Assessing plant responses to gravity may be the key to unlocking Martian agriculture

For humans to become a multi-planetary species, we must first overcome many technological and biological hurdles. The closest two potential sites for extraterrestrial colonization (apart from low Earth orbit) are the Moon and Mars. The Moon exhibits approximately ? of the gravity we experience on Earth and Mars about 1/4. Plants utilize gravity as a guide for organ growth, a process known as gravitropism. This mechanism directs the roots downward into the soil to anchor the plant and allow for the uptake of water and nutrients, while also guiding the shoots upward to access light for photosynthesis, allow the exchange gases with the air, and to promote efficient reproduction. Thus, if humankind is to create sustainable extra-terrestrial communities, then our species will have to select traits in our companion organisms (plants) that allow them to adapt to these novel alterations in the gravitational field.

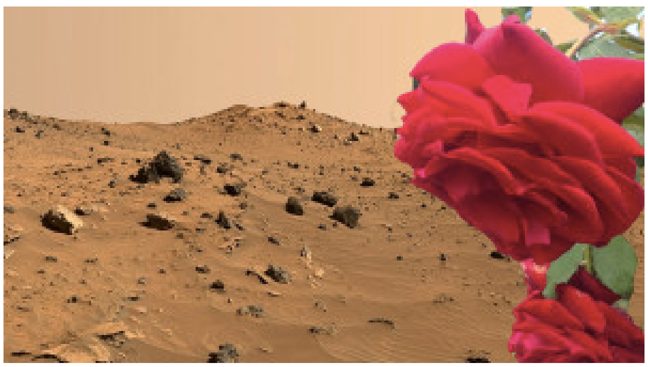

Fig. 1. SpaceX founder and CEO Elon Musk has stated he plans to grow a rose on Mars. Image above is an artistic interpretation of what a Prince William Rose may look like on the martian surface.

The plant *Arabidopsis thaliana* (Mouse Ear cress) represents a powerful tool to begin to define these traits. Aranbidopsis was the first higher organism to have its entire genome sequenced and is now widely regarded as the model plant for genetics research. Like all plants, Arabidopsis changes its growth patterns in response to a variety of environmental stimuli. The easiest way to observe plant response to gravity is by observing root and shoot growth after the plants have been rotated 90 degrees so they are parallel with the ground. Under these circumstances, the root redirects growth to reorient downwards whereas the shoot bends upwards. Time-lapse photography performed using cameras, microscopes, scanners, infra-red camera's, and even mobile phones can all be used to observe the dynamics of this reorientation and by measuring the speed and directionality of the response, a wealth of insight into how the plant is sensing and responding can be obtained.

Plants grown from different size seeds or that are different ages all have a varying sensitivity to gravity and respond at different rates. In fact, even growing plants in differing environments (e.g., different temperatures or varying light quality) can change their sensitivity to a host of stimuli. As there are so many factors that can alter the plant's sensitivity to gravity, most current research is performed with the plants grown in a constant environment and at a single stage of development. Defining the interaction of these environmental factors on gravity response is a major challenge in current plant research.

The creation of higher throughput tools can potentially greatly accelerate the investigation of these effects of environmental or genetic variations on plant sensitivity to gravity. Recent advances in technology have led to a dramatic reduction in the cost of the mechanical components required to automate scanning cameras across multiple samples and allow control of the quality and direction of light during plant growth. However, the automation of the movement of time-lapse photography systems is not without difficulties and the recent establishment of the ultra low cost educational microcomputer market now makes it economically feasible to have a computer attached to every camera as an alternative method to increase the efficiency of time-lapse image acquisition during plant root tip reorientation. This coupled with the recent availability of cloud based image storage and analyses are now making these research methods available to not only specialist researchers but also to the general public, potentially empowering a new era of citizen science.

With these advances in high throughput technologies we can discover which plant genes and environmental factors are most important for plant survival under the conditions we will encounter during spaceflight or in extraterrestrial colonies, such as altered gravity. With this information, we can then rationally engineer plants that are adapted to, for example, low gravity, and so could provide ecosystem services and food to astronauts. This work will bring us one giant leap closer to deep space exploration and colonizing Mars and beyond.

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