To resolve the food problem, China has been carrying out space breeding for 34 years since 1987 with a recoverable satellite and has produced about 200 new types of mutated plants that have been approved for cultivation. (People's Daily Online, 2021). China has reported its first batch of rice harvest that it is calling “space rice” or “rice from heaven” (Anqi, 2021) that had made a trip round to the moon as part of China’s Chang’e-5 mission.

Bottleneck issues for breeding plants in space (Zhang, 2020)

- High cost
- Limited accessibility
- Low rate of success, as all seeds sent into space do not generate mutations and only seeds that help farmers can be considered successful.

With more focus on seed selection and development of prosperous commercial spaceflight industry, it will provide more opportunities to launch, reducing the cost of space travel and will make the technology of space breeding as a more accessible and mainstream technology in plant breeding.

CONCLUSIONS

Space breeding as a potential technology to create genetic variability and as a tool in molecular biology to improve the breeding material must be popularized among countries along with an effort to reduce the cost and making it more accessible to be taken up as a mainstream technology in plant breeding.

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