Soilless Plant Cultivation

Introduction for the Teacher:

Plants are living organisms. This is difficult for us to comprehend since most plants hardly move and it is very difficult to detect their means of communication. This being said, if we observe them over time, we will be able to notice that they grow, develop and respond to their environment. In order for a plant to grow and produce fruits and seeds, it has to have the following basic needs fulfilled in the proper quantities: light, water, air, nutrients, an anchoring point, protection against pests and the correct temperature.

Most plants grow naturally in soil, which enables them to obtain most of their basic needs: a protective environment, anchorage, nutrients, water and even oxygen.
Using the hydroponic cultivation method, plants can be grown without soil (soilless cultivation). This method enables a more accurate fulfillment of the plant's basic needs, while saving on water and nutrients. The result is more efficient growth and the reduction of the environmental impact. Soilless cultivation is also faster and cleaner.

In this unit, we will learn what plants' basic needs are and what the hydroponic growing method is. In addition, we will understand its advantages for the plants, the farmer and the environment.

Goals:

- The students will identify plants' characteristics of life
- The students will list plants' basic needs
- The students will research and explain how different hydroponic cultivation systems provide the plants with all their basic needs
- The students will experience searching for information and presentation of their work.

Recommended duration

90 minutes

Key terminology

Characteristics of life, basic needs, hydroponics, hydroponic system

Acquired skills

Finding relevant information, presentation

Prepare in advance

Accompanying presentation

A computer, linked to a projector

Mobile phones or computers for the research

Animal? Vegetable? Mineral?

Plants are almost everywhere around us. Not only in the ground - they pop up through cracks in the pavement and in walls, they grow on every one of Earth's continents, including Antarctica.

What do you think - are plants living organisms? Yes? No? Partially?

The answer is that plants are living organisms, meaning they possess all of the characteristics of life.

Plants as Living Organisms

Watch the video in this link and write down the plants' characteristics of life you can identify.
We recommend you watch this at 1.5X speed.

https://www.youtube.com/watch?v=UoL1dg3SzOI

Observable characteristics of life in the video are:

- Feeding (hunting of insects - exists only in carnivorous plants)
- Reproduction (flowers)
- Growth and development
- Movement (plants are anchored in place but the plant parts are able to move)
- Communication with the environment (response to external stimuli, for example: springing a trap when an animal touches it).
- Another characteristic of life is breathing (although plants' intake of oxygen cannot be observed, they are in an open, ventilated space).

Carnivorous plants are interesting. It is also easier to notice that these plants are indeed living organisms. But these characteristics of life are common to all plants. Most plants move slower than the carnivorous plants, but if you watch time-lapse videos of the kind we have just watched, you will see that all plants move and respond to their environment in one way or another.

What Are the Plant's Basic Needs?

A plant is a living organism. As with any other living creature, it has basic needs - materials and conditions it requires in order to exist, to grow and to reproduce.
What are the plant's main basic needs?

- Light
- Water
- Air
- Nutrients
- Anchorage
- Protection against pests
- Proper temperature

Light water and air are necessary for plants in order to photosynthesize - a process in which the plant produces its own sugar as a source of food and energy.
In this process, the plant's green parts take in light, water and carbon dioxide - CO_2 - which is present in the air, and it releases oxygen and water vapor into the environment.

Water is also necessary for the plant in order to transport the substances dissolved in the water to all of the plant's parts, for keeping the plant upright and for assisting in the plant's temperature regulation process.
The plant absorbs water through its roots.

Nutrients are vital for the plant's existence and its functions. The plant's main nutrient is sugar, which is produced through photosynthesis. However the plant, like any other living organism, also needs other nutrients (for example, nitrogen, phosphorus, potassium, iron and other minerals). These nutrients exist naturally in soil. They can also be added in the form of fertilizer. These substances get dissolved in water and the plant's roots absorb them.

Are the Quantities Important?

The quantities the plant receives are of great importance in fulfilling its basic needs.

Different plants need different amounts of light,

A shortage of water will cause the plant to wilt, while excess water will prevent the roots from absorbing oxygen, thereby causing the roots to rot.

The amounts of nutrients have to be suitable for the plant and for its various growth phases.

Why is Soil Needed in the First Place?

Most plants grow naturally in soil. One can assume the soil plays a significant role in the plant growth.

What role does the soil have in obtaining the plant's various basic needs?

Basic Needs	**What role does soil play in fulfilling this need?**
Water	The soil absorbs water, so the water the plant needs to remain in the soil for a long time. The roots are capable of absorbing water from the soil when the plant needs it.
Air	As long as the soil is not completely saturated with water, it contains air pockets that allow the roots to obtain oxygen.
Nutrients	The water in the soil contains numerous dissolved minerals - obtained either naturally or through the addition of fertilizer. The roots are able to absorb the various nutrients from the soil according to the plant's needs. Soil is also the breeding ground for bacteria and fungi, which are helpful to the plant.
Anchorage	Burrowing The roots burrow into the ground to stabilize the plant, preventing it from toppling in the wind and keeping it stable to enable it to grow upright.
Proper temperature	The soil insulates the roots (like a blanket) and protects the roots against overheating and overcooling.

At the same time, soil is a source of numerous pests, which are harmful to the plant: weeds, insects and diseases.

Hydroponics - Growing Without Soil

One of the most common methods in urban agriculture is **hydroponics** (hydro = water, ponic = work). This method presents a different approach to plant cultivation - soilless cultivation based on a bed of water containing dissolved nutrients, mostly operating in closed systems, meaning systems which circulate the solution. This method of cultivation is not new - there are descriptions of hydroponic systems being built about 400 years ago. However, advances in science and technology have enabled the systems to be greatly improved and nowadays hydroponics can be used for efficient cultivation of a variety of plants virtually anywhere.

Some of the systems include a **growth medium** within the planting vessel, which consists of material of no nutritional value, whose role is mostly to support the root system. This growth medium usually contains pores capable of transporting air and also absorbing certain amounts of water. Growth media can be made of coconut fibers, clay pebbles (hydroton) or other porous materials (Perlite, Vermiculite).

Hydroponics - A Technological Solution for Plants' Needs

The technological system provides a technological solution for the plants' needs. The better the hydroponic system is able to fulfill more of the soil's functions, providing more of the plants' needs, the better and more efficiently it enables the plants to grow.

There are many kinds of hydroponic systems, ranging from small systems enabling cultivation of just a small number of plants within a home setting, to very large systems for commercial use. Systems can be purchased ready-made or they can be assembled independently.

Common types of hydroponic systems are:

- DWC
- NFT
- Wick

Hydroponic Systems in Space

The International Space Station (ISS) orbits Earth and serves as a space-based research station. The station has been permanently manned since 2000. Astronaut crews stay on it for a few months at a time before being rotated. Supplies are ferried regularly to the station via space shuttles, as it is important to provide the astronauts with fresh fruits and vegetables. This can pose a problem when considering sending astronauts further away, for example, on a planned mission to Mars. It can take about 6 months just to reach Mars and the astronauts will stay there for a long time. They will probably have to grow their own plants there, although the soil on Mars is not suitable for growing food. These days, the crew on board the International Space Station grows fruit and vegetables in space. The astronauts have managed to grow lettuce, kale, and chili peppers. One of the methods enabling soilless cultivation of vegetables in space is hydroponics and this method will also be suitable for Mars.

Group Activity - Researching and Recommending a Hydroponic System

The activity will take place in three groups. Each group will research one of the types of hydroponic systems using the videos in the links (these links are both in the accompanying presentation, and in appendix 1 of this document) and other information they will be able to find.

Each group will prepare a 2-minute elevator pitch:

- How does the system provide the plant with its key needs?
- Why do they think this system is recommended for use for growing plants on Mars?

For an explanation of an elevator pitch: **https://www.youtube.com/watch?v=Tq0tan49rmc**

After each group has presented its system (in about 2 minutes), the class will vote: Which system presented has been the most convincing? Of course students must not vote in favor of their own group's system.

Hydroponic Systems - Similarities and Differences

In our research work, we saw that there are various kinds of hydroponic systems, each with its own advantages and disadvantages.

What do all the hydroponic systems have in common?

- They provide the plants with their basic needs.
- The use of a nutrient solution composed of water and fertilizer.
- The conditions within the nutrient solution can be measured and controlled.
- A main reservoir of the nutrient solution.
- Planting vessels (a basket or a perforated container).

What are the differences between the various systems?

- The method of delivering the oxygen to the roots: use of an air pump and air stone, water flow, keeping some of the roots outside the water.
- With or without nutrient solution flow.
- The volume of the nutrient solution reservoir.
- Location of the plant - with or without contact with a growth medium.

The hydroponic systems are usually divided into two kinds:

- Passive: not requiring electricity.
- Active: requiring electricity (to operate the water pump and/or the air pump).

The kind and size of plants that can be grown also varies - also the number of plants, the possible locations for the system, the systems' stability, their cost and ease of operation.
It is impossible to clearly state which system is better. One has to examine which system is better suited to the needs and limitations of the grower and of the location.

Hydroponics - Advantages and Challenges

Advantages of Hydroponic Cultivation

- The possibility of growing plants **even in places where there is no soil** at all or where the soil is of low quality. For example: urban spaces paved with concrete, balconies or inside homes, in deserts and even in space.
- The **supply of the nutrients can be controlled** by adjusting the concentration of the fertilizers within the nutrient solution reservoir.
- It enables **maximizing the plants' growth rate**, since the plants are provided with optimal conditions in terms of quantities of nutrients, water, air and temperature.
- In most cases, hydroponic crops **need less water** than conventional crops thanks to the re-use of the nutrient solution.
- Hydroponic systems **are almost completely free of weeds, insects and diseases**, since these come mostly from the soil. If necessary, the system can be thoroughly cleaned. This makes it easier to grow organic crops without the use of pesticides or herbicides.
- **Reduction of the use of pesticides and fertilizers** is beneficial for the environment.
- Plants which are cultivated in a hydroponic system are **cleaner** than soil-grown plants. This necessitates less cleaning of the produce, saving water and time.

Challenges and Limitations of Hydroponic Cultivation

- The initial set-up cost is usually high.
- It requires knowledge to maintain the system correctly and to balance the nutrient solution.
- In some of the systems, plant growth depends on a regular electricity supply and therefore, these systems are prone to instability.
- Consumption of electricity is usually higher than with conventional cultivation.
- Hydroponic cultivation is not suitable for all plant types.

Summary

We learned that plants can be grown almost anywhere, even without the use of soil at all.

We learned about various kinds of hydroponic systems. What they all have in common is the ability to provide all of the plants' needs under finely-tuned conditions, facilitating efficient growth, saving on water, fertilizers and pesticides and protecting the environment.

Appendix 1

Links for the Group Activity “Researching and Recommending a Hydroponic System”

- **DWC**


- **NFT**


- **Wick**