Soil Versus Water: Exploring Hydroponics

Overview: This lesson guides students to compare plants grown traditionally in soil with plants grown hydroponically providing an innovative and engaging way for older students to explore plant needs.

Grade Level/Range: 6- 12th Grade

Objective
Students will:

- Review what plants need to grow
- Explore how traditional soil-based gardening techniques provide for plant needs
- Explore how hydroponic growing techniques provide for plant needs
- Conduct an experiment to observe differences between traditional and hydroponic growing techniques

Time: 4 to 8 weeks

Materials

- lettuce or basil seeds
- raised garden beds and/or potting soil and pots
- DIY hydroponic system or prefabricated hydroponic system

Background Information

Plants, like all living things, have certain requirements that need to be met for them to grow and thrive. These include water, nutrients, light, air, and structural support for the roots. In nature and through traditional gardening/farming techniques, soil is very important to providing these plant needs. Soil provides support for the roots to anchor the plant so they can remain upright for protection from animals and to reach sunlight. Pore space created through soil structure provides both water and air for the roots. Decomposing organic matter in the soil offers plants the nutrients they need. Healthy soil offers the conditions and foundation plants need to thrive.

However, soil is not the only way a plant's needs can be met. Hydroponics, in its simplest form, is growing plants by supplying all necessary nutrients in the plants' water supply rather than through the soil. It is a growing technique that has been used for thousands of years to produce food in parts of the world where space, good soil, and/or water are limited. Additionally, hydroponics is being explored as a way to meet the challenges presented by our growing urban populations and ease the demands on our environment and natural resources.

Some of the ways hydroponics meets plant needs include:

Meeting Water and Air Needs

In the soil there are naturally occurring pockets of air and water, both of which contribute to proper root growth and functioning. It is important for students to understand that even roots must have oxygen for the plant to survive, so hydroponic systems can not merely submerge the roots in a bath of water for a plant to function properly and survive long-term.

There are many different ways for hydroponic systems to deliver this mix of water and oxygen to the roots. In some hydroponic units, water and nutrients reach the roots via a wick made of absorbent material, and part of the roots are continually exposed to air. Others actually grow the plants in a porous medium like rockwool, which acts as a soil substitute due to its capacity to offer similar pockets of air and water for roots. Some hydroponic systems use a pump to infuse oxygen into the water, similar to how a fish tank aquarium works. Another option is for the medium and roots to be periodically splashed or flooded with a nutrient solution, allowing oxygen to bathe the roots in the interim.

A Place to Grow - Root Support

The material that a plant lives in or on is called its medium or substrate. For most plants, the medium is soil. As stated above, soil naturally provides pockets of both water and air and provides plant roots with the structure necessary so the plant can anchor itself securely.

Hydroponic growers find other ways to support growth — and to prevent drowning roots by allowing them to remain sitting in water. Many setups use an inert, sterile medium to serve as a base (like a soil substitute). Some of the more popular choices included gravel, clean sand, perlite (volcanic material that is heated until it expands into a lightweight, Styrofoam-like material), a lightweight pebble-like aggregate, and rockwool (an inorganic, spongy, fibrous substance that holds large amounts of water and air). These materials provide passages among the particles or fibers where air and water can circulate.

Each medium has strengths and weaknesses. Gravel and sand, for instance, provide support and good drainage, but can be heavy when wet and will dry out fast. Perlite is light and holds water well, but its fine dust can irritate lungs. (Sprinkle it lightly with water to avoid this.) Rockwool holds water and air nicely and makes it easy to move plants around, but breaks down fairly quickly.

Some hydroponics systems have no real support media, but rather incorporate more or less elaborate ways of suspending plants in nutrient solutions. In nutrient film technique (NFT) and aeroponic systems, for instance, the roots lie or are suspended in a dark channel and nutrients are sprayed or trickled along the root zone.

Light

When growing outdoors in soil, plant rely on sunlight to meet their light needs. Many hydroponic systems are set up in indoor environments so plants meet light needs through sunny windowsills or though artificial light.

Nutrients

In soil, nutrients come from rock and mineral leaching and organic matter decomposition. They are "held" by the soil particles and dissolved in the surrounding water before being absorbed the roots. In hydroponics, growers add nutrients to the irrigation water being applied to the roots.

The easiest way to supply these nutrients is to purchase prepared hydroponic nutrients in dried or liquid form. Most are concentrated and must be mixed with water. Water between 65 and 75 degrees F makes nutrients most available to plants. Tap water may contain significant concentrations of chlorine, which can adversely affect plant growth. If water has a lot of chlorine, gardeners can use distilled water or simply let water stand uncovered for a couple of days before using it.

Laying the Groundwork

Begin by taking a secret ballot. Ask students to answer the question: "Do plants need soil to live and grow?" Collect their answers and hold on to them until the end of the lesson.

Introduce hydroponics using the background information above. Review the needs of plants and then make a chart to explain how traditional, soil-based growing techniques and hydroponic techniques meet plants' needs.

Watch a video showing plants being grown hydroponically. Here are a few options:

Exploratorium Subzero Water Works in McMurdo Station on Ross Island, Antarctica:
https://www.exploratorium.edu/video/subzero-water-works

Exploratorium Polar Paradise:
https://www.exploratorium.edu/video/polar-paradise?autoplay=true

Australian Antarctic Division: Hydroponics:
http://www.antarctica.gov.au/living-and-working/station-life-and-activities/food/hydroponics

Science and More: Scientists in Antarctica have harvested the first crop of vegetables grown without soil or light:
https://www.youtube.com/watch?v=MSJF5t0xX6Y

Space Station Live: Lettuce Look at Veggie:
https://www.nasa.gov/mission_pages/station/research/news/meals_ready_to_eat

Doug Ming on Technologies for Required for Living on Mars:
https://www.nasa.gov/offices/marsplanning/faqs/

Ask students again, do plants need soil to live and grow?

Exploration

1. Set up an experiment to observe plants grow from seed to harvest using both traditional and hydroponic techniques.

For your soil-based bed, utilize existing garden space if it is available to you. If you do not already have available space, consider either

outdoor or indoor container gardens. KidsGardening offers resources to help you plan and plant container gardens.
Container gardens:
https://kidsgardening.org/designing-a-school-garden-consider-container-gardening/

Indoor gardening:
https://kidsgardening.org/gardening-basics-indoor-gardening/

For your hydroponic unit, you can purchase a prefabricated hydroponic growing system or you can make your own. A number of DIY hydroponic techniques can be found online, or here are some instructions for a Floating Styrofoam Raft System, a simple system that has been used by many schools and can be designed to be used indoors or outdoors:

To build a floating Styrofoam raft hydroponic system:
You will need rockwool cubes, a waterproof container, a sheet of Styrofoam to fit the container, an aquarium pump and aquarium tubing.

Soak rockwool cubes with a dilute nutrient solution and place a seed in the top of each cube.

Cut a Styrofoam raft to fit in the container, then cut holes in the raft, spaced 6 to 9 inches apart, to snugly fit the rockwool cubes. Be sure the cubes extend to the bottom of the raft.

Poke aquarium tubing through the raft into the solution. An optional attachment, you can add an air stone to the submerged end of the tubing. Air stones are made of porous materials and are designed to disperse the air into smaller bubbles. Air stones can help with the circulation of the water, help keep the tubing in place and may also decrease the noise of your system. Attach the other end of the tubing to the aquarium pump that is kept outside the base.

Fill the container with water (around 70 F) to within 1 inch of the top, then float the raft with planted cubes on the surface.

When seedlings appear, add nutrients to the water at half the recommended strength. Try to keep the pH between 5.8 and 6.5. Let the air pump run continuously. After a week, raise the nutrient solution to full strength and maintain a constant level. Change the entire solution every 2 weeks.

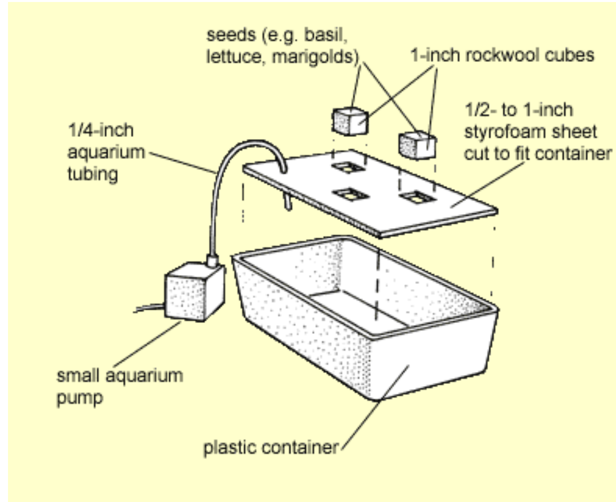
Check out this video from 2017 Carton 2 Garden Winner Bethel Elementary in Midland, North Carolina for ideas on how to create a raft system using repurposed milk cartons:
https://www.youtube.com/watch?v=8Sr8TOnkH74

2. Decide what kind of plants you want to grow. To control your variables, you need to plant the same variety of plants and approximately the same quantity of plants in both gardens. Lettuce and basil are two easy-to-grow options that should perform well in both types of systems and in many climates.

3. Track growth and make observations. Provide time to track your plants at least once a week and preferably every other day (Monday,

Wednesday and Friday would be a good schedule). Any data you can collect may be useful during your analysis of the systems.

4. After approximately 4 to 8 weeks, compile your results and create a graph to compare the growth of your plants growing in the two systems. Also compare the vigor of your growth (leaf color and number is one way to compare this information). Discuss your findings.



5. Although this information may tell you which system resulted in the healthiest plant growth in your conditions, explain to your students that there are other factors to consider related to your design. Discuss factors such as cost, supplies needed, and ease of building and maintaining each system to support your discussion of the results.

6. Before making any final conclusions, create a list of uncontrolled variables that you think may have influenced your results. This may include things like differences in light or water availability. Also make an additional list of benefits and challenges of each system based on their growing experience.

7. Finally, ask students to consider all of this collected data to come to a conclusion about which type of growing system is the best fit for the conditions and needs of your school. Brainstorm a list of questions or additional investigations they would like to conduct to further explore the Water versus Soil discussion. How could your experiment be improved or enhanced?

Making Connections

Ask student to brainstorm reasons why people would want to grow plants hydroponically rather than through traditional gardening/farming methods. Their answers may include:

- to grow food in location where good soil is not available
- to grow food near urban areas
- to maintain control over the plant's environment – can grow plants year round, do not need to worry about temperature, light, season
- to produce plants in small spaces
- to control nutrient availability
- to conserve water
- to avoid weeds, insect and disease problems
- to decrease cleaning needed before consuming harvest

As our global population grows and urban areas expand, farmers and scientists are increasingly interested in finding ways to boost food production, especially in dense population centers, while also decreasing environmental impacts and increasing efficient use of natural resources. Hydroponic growing techniques are at the forefront of current research regarding food production of the future.

Watch the following video to learn more about how hydroponics is being used in our food system today:
High Tech Farmer – Growing Kale in a Factory
https://www.youtube.com/watch?v=AGcYApKfHuY

Discuss hydroponics as a solution to the environmental challenges facing our globe and the food system challenges due to growth in human population. Is hydroponics a viable solution? How can we test our theory? What information do we need to collect to evaluate our theory?

Branching Out:
Ask students to conduct research on different types of hydroponic systems. Ask them to draft plans for their own unit.

Stage a debate to discuss the pros and cons of growing plants hydroponically versus growing in soil. Which method is more cost efficient? Which method is more environmentally friendly? Is there one best method?

Even though hydroponics has been around for a long time, it is not a well-known growing technique. Ask students to write a newspaper article to teach more people about hydroponics.

Link to Standards:
MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.