Food Production on Earth and Beyond!

LEVEL:  Grade 3-6  
TIME:  6 sessions of 45 min  
PURPOSE:  Students will learn about different methods of food production on Earth and in space.  
STANDARDS ADDRESSED:  AZ College & Career Ready Standards – Reading Informational Text, Writing, Speaking and Listening, Literacy in Science and Technology.

MATERIALS
Online Articles, Video, & Worksheet (URLs provided at end of lesson):
• Growing Plants and Vegetables in a Space Garden
• Lada greenhouse information sheet
• Veggie Will Expand Food Production on Space Station
• This Land is Your Land
• NASA Astronauts Eat First Space-Grown Veggies
• Venn Diagram Graphic

VOCABULARY
Hydroponics: The process of growing plants in sand, gravel, or liquid, with added nutrients but without soil.
Aquaponics: A system of aquaculture in which the waste produced by farmed fish or other aquatic animals supplies nutrients for plants grown hydroponically, which in turn purify the water.
Roof top farming: A garden on the roof of a building.
Conventional farming: To cultivate, breed, or raise plants or animals for human consumption which may entail adding natural and/or synthetic fertilizers, pesticides and herbicides.
Nutrients: A substance that provides nourishment essential for growth and the maintenance of life.
Crop: A cultivated plant that is grown as food, especially a grain, fruit, or vegetable.

Ultra violet light: Having a wavelength shorter than that of the violet end of the visible spectrum but longer than that of X-rays.
Population: All the inhabitants of a particular town, area, or country.
Natural Resources: Materials or substances such as minerals, forests, water, and fertile land that occur in nature and can be used for economic gain.

INSTRUCTION PROCEDURE
DAY 1
1) Ask students the following questions: What do plants need to grow? How has science impacted the field of agriculture? Can you grow food in space?
   Have students think-pair-share (brain storm on your own, share ideas with a shoulder partner, then share your ideas with the class/group)
2) Introduce key vocabulary words. Ask students if they know what each word means then provide them with the definition.
3) Close read the article Growing Plants and Veggies in a Space Garden. Students read one time to get main idea, students read second time to make think marks (star key words or important facts, circle unknown words, and question marks for things that confuse them). The teacher then reads the story out loud and class discusses their think marks.
4) Watch the video NASA Astronauts Eat First Space-Grown Veggies.

LESSON OBJECTIVE
Students will be able to compare and contrast food production methods used at the Space Station to methods used on Earth. Students will be able to state scientific advances that make food production viable. Students will be able to list 3 ways food production impacts our daily lives.

National Agricultural Literacy Outcomes Addressed
• Science, Technology, Engineering & Mathematics Outcomes.
• Grades 3 – 5: Provide examples of science being applied in farming food, clothing and shelter products.
• Grades 6 8: Provide examples of science and technology used in agricultural systems; explain how they meet our basic needs; and detail their social, economic, and environmental impacts.
DAY 2
Break students into small groups. Provide half the groups with the LADA Greenhouse information sheet and the other half with the Veggie Will Expand Fresh Food Production on Space Station article. Each group will read the article to gather information on how each piece of technology is being used to grow food. The groups will then break apart and meet with a student from the other group to compare and contrast the two pieces of technology.

DAY 3
Read as a class This Land is Your Land. As you read, discuss with students the different ways food is produced. Make a list summarizing key information about each production method mentioned in the article to refer back to at a later time. Have students brainstorm food production not mentioned in the article and add it to the list.

DAY 4
Review with students how food is grown in space and on earth. Have students complete a Venn diagram comparing the two settings. After Venn diagram is complete have students begin their writing assignment. Tell students, Today you will draft a 5 paragraph paper that addresses the following: compares and contrasts food production in space and on Earth, states how science has advanced food production, list 3 ways food production impacts our daily lives, as well as state how they would solve the problem of increasing food production with decreasing resources.

DAY 5 and 6
Have students complete their writing assignment.

ASSESSMENT
(5 essential questions that students should understand and be able to answer after having been taught the lesson)

Questions should be answered within the student’s writing assignment.

1) What methods are used to grow food in space?
2) What methods are used to grow food on Earth?
3) How has science impacted food production?
4) How does food production impact our daily lives?
5) How can we solve the problem of increasing food production with decreasing resources?

ONLINE ARTICLES, VIDEO, AND WORKSHEET

- Growing Plants and Vegetables in a Space Garden
- LADA Greenhouse information sheet
- Veggie Will Expand Food Production on Space Station
- This Land is Your Land
- NASA Astronauts Eat First Space-Grown Veggies
  [https://www.youtube.com/watch?v=m17Tbr98kJQ](https://www.youtube.com/watch?v=m17Tbr98kJQ)
- Venn Diagram Graphic
Growing Plants and Vegetables in a Space Garden
by Lori Meggs, AI Signal Research, Inc.
NASA's Marshall Space Flight Center 06.15.10

Lettuce, peas and radishes are just a few vegetables that are found in a summer garden. But did you know these same vegetables also can be grown in space? Crew members aboard the International Space Station have been growing such plants and vegetables for years in their "space garden."

A space station study is helping investigators develop procedures and methods that allow astronauts to grow and safely eat space-grown vegetables. The experiment also is investigating another benefit of growing plants in space: the non-nutritional value of providing comfort and relaxation to the crew.

"Growing food to supplement and minimize the food that must be carried to space will be increasingly important on long-duration missions," said Shane Topham, an engineer with Space Dynamics Laboratory at Utah State University in Logan. "We also are learning about the psychological benefits of growing plants in space -- something that will become more important as crews travel farther from Earth."

The experiment, known as Lada Validating Vegetable Production Unit -- Plants, Protocols, Procedures and Requirements -- uses a very simple chamber similar to a greenhouse. Water and light levels are controlled automatically.

The experiment has four major objectives: to find out if the produce grown in space can be consumed safely; what types of microorganisms might grow on the plants and what can be done to reduce the threat of microorganisms in the hardware prior to launch; what can be done to clean or sanitize the produce after it has been harvested; and how to optimize production compared to the resources required to grow it.

Since 2002, the Lada greenhouse has been used to perform almost continuous plant growth experiments on the station. Fifteen modules containing root media, or root modules, have been launched to the station and 20 separate plant growth experiments have been performed.

The most recent "crop" -- a type of Japanese lettuce called Mizuna -- returned to Earth in April aboard space shuttle Discovery. It was the first time two chamber experiments were conducted simultaneously for a side-by-side comparison of plants grown using different fertilizers and treatments.

"The idea was to validate in space the results of ground tests, to show that minimizing water usage and salt accumulations would produce healthier plants in space," said Topham. "For years we’ve used the same method for packing root modules, so this was a comparison study between old and potential improvements and so far we have found a couple of surprising results."

First, a sensor failure in the traditional root module on the station caused the plants to receive higher than specified water levels. Investigators believed the overwatering would disrupt nutrients and oxygen in the traditional module, making the newer improved module look better in the comparison.

http://www.nasa.gov/mission_pages/station/research/10-074.html
Surprises in microgravity research are not unusual, though, and it turned out that overwatered traditional module sprouted and developed leaves about twice as fast. "This suggests the conservative water level we have been using for all our previous experiments may be below optimal for plant growth in microgravity," said Topham.

The second surprising result was discovered when the root modules were unpacked on the ground. The new fertilizer being tested had a slower and more even release rate, which had helped lower the plants' accumulation of salts during ground studies. Investigators expected to see higher salt accumulation in the space modules, but the opposite occurred.

"The current theory is that the extra water and larger plant uptake of fertilizer caused the root modules to remove nutrients faster and release fertilizer faster, thus preventing the salt accumulations that were observed in the slower-growing ground studies," said Topham.

"The space station's ability to provide on-the-spot adjustments to experiment conditions or opportunities to quickly repeat microgravity experiments with new conditions are a big plus for researchers," said Julie Robinson, International Space Station program scientist at Johnson Space Center. "This work also shows the surprising results that investigators find when they take a well-understood experiment on Earth and reproduce it on the space station."

Data from this investigation also will help advance Earth-based greenhouses and controlled-environment agricultural systems and help farmers produce better, healthier crops in small spaces using the optimum amount of water and nutrients.

The experiment takes advantage of a 20-year-old cooperative agreement between the Space Dynamics Laboratory and the Institute for Biomedical Problems in Moscow, Russia. Each organization benefits from resources provided by their respective national space programs -- the Space Dynamics Laboratory with NASA, and the Institute for Biomedical Problems with the Russian Federal Space Agency.

Root modules with seeds are launched to the space station on Russian Progress supply vehicles. Russian crew members water the plant seeds and perform maintenance. They also harvest the vegetables and place them in a station freezer before transferring them to a space shuttle freezer for return to Earth for analysis by U.S. investigators at the Space Dynamics Laboratory.

"I don’t see future space crews leaving the Earth for long durations without having the ability to grow their own food," said Topham. "The knowledge that we are gaining is enabling us to extend our exploration and future colonization of space."

http://www.nasa.gov/mission_pages/station/research/10-074.html
LADA, A New Joint Russian - U.S. Plant Greenhouse: Continuing the “Svet” Science and Technology Development Tradition on ISS

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Introduction
A new greenhouse of the Svet style is being prepared for deployment in the Russian section of the International Space Station. Svet was used for seven experiments on Mir between 1990 and 2000. LADA is being developed under a joint cooperative agreement between the Institute of Bio-Medical Problems, RAS, Moscow, Russia and Space Dynamics Laboratory / Utah State University. LADA is currently completing qualification and biotechnology testing and is expected to launch to the ISS in mid 2002. LADA is being developed to allow continuation of the Russian National Program on Microgravity Plant Technology. Cooperation with other international partners is being sought for experiments utilizing LADA. These cooperative programs are expected to be structured like those conducted in the Svet greenhouse on Mir.

First Flight
• LADA is manifest to launch to the ISS on a Progress in June, 2002.
• For its first experiments, LADA will be configured with a single vegetation module (light bank, leaf chamber and root module) to minimize launch weight, volume and power use.
• Hardware checkout is scheduled for September, 2002.
• The LADA 1 plant growth experiment will begin in October and will terminate in conjunction with the next Soyuz rotation (November, 2002).

Initial Experiment
• LADA’s initial (2002) experiment will involve both Russian and US participation (additional participation is in negotiation) and is designed to evaluate the capabilities of the new growth chamber system. In this evaluation, LADA will conduct an experiment similar to the last experiment performed in Svet on MIR.
• LADA 1 will grow Mizuna (B. rapa var. nipposinica), using a single greenhouse for power considerations. While LADA can support two vegetation modules, the use of only one reduces the lights-on power requirement to less than 100 watts.
• The Mizuna plants grow during LADA 1 will be thinned at 14-19 days, providing green material for the crew to sample.
• LADA 1 is scheduled to last for 38-34 days, which should produce fully developed Mizuna for both crew evaluation and fresh material return. One half of the green material will be packaged and returned to earth.
• LADA 1 will include a full suite of soil moisture and soil water tension measurements, aiming to produce the first soil water characteristic curves developed in a root-filled substrate in space.

Design Considerations
• Allow two chamber comparisons in space
• LADA utilizes much of the same technology and approaches that were present in Svet, but with lower volume and power requirements. The total plant growing area is one half that of Svet, but is divided into separate Vegetation Modules so that the treatments do not intersect.
• Provide detailed substrate physics studies
• LADA root modules have the same plant growth area as the BMPS, but the depth is 9 cm to allow full root development for long experiments. Sensors for moisture, matrix potential and oxygen can be mounted at various levels.
• Allow maximum access to plants by cosmonauts
• LADA follows the Svet vegetation module model, including wall mounting in the crew cabin, door access to the plants, and cabin air exchange.
• Provide good plant growth conditions and measurements
• LADA provides a down-looking camera, light, RH and air and leaf temperature measurements in the leaf chamber area. Light levels are similar to Svet.

Summary
• The LADA greenhouse has completed its development phase and is nearing the end of its qualification testing. Under the Russian plan, it will remain on ISS, with new root modules and supplies sent up as required.
• A unique feature of this plan is to allow the crew to use LADA to grow vegetables for diet and recreational use when it is not being used for scientific experiments. All of their crew members will be trained to operate LADA.
• A new aspect of plant research will be the study of Crew-Plant interactions, including psychological aspects.

References

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Veggie Will Expand Fresh Food Production on Space Station

April 10, 2014

By Linda Herridge NASA’s Kennedy Space Center

A plant growth chamber bound for the International Space Station inside the Dragon capsule on the SpaceX-3 resupply mission may help expand in-orbit food production capabilities in more ways than one, and offer astronauts something they don’t take for granted, fresh food.

NASA’s Veg-01 experiment will be used to study the in-orbit function and performance of a new expandable plant growth facility called Veggie and its plant “pillows.” The investigation will focus on the growth and development of “Outredgeous” lettuce seedlings in the spaceflight environment.

“Veggie will provide a new resource for U.S. astronauts and researchers as we begin to develop the capabilities of growing fresh produce and other large plants on the space station,” said Gioia Massa, NASA payload scientist for Veggie. “Determining food safety is one of our primary goals for this validation test.”

Veggie is a low-cost plant growth chamber that uses a flat-panel light bank that includes red, blue and green LEDs for plant growth and crew observation. Veggie’s unique design is collapsible for transport and storage and expandable up to a foot and a half as plants grow inside it.

“The internal growing area is 11.5 inches wide by 14.5 inches deep, making it the largest plant growth chamber for space to date,” Massa said.

Orbital Technologies Corporation (ORBITEC) in Madison, Wis., developed Veggie through a Small Business Innovative Research Program. NASA and ORBITEC engineers and collaborators at NASA’s Kennedy Space Center in Florida worked to get the unit’s hardware flight-certified for use on the space station.

Because real estate on the station is limited, some adjustments to the growth chamber were made to accommodate space requirements. At Kennedy’s Space Life Sciences Laboratory, a crop of lettuce and radishes was grown in the prototype test unit. Seedlings were placed in the Veggie root-mat pillows, and their growth was monitored for health, size, amount of water used, and the microorganisms that grew on them.

“I am thrilled to be a member of the Veggie and Veg-01 team and proud of all the work we have done to prepare for flight,” Massa said. “Our team is very excited to see the hardware in use on the space station.”

As NASA moves toward long-duration exploration missions, Massa hopes that Veggie will be a resource for crew food growth and consumption. It also could be used by astronauts for recreational gardening activities during long-duration space missions. The system may have implications for improving growth and biomass production on Earth, thus benefiting the average citizen.

For the future, Massa said she is looking forward to seeing all sorts of “neat payloads” in the Veggie unit and expanding its capability as NASA learns more about the food safety of crops grown in microgravity.

This Land Is Your Land

Feeding nine billion—and eventually ten billion—means growing crops faster, smarter, and in new places. Do we need to find more land?

Light, seeds, soil, and water. The recipe for growing food out of the ground is among the planet’s simplest equations. Tweak the variables—less light, different dirt—and you can grow anything from feathery lettuce that’s lighter than air to a beefy jackfruit, the world’s densest fruit, which can weigh more than a hundred pounds.

So it’s strange that in the middle of the day on a recent Thursday we’re walking through a dark tunnel on the way to a farm. The facility is a hundred feet below the streets of London, 179 steps down, in an old air-raid shelter built in 1944 for protection from German bombs. During the blitz more than 6,000 people huddled shoulder to shoulder in this small tunnel. Today the only overnight occupants are a few green shoots of radish, celery, and spinach. They’re prodded to grow by a simple aquaponics system where water circulates through a series of trays that hold the crops. There’s no soil, only old carpet from renovated hotel rooms. LED lights powered by wind turbines on the surface emit a light pink hue, the precise mix of ultraviolet and infrared light that the plants need. Anything extra would be wasted energy.

“We don’t know entirely what to expect,” says Steve Dring while we’re walking through the dark tunnel. Dring, along with his business partner, Richard Ballard, came up with the idea last year to build a farm underground, away from a natural source of water and far removed from the sun. Rent for the space was cheap as long as they could live with a few small water leaks in the 70-year-old tunnels. No one else was using the facility (a night club was turned away because there weren’t enough exits). Once Dring and Ballard had gotten a lease to grow crops, their lawyer admitted that he was curious about what the two men might actually grow in a dark, private space using artificial lights.

The novelty of an underground farm that grows spinach and garnish herbs for high-end salads isn’t lost on them. They know farming underground isn’t the key to feeding a global population. But the quirkiness of the idea could provoke questions about what tomorrow’s farms might look like. It also makes for good PR and fund-raising: Virtually every tech-news outlet has come asking for a tour, hoping to provoke its readers with a shocking headline about whether growing underground is the future of global agriculture.

Of course it’s not. News of an underground farm in London isn’t enough to make corn farmers in Nebraska and rice growers in Indonesia lay down their hoes in defeat. Even earth powered by the most highly phosphorous fertilizer and the brightest lightbulb couldn’t compete with the rich soil of a Napa Valley or the well-watered farmland of Congo or Argentina.

Instead the notion is a gesture of ingenuity, a token approach very much outside the box to how our species might grow more food for an increasing population on a planet of limited size. “We’re not planning to take over traditional farming,” Steve Dring says. “But we are trying to confront the idea that we’re running out of land and need to find new places to produce food.”

Arable farmland—the expanse of Earth that can be used to grow crops—can be a funny thing to measure. Land, like people, comes in different shapes. It also changes over time, formed by a quick deluge or a long, punishing drought. When abused, it’s easily exhausted. There’s no such thing as land that stays prime forever.

To understand how much space on Earth is suitable for farming, imagine the globe as an apple, and slice it into four wedges. Three of the wedges represent Earth’s bodies of water, and are disqualified for growing crops. Of the remaining wedge, half represents land unwelcoming to agriculture, in deserts or near the frigid Poles. The rest of the apple (one-eighth of the planet) represents land where food could grow—except that three-fourths of it has been paved over by cities and roads and other human civilization. All that’s left is one-fourth of that last wedge, or one thirty-second of the surface of the Earth.

That amounts to 57 million square miles of farmland globally. Splitting the land among the world’s 7.1 billion people would give each person alive about five acres. That’s more than enough to raise livestock and grow a rounded diet of fruits and vegetables.
Yet that land is highly disproportionate. Some 90 percent is located in Latin America and sub-Saharan Africa. Half is concentrated in just seven countries: Angola, Argentina, Bolivia, Brazil, Colombia, Congo, and Sudan. Areas with notably booming populations—like China and Qatar—have the least available farmland per capita of anywhere on Earth. This pushes them to buy land abroad, especially in Ukraine and Morocco, which have large expanses of usable land and hearty reserves of phosphorus—the main ingredient in fertilizer.

Altogether, that area of land produces about four billion tons of crops every year. Yet not all food is equal. More than half the crops grown every year become rice or grain. Potatoes are the single most eaten vegetable, followed by tomatoes, cassavas, and oranges.

For now the system is mostly stable. Despite beauty queens’ best efforts to end hunger, people continue to go hungry. Yet the world actually produces a surplus of calories every year. “Hunger is caused by poverty and inequality, not scarcity,” Eric Holt Giménez, director of the Institute for Food and Development Policy, wrote last year. “For the past two decades, the rate of global food production has increased faster than the rate of global population growth.” Instead, feeding the poor corners of the world as well as the 70 million new mouths being born every year will mean farming smarter and on less land—even occasionally in dark tunnels.

Yet a few expectations for the future add urgency. One of the most pressing concerns, laments Berkeley economist David Zilberman, is that one billion people currently “eat like Westerners,” meaning they have diets high in meat and dairy that take longer and are costlier to produce. Never mind that a few billion more people will soon be born. Billions of people already alive have ambitions to upscale their diets.

Somehow the market is expected to work, but not seamlessly. The price of food is expected to rise 2 to 3 percent each year, which is expected to encourage more production, which is expected to encourage more development over wetlands and forests. Faced with the reality that the majority of the world’s industrial farmers are over 50 and will soon retire (the average U.S. farmer is 57), farming will have to become a more attractive proposition to draw younger people. The ultimate impact is likely to be food prices that rise faster than inflation. “It’s a heck of a big problem,” says Andrew McElwaine, president of American Farmland Trust, the advocacy group that pioneered the imagine-the-apple-as-the-Earth metaphor. “There is a sense of urgency because of this convergence of growing population and limited availability of arable land. When those lines cross, it won’t be pretty.”

But it’s not entirely inevitable. The saving grace is innovation, the marketing term for producing more food from less land. Until about 1940 yields of most crops in the United States were consistent every year and proportional to the amount of land they were grown on. The introduction of nitrogen fertilizer, genetically optimized seeds, and mechanical plowing methods has produced yields that would make a Neanderthal’s head explode in envy. Since 1960 yields have doubled, or even tripled, everywhere in the world except Africa, while most land for farming has increased by only 10 percent.

Last December a modest farmer in Charles City, Virginia, named Dave Hula won an agricultural award that demonstrated the leaps made by modern humans. Using seeds engineered to produce voluminous yields with minimal input of fertilizer and water, Hula grew 454 bushels of corn on one acre. Compared with the industrial norm of about 125 bushels, Hula had farmed the most productive acre in human history.

Not everyone has the power or know-how to grow food. That might be the ethos of modern industrial farming, in which large corporations and the sprawling farms that buy their seed and fertilizer produce a growing amount of the world’s nutrition. (Disclaimer: one of those companies, Syngenta, has purchased advertising with National Geographic.)

As large-scale food production has grown, one counterbalance has been the concept of food miles. Learning how far tomatoes or frozen chicken need to travel to reach supermarket shelves brings awareness about environmental impact. From California, which grows more than three-quarters of most of America’s fruits and vegetables, to a supermarket in Washington, D.C., produce trucks
carry spinach, garlic, and blueberries the width of the entire continent in usually less than a week. Each truck can burn over 500 gallons of diesel along the way.

That guilt-inducing fuel consumption, as well as a rise in locavore thinking, has been the driving force behind decentralized farming. The idea of buying food from someone who grew it nearby came back into vogue in the mid-1990s. During the first term of the Clinton Administration, there were 1,700 registered farmers markets in the United States. Today the number has more than quadrupled.

“The trend is very clear,” says Nicholas Leschke. Like the men in London with the tunnel idea, Leschke is part of a two-man team of entrepreneurs—not farmers—trying to imagine the future of urban farming. “People want food that’s high quality—produced locally and very efficiently.”

Maybe they do. Certainly some people just care that there’s food on the shelf when they go to buy it, no matter where it was actually grown. But Leschke is banking on a future where people not only want local food but also want to be able to reliably grow it themselves. In an old industrial parking lot in Berlin, he and his business partner developed a farm out of a repurposed shipping container—called, in the spirit of German directness, a “container farm”—that produces both fish and fresh crops.

The container farm runs an aquaponics loop, where fish swim on the first level, and fresh vegetables like tomatoes, peppers, and potatoes grow in the greenhouse above. The fish waste is used to fertilize the plants. The plants help purify the water and return it to the fish below. When the farm expands later this year, the developers expect it to produce 6,000 tons of fresh fish—raised locally and with minimal input.

In theory a hundred years from now, every family’s roof could have a farm to grow vegetables, fruits, fish, and even meat from just a few cells in a petri dish. But aside from people who farm in London tunnels or on Beijing rooftops or who attend meetings at a Brooklyn food co-op, there’s the pesky question of whether that’s really the most efficient way to produce food for billions of people.

The answer might be the best indication of where future food will actually be grown—and more important, who will grow it and on how much land. One running joke among farmers is that a lot of people like to garden, but very few like to farm. Eating tomatoes you grew yourself is worthwhile, but it isn’t scalable for the planet, says Jesse Ausubel, an ecologist and food analyst at Rockefeller University in New York.

The day I talked to Ausubel, I was working through lunch. In front of me was a turkey sandwich made with meat produced on a factory farm, accompanied by a bottle of juice squeezed from oranges grown in both Brazil and Florida. As much as I think and write about food, I was eating one of the most generic American lunches, created by farmers who have demands to keep up with rising appetites—and who, based on how easy it was for me to buy each item, seemed to be succeeding.

Food, Ausubel told me, is a little like clothing. “There are large companies that turn out the blue jeans and T-shirts we all wear. We don't mind large scale for that. But sometimes we all want a little something nicer, a little more fashionable. Even people without much money want something of their own or something they made themselves. Character matters, so does a sense of ownership. It's the same story with food.”
