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Agriculture in Space

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Introduction

Throughout history, agriculture has constantly evolved, playing a vital role in human evolution, shaping societies, economies and cultures by adapting to changing environmental and technological scenarios (Harris and Fuller, 2014). In recent years climate change has emerged as a major problem for flora and fauna. If ignored it will take a dire form in the coming centuries and eventually flora and fauna will be shifted to other celestial bodies like Moon, Mars etc. Which species on earth do you think is the most dangerous to human civilization? Yes, it is human beings themselves who are the biggest threat to flora and fauna, possibly the most problematic species on earth. Why am I saying this? As we all know we are exploiting flora and fauna for our personal gain. Earth is a bowl of resources. Due to overexploitation and industrial revolution, problems like land degradation and degradation of soil quality, loss of arable land, water pollution and depletion, monoculture and loss of biodiversity, chemical dependency, impact of climate change, land fragmentation are increasing and if these are not taken care of, in the coming centuries the environment will not be suitable for humans, animals or plants and we will need interplanetary migration. In the last few years, the exploitation of resources has reached its peak and already we are seeing climate change, melting of glaciers, increase in greenhouse gases and many other problems. We cannot deal with these problems overnight or in the coming decades. Keeping these things in mind, many space agencies like NASA, ISRO, ESA, Roscosmos, SpaceX etc. and many scientists around the world are looking at neighbouring celestial bodies as an alternative to Earth. The idea of colonization in space will depend heavily on our daily metabolic needs like oxygen, water, food and industrialization etc. The idea of agriculture in space has long been fascinating and intriguing to scientists and space enthusiasts. Recent years have seen remarkable progress in this field, with gardening experiments conducted on the International Space Station (ISS), and plans to extract minerals from the surface of the Moon and Mars for research. In this article, we will explore these exciting discoveries in space agriculture and mineral extraction, focusing on their potential implications for future space exploration and life on earth (Wright, 2022).

Agriculture's crucial Role

Central to this approach is the development of sustainable agriculture beyond Earth. Agriculture is not just about growing crops; it is about sustaining life and human existence. On other planets, where no natural ecosystems exist, agriculture becomes the cornerstone of survival and self-sufficiency. Agriculture is essential to sustain life on any celestial body, whether it is the Moon, Mars, any planet, or any long-duration space mission (Anonymous, 2013). Recent experiments conducted on the International Space Station have shown that plants can thrive

in the microgravity environment of space, providing fresh food for astronauts and future colonists. Vegetable experiments conducted on the International Space Station are a prime example of this. By the 1950s, the US Air Force, in collaboration with NASA, began developing algae-based life support systems for potential astronauts.

In the 1970s and 1980s, the Soviet Union went even further by delivering crops such as onions and flax to its first space stations, demonstrating that living plants could grow in microgravity. Also, they built isolated, closed habitats, like Tsiolkovsky's greenhouses on Earth, to explore how plants could provide food and dispose of human waste without any external assistance. Astronauts have successfully grown crops such as lettuce, radishes, kale and zinnia, demonstrating the possibility of sustainable food production in space. Gioia Massa, an astrobotanist at NASA Kennedy Space Center, has been successfully conducting a space gardening experiment - the Vegetable Production System - which has been growing crops from seeds using an advanced plant growth chamber using RGB LED lights to stimulate plant growth on the International Space Station since 2014.

The benefits of space agriculture are numerous. Gardening can give astronauts or people living there a sense of connection to the natural world. In addition, plants help purify the air by removing carbon dioxide and producing oxygen, which is extremely important for life support systems outside the Earth. Recent experiments have broadened the scope of space gardening. For example, the "Arabidopsis" experiment involved cultivating a small flowering plant from the mustard family on the International Space Station. The purpose of this experiment was to understand how microgravity affects gene expression and plant growth, which provided information about how to optimize crops for cultivation in space. NASA's Advanced Plant Habitat (APH) is another important development. The APH is a fully automated plant chamber, allowing precise control of temperature, humidity, and carbon dioxide levels. This technology enables scientists to study plant growth in space with unparalleled accuracy and efficiency (Monje et al., 2003).

Mineral Extraction from the Moon and Mars

Space agencies are eyeing the Moon and Mars for their mineral resources. The Moon is known to have vast deposits of valuable minerals, including water ice, helium-3, and rare earth elements. Water ice, when converted into water and split into hydrogen and oxygen, can be used as a life preserver and rocket fuel. Helium-3 is a potential fuel for future fusion reactors, while rare earth elements are essential for electronics and technology (Anonymous, 2015).

Mining operations on the lunar surface are in the planning stage, and the Artemis program aims to establish a permanent presence on the Moon by the late 2020s. Innovative technologies such as autonomous robots will be essential for efficient mining and processing. There are also possibilities for mineral extraction on Mars. The Red Planet is believed to contain a variety of minerals, including iron, magnesium and sulphur. In-situ resource utilization (ISRU) is extremely important for future Mars missions, where colonists could generate resources needed for life and fuel production by extracting and processing these minerals.

Challenges in Extraterrestrial Agriculture

The challenges of growing crops on planets like Mars or the Moon are daunting. Harsh conditions such as extreme temperatures, water scarcity, and low-gravity environments pose major obstacles. Traditional agricultural practices are outdated, and new agricultural techniques adapted to extraterrestrial conditions are needed.

Yet, these challenges also present opportunities for scientific innovation. Controlled atmosphere systems, hydroponics, aeroponics, and bio-regenerative life support systems are emerging as viable solutions. These advanced methods not only sustain plant growth; they also create closed-loop ecosystems, recycle waste, and produce essential resources such as oxygen. The

pursuit of sustainable agriculture on other planets involves a multifaceted approach. Research on plant genetics, the development of resilient crop varieties, and understanding how plants respond to low gravity and increased radiation are crucial. Creating artificial soil structures and optimizing resources are paramount to successful extraterrestrial agriculture.

In addition, innovations in energy production such as solar or renewable sources will power these agricultural systems. The integration of robotics and AI in agricultural processes becomes imperative, which will compensate for the lack of human labour in extreme conditions.

The idea of colonizing other planets is not a distant dream but a necessity for humanity's survival. Agriculture serves as a critical component in this ambitious venture, which not only promotes sustenance but also lays the foundation for successful interplanetary civilizations. As we move forward on this path, collaboration between scientists, engineers, agriculturists, and space agencies becomes crucial. The collective effort to advance sustainable agricultural systems for space colonization will not only benefit space exploration but also address food security challenges on Earth.

Conclusion

The shift towards interplanetary habitation is not just a leap in scientific achievement, but a proactive step towards securing humanity's future. Agriculture, the cornerstone of civilisation, is a step towards unlocking the potential of interplanetary settlements, ensuring the continuation of life beyond the boundaries of our mother planet.

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