Plants on Mars: On the Next Mission and in the Long Term Future

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Abstract

Current research on greenhouses for Mars is centered on their use as life support for human missions and should be expanded to include systems for near term landers as well as experiments in the long term establishment of natural ecosystems on Mars. The deployment of a simple plant growth module, containing just one plant, in near term robotic missions to Mars would be an important way to test systems and materials for use in larger greenhouses. In addition, a near term plant growth module would focus interest on biological life support and generate interest in the public and within NASA. In the long term, biological life support must leave the greenhouse and spread over the entire planet. In parallel with the development of crop plants, research into plant growth under martian conditions should begin to look at the creation of natural alpine-like ecosystems on Mars as part of an overall terraforming program.

Introduction

Mars is a target for human exploration because of its interesting past history of water activity and possibly life. All the elements needed to support life are present in the martian environment, albeit at low levels. For example the martian atmosphere contains carbon dioxide, water vapor, and nitrogen. These resources can be used to produce rocket fuel (Ash et al., 1978; Clark, 1979) as well as life support consumables (Clark, 1979; Meyer, 1981; Meyer and McKay, 1989; McKay et al., 1993). Thus, one significant attraction of Mars for human exploration is the prospect that the air and water needed for a human crew can be produced on Mars rather than transported from Earth. This logic can extend to food as well. Considerable thought has gone into designs for food production in greenhouses for martian applications (e.g., Boston, 1981; 1985; Schwartzkopf and Mancinelli, 1991; Andre and Massimino, 1992).

Most of the research focus has, understandably, been on greenhouses containing crop plants to support a near term human base consisting of up to a dozen or so astronauts. The greenhouse would provide food and oxygen for the human habitat we well as providing a waste recycling function (Boston, 1985; MacElroy et al., 1992; McKay et al., 1993).

However it is also important to consider plant growth applications on Mars that are come before and after human-focused greenhouse. This paper considers near term experiments that could be conducted on a Mars lander as well as long term experiments in natural ecosynthesis on Mars.

Plants on the Next Mission to Mars

Logically, the first plant growth module on Mars should not be a full scale greenhouse design to support a human crew. Instead it should be a technology testbed in which one or a few plants are grown in a system that tests possible greenhouse materials and the utilization of martian resources.

A small plant growth module on a near term Mars lander would serve many important functions. By using martian soil as a plant growth medium it would test for toxic components and indicate the level of nutrients that must be added to the soil to optimize plant growth. A plant growth module could demonstrate the use of martian atmospheric gases for a greenhouse working in combination with systems being built to extract carbon dioxide, oxygen and water from the martian atmosphere.

A growth module on Mars could also test materials under consideration for martian greenhouses. One of the important design questions for martian greenhouse is the covering material. Ideally one the greenhouse would be covered with a material that allowed for maximal light transmission for plant growth, protected against ultraviolet light without being destroyed by it, and was strong enough to support a considerable pressure difference against the low ambient martian pressure (0.6 KPa). Currently such a material does not exist and if one is not developed martian greenhouses may well have to be located underground with the attendant costs of providing for artificial lighting.

As candidate materials are developed it would be important to test them in small scale systems before incorporating them in full greenhouse designs. From a technical point of view this alone would justify a small scale experiment on a near term Mars lander.

Simple plant growth modules on near term landers could provide a basis for designs of larger test systems that could be deployed robotically in advance of human missions. Such large scale systems could be the center piece of what is now called the "robotic outpost" phase of Mars exploration. This phase is imagined to be the segue between the current small lander missions and a human base.

Developing a flight program for plant growth on Mars would have technical as well as programmatic benefits. Programmatically, the development of a plant growth module would motivate an early accommodation between the current planetary protection policy - which prevents sending Earth life to Mars - and the need to grow plants and send humans to Mars. In addition demonstrated growth in martian soil would help alleviate back contamination issues. Perhaps most importantly from a programmatic point of view, a flight program would ensure continuity and visibility for biological based life support systems on Mars.

Plants in the Long Term Future on Mars

The cooperative agreement notice (CAN) that initiated NASA's program of Astrobiology included among its six key questions "What is the potential for survival and biological evolution beyond the planet of origin?" Evolution is a property not of individual organisms or even individual species, but of ecosystems over many generations. In our solar system the only possible candidate for testing biological evolution beyond the planet of origin is Mars. The restoration of Mars to a biological state, known as terraforming, or more appropriately ecosynthesis, is an application of plant based life support to the planet Mars as a whole (Averner and MacElroy, 1976; McKay, 1982; McKay et al., 1991).

The first step in ecosynthesis on Mars is warming the planet and is primarily an engineering problem (McKay et al., 1991). However, as the martian environmental conditions become more clement plants from Earth could be introduced on Mars. The first plants grown naturally on Mars are likely to be hardy polar and alpine varieties. Eventually, as the martian biosphere became more Earth-like other temperate plants would be introduced. The temporal succession of ecosystems on Mars might be similar to the spatial succession observed on the slopes of mountain (Graham, 2000). An important difference between natural ecosystems and greenhouse ecosystems is that in natural ecosystems crop plants are not the focus.

Although the introduction of plants into the natural martian environment is still many years away it would be useful to begin basic research in plant response to martian conditions for two reasons. First, the plants that would be under study - arctic and alpine - are likely to contain genes that assist in their survival at low temperature, low pressure, low water availability and other extremes. These capabilities might be usefully transplanted into crop plants for use in martian greenhouses and may be useful on Earth as well. For example some types of algae can grow under pure carbon dioxide (Seckbach et al., 1970). The second reason to begin testing of alpine and arctic plants is to allow for long term generational studies that would be key to understanding ecosystem evolution on a terraformed Mars.

Conclusion

In parallel with current research on greenhouses designed for human bases on Mars it would be useful to begin work directed toward placing a plant growth module on a near term Mars lander. In addition, studies of the ability of non-crop plants to survive in martian conditions could contribute to the development of hardy strains of crop plants optimized for use on Mars. Studies of plant growth on Mars are a continuum; from near term single plant modules, to greenhouses for human life support, to the synthesis of natural ecosystems on Mars.

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