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# K-12 Partnership Lesson Plan

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# *Fun with Plants*

# *Understanding the functions of mineral elements*

## Overview

The aim of this project is to help students to gain deeper understanding on how and why mineral elements are necessary for plants to grow. Plants will exhibit certain symptoms of nutrition deficiency when suffering from malnutrition, which can be best studied by a water culture (hydroponics) system. This lesson starts with a brief introduction on what plant nutrition is and why fertilizer is important for plants. After the theory session, instructors and students will build seed starting and hydroponics experimental systems together. Different treatments, i.e. nutrient solutions that are absent of certain mineral elements, will be set up and students will be divided into small groups to observe how plants react and adjust under various environments. Students will spend time on 1) recording plant nutrient deficiency symptom; 2) maintaining hydroponics systems; 3) collecting plant morphological and physiological data.

**Objectives**

At the conclusion of the lesson, students will be able to:

* Tell the difference between macronutrients and micronutrients
* Understand the functions of N, P, and K on plant development
* Identify typical deficiency symptoms on plant organs associated with the absence of essential elements
* Explain why water is an alternative medium for plants to grow
* Explain and apply basic hydroponics techniques
* Graph data of plant height, plant biomass and chlorophyll generated during the experiment

**Length of Lesson**

It will take 4-6 weeks to complete this lesson. Using seedlings rather than starting from seed starters will shorten this lesson (how much time you can save depends on what plants you select).

**Grade Levels**

Middle school (5-7th) and high school

**Standards covered (NGSS)**

Disciplinary Core Ideas:

* **MS-LS2-1**: analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations in an ecosystem
* **MS-LS2-4**: construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations
* **MS-LS1-5**: construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms

Cross Cutting Concepts:

* Patterns
* Cause and effect
* Structure and function

Science and Engineering Practices

* Planning and carrying out investigations
* Analyzing and interpreting data

**Materials**

* Seeds (lettuce, radish or basil)
* Seed starters (peat pellets, see photos below)
* 3 or 6 gallon containers (a Tupperware or a garbage can)
* Net pots (cut the lids of containers to fit the net pots). **Notice**: it’s better to have 6-15 net pots per containers (see photos below)
* Hydroton clay (see photos below)
* Solutions (please refer to “Resources” to learn how to prepare each nutrient solution)
* Aquarium air pumps and air stones
* pH paper or pH meter
* pH Up and pH Down (or prepare potassium hydroxide and hydrochloric acid by yourself)
* chlorophyll meter
* PPM meter/EC meter
* Aluminum foil
* Tape

**Background**

Plants uptake different mineral elements to grow and develop. Various symptoms, such as yellowing leaves and rotten sprouts, will occur when plants lack necessary nutrition. It is difficult, however, to observe those symptoms with fertilized soil as nutrients are ample and sometimes even excessive. Also, it is unclear how fertilizers ingredients (such as N, P and K) contribute to the metabolism of plants in fertile soil environments. With the help of hydroponics techniques, plants can be cultured in nutrient solutions that are absent of certain elements, which will allow students to watch corresponding unique deficiency symptom on plants and thus gain better understanding on the functions of fertilizers.

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Hydroponics is not a new concept. The origin of hydroponics could date back to around 600 B.C. The Hanging Gardens of Babylon was considered to design follow the principles of hydroponics. Francis Bacon (22 January 1561 – 9 April 1626), an English philosopher, published his work on growing plants without soil in 1627, which intrigued great research interests on hydroponics since then. In 1929, Frederick Gerick, a scientist of University of California Berkeley, successfully grew massive tomato in his back yard with nutrient solutions without soil. He is also believed to be the person who created the term “hydroponics”. Later on, Dennis Hoagland and Daniel Arnon, two other scientists from University of California Berkeley redeveloped Frederick’s formula and created the famous “Hoagland Solution”, which is still widely used today.

Compared to traditional soil cultivation, hydroponics has great advantages in water or resources limited area in the world. Japan, where arable land is at a premium, has at least 150 hydroponics factories at present. As hydroponic lettuce requires only 1% and 25% of the soil culture based water and fertilizer demand, Japan’s indoor farming will be able to produce 10% of the total national lettuce production in the future. Another example is Israel. As Israel is scant in water resource for crop production, Israeli has developed advanced hydroponics techniques long time ago in the dry and barren environment. Combining the drop irrigation method, both nutrients and water are provided at a predetermined rate given to the specific need of the crop, which is regarded as one of the most phenomenal advancements in agriculture within the past 30 years.

### Activities of the session

1. Go over all the lab supplies needed for this project.
2. Have a discussion on how to design this experiment: which plants to grow, how many plants to grow in each reservoir, how much nutrient solutions to use, what’s the function of each solution, etc.
3. Teach students to use seed starters and understand what germination rate is. Then plant seeds and discuss how to guarantee higher germination rates.
4. Assemble the hydroponics system and cover the containers with aluminum foil. Ask students: what is the volume of each container (reservoir)? What are the treatments? Why pH of the solution is important? Will concentrations and pH of the solutions change over time? What is the function of the air pump?
5. Weekly measurement of plant growth: the height of the plants, the leaves of the plants, element deficiency symptoms, the chlorophyll concentrations of the leaves.
6. Keep records on the changes of pH and PPM (part per million) or EC (electrical conductivity) of the solution for the first week. Learn the importance of refill solutions.
7. Maintain the hydroponics system appropriately every week.

**Resources**

* Leonard Machlis and John Torrey, Plants in Action: A Laboratory Manual of Plant Physiology, 1956, W.H.Freeman & Co., Sanfranciso, CA.
* Bruce Bugbee, Nutrient Management in Recirculating Hydroponic Culture, 2004, Acta Hort:99-112.
* Melissa Brechner, Floating Hydroponics: A Guide to Student Experiments Growing Plants without Soil, teacher’s guide, Cornell Science Inquiry Partnership program.

**Extensions and Modifications**

1. Covering the reservoir with Aluminum foil: the reason we do that is because we want to prevent algae. However, algae itself isn’t really “bad”. Algae can compete with plants for nutrients but this influence is actually very small. What does matter is the decomposing of dead algae would attract fungus gnats, which can induce severe fungal disease of plants such as Pythium.
2. In high school or higher levels, it would be interesting to analyze the nutrient dynamic in different plant tissues and design solutions formula based on the different element uptake rates by plants. That is actually what modern hydroponics companies and factories will do today.

**Assessment**

Students will be assessed based on the weekly lab report and final presentations (graph data and interpret the results). Please refer to the worksheet accompanies this course plan.