Gardening of the Future—From Outer to Urban Space

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Moving from freeze-dried ice cream to fresh-picked salad greens

Astronauts grow weary of packaged food on space missions and crave more variety and freshness. Food has a powerful impact on morale, according to postmission surveys of astronauts. Photograph: NASA.

Astronauts in space crave the taste and texture of fresh food. Scientists are testing technologies that someday could allow space travelers to grow and pick greens and other nutritious foods on spaceships, in lunar villages, and during missions to Mars. Decades of space-farming research have also helped jumpstart a new kind of high-tech indoor agriculture on Earth, influencing how cities of the future could grow their own produce.

A long-term diet of packaged space food causes menu fatigue among crews already struggling to maintain weight and strength in the low-gravity environment of the International Space Station (ISS). Food is one of the important factors (if not the most important) for morale, according to postmission surveys of astronauts. That is one reason why growing food in space is an essential—but still somewhat distant—goal for NASA.

ISS astronauts receive infrequent fresh food packages from Earth, but those supplies must be scarfed down quickly before spoilage, because refrigerator space is so precious. Then astronauts must wait months for the next shipment. "More fresh food would support crew health and performance with nutrients that they may not get with packaged food," says Grace Douglas, a food technology scientist at NASA's Johnson Space Center. "It could provide psychological benefits to the crew, because they can grow something green that connects them to Earth. Having something fresh to eat allows you to customize your food a bit," reducing the monotony of space food.

A new space race is ramping up, and lunar fever is infecting more nations than ever before. NASA plans to land astronauts on the moon in 2024 and build research stations there. China aims to have an inhabited research station near the moon's south pole within about a decade. Russia has announced plans to land cosmonauts on the moon in 2031 and to begin constructing a lunar base in 2034. The European Space Agency wants to build a moon village on the lunar surface. Billionaires Jeff Bezos and Elon Musk aim to launch ambitious space travel enterprises.

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Lunar outposts will test methods of growing food beyond Earth's orbit. To photosynthesize and develop, plants need light, which is timed differently in space, if it is available at all. Lunar days and nights are 2 weeks long, so colonists would use powerful electric lighting to cultivate crops.

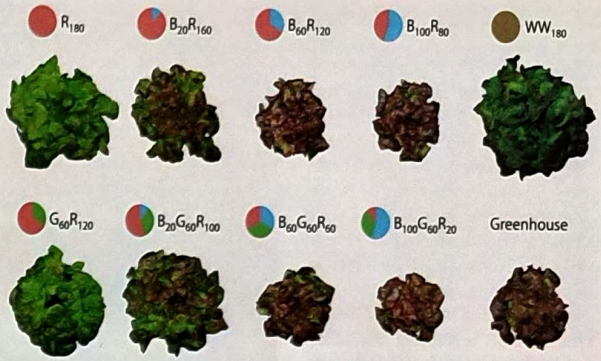
About 150 years ago, botanists showed that plants can grow under artificial light using carbon arc lamps. Flowering was faster under constant light for the majority of almost 100 plant species, including vegetables, grains, weed species, herbs, and garden ornamentals.

In the 1970s, however, NASA-funded plant scientists found that available lighting technologies were too hot and required too much energy for practical use in space. But in 1990, that limitation was upended by researchers at the University of Wisconsin. They discovered that plant growth and development actually flourished under cooler red and blue wavelengths of light-emitting diodes (LEDs), originally used in calculator displays. LEDs are made of layered semiconductor materials that convert electricity directly into light particles, or photons. LEDs are more energy efficient, last longer, and produce much less surface heat than previous generations of lamps.

Over the past decade, scientists have experimented with various new LED recipes for farming on Earth, blending ingredients that include the number of hours illuminated, the intensity of released photons, and the timing of color wavelengths—typically, red, blue, and green. Each LED ingredient can be precisely tuned to each cultivar and stage of life.

LED recipes can alter how rapidly plants grow, when they flower, how they look and taste, how long they last on store shelves, and their levels of vitamins and antioxidants. Even small changes in LED colors can make lettuce look redder or greener, make it taste spicier or milder, or help it grow fuller.

There are different trade-offs in LED recipes. Consumers may prefer certain colors—redder leaves, for instance—in lettuce, but those colors come with disadvantages. "When you get some of the increase in pigmentation or coloration, you also tend to get more bitterness—the compounds that cause that bitter taste," says Erik Runkle, a plant scientist at Michigan State University.



Even modest changes in LED wavelengths can turn lettuce redder or greener, make it taste spicier or milder, help it grow fuller or more compact, and change other characteristics. A Michigan State University team studied the redleaf lettuce variety Rouxi under various LED colors and light intensities measured in micromoles (µmol) per second. The control LED recipe (top row, middle) of 120 µmol red and 60 µmol blue for Rouxi created low yields, small compact leaves, and dark red coloration. Image: Qingwu Meng and Erik Runkle/ Michigan State University.

Now, dozens of major controlled-environment enterprises around the world use LEDs exclusively for growing plants, no sunlight needed. A number of large US companies—Plenty, in San Francisco, and Bowery, in New York, for instance—are raising funds from technology investors to expand their LED plant-growing operations.

On a typical sunless farm, hydroponic (grown without soil) plants are stacked on vertical platforms, receiving timed doses of LED light and recirculating water and nutrients. Sensors and algorithms autonomously manage the planting systems. Some companies use robotics and artificial intelligence to bolster energy efficiency and manage production costs. An increasing number of grocery stores and restaurants offer locally harvested greens and other vegetables grown year-round under electric lights in windowless rehabbed warehouses and shipping containers, adapting techniques originally tested for space farming.

"This kind of agriculture will never feed the world," says Runkle, "It shouldn't be thought of as a way to solve food problems. But it could produce high-quality, high-value greens and other plants year-round." Sunless agriculture could slash some traditional farm-to-market supply chains that extend hundreds or thousands of miles, cutting truck emissions.

In the mid-2000s, NASA cut academic funding for space agriculture, but the agency's research centers continued to work on it. The US Department of Agriculture and the National Science Foundation took up the slack, supporting university research in LED development that has advanced the global horticulture industry.

Early space agriculture research paved the way for advanced indoor farming on Earth, which, in turn, is inspiring plant scientists to adapt LED technologies for spacecraft. "People are finding out really amazing things