Soil Solutions

Nº. 79

SENIOR

Biology

LESSON SUMMARY

Students will explore how plant growth can be affected by soil and soil health.

FORESTS ONTARIO

Focus on Forests

Activity Information

Grade Level: Senior

Estimated duration: 4 to 6 weeks

Materials:

- Greenhouse potting mixture
- Up to 60 7.5 cm plastic pots (with drainage holes in the bottom) (* see Teaching Note #4)
- Pea seeds & soybean seeds (soak bean seeds overnight in water to speed up germination)
- Tap water
- Distilled water
- Waterproof marking pen
- Wooden tongue depressors
- Fertilizer (20:20:20 N, P, K) or another commercially available product
- Dilute acids (sulfuric and/or nitric)
- Salt
- Spray bottles with adjustable nozzles
- Cutting utensil (scissors/scalpel/razor blades)
- Ruler
- Copies of Instruction Sheet and List of Possible Treatments sheet (one per student or group of students)

Setting: Indoors

Key Vocabulary: Bioassay, soil acidity, saline, soil pH

Curriculum Links Grade 11, College Preparation (SBI3C)
OE F2.2 Investigate factors that affect plant growth
OE F2.3 Investigate how chemical compounds and physical factors affect plant growth

Learning Goals

1. Students will learn how factors such as nutrient availability, drought stress, and road salt can affect tree growth and health and consequently contribute to forest decline.
2. Students will employ scientific methods to test hypotheses

Teacher Background

There are many factors that can affect the health of a forest – including soil. Soil conditions can affect what nutrients are available for plant growth thereby influencing health. When looking to evaluate soil health there several factors to consider including soil type, possible nutrient deficiencies and drainage. In this lesson plan we will explore different ways soils can be affected by the environment (or people!) and how in turn, the condition of the soil affects plant growth.

The following six treatments have been selected to mimic various soil conditions:

1. Control (No Treatment)
2. Drought
3. Flood
4. Application of Fertilizer
5. Acidic soil
6. Saline soil

Each of these six treatments affects the way a plant grows and the control treatment will have no additives. This type of experiment is known as a bioassay, which is a test of a particular unknown variable (ex. amount of plant growth) using the performance of a living organism as an indicator. It is necessary to compare the test results to some standard or control (a known variable). In this experiment, pea and bean seedlings will be used as test organisms to evaluate reactions of plants to various environmental conditions.

Plant Nutrients:

Primary – N P K

Secondary – Ca Mg S

Micro-nutrients – Cl Mn I Cu Zn Mo B Fe V Cr Co Ni Sn Se Ag Na Si Se F

Constitutive elements – C H O

Toxic Elements:

Li Be Al

Drought treatment

When water is limited the basic functions of plants can be disrupted. A lack of water can affect not only a plants ability to perform photosynthesis and transpiration but also its ability to stay straight and tall. Some plants have mechanisms to mitigate drought conditions, these plants are seen as being "drought tolerant".

Symptoms of drought stress include: wilt, death/damage, decreased growth, chlorosis (yellowing of the leaves), and leaf scorching (browning on the outer edge of the leaves or in between the veins), (see figure 1).

Flood treatment

Although water is vital for life, too much water can be harmful as well. If soil has too much water in it, oxygen is driven out. In turn this means that the roots do not get enough oxygen to perform basic functions, such as respiration. This causes photosynthesis to be disturbed, allowing a build-up of toxic gases around the roots (such as carbon dioxide, hydrogen gas, methane, and nitrogen).

Symptoms of flooding stress include: yellowing or browning of leaves, wilting, decreased growth and leaf size, leaves die and fall off, and leaves curl.

Fertilizer treatment

Adding fertilizer to the plant should increase growth, by providing all the nutrients plants require for growth. Unless too much fertilizer is applied, there should be no negative affects to the plant.

Acid treatment

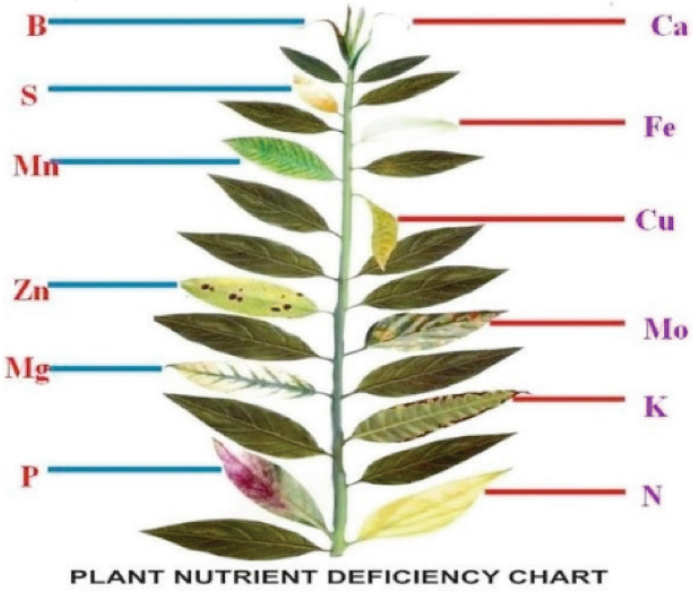
pH is an indication of acidity or alkalinity of soil and it is measured in pH units. The pH scale is a logarithmic scale that represents the concentration of hydrogen ions in an aqueous solution (a solution that has been dissolved in water). The scale goes from 0 (acidic) to 14 (basic), with 7 being neutral. Acidic soil has a higher concentration of H+ ions and the pH values are less than 7; basic soil has a pH above 7 and a lower concentration of H+ ions.

For plants, the pH of the soil is important because the availability of the nutrients that plants require will change at various pH levels. Changing the pH can alter the solubility of nutrients and the chemical form they take. Most plants prefer a pH between 5.5 and 7.5, because in this pH range, the nutrients plants require are at the right concentration and can be easily taken up by the roots of the plant.

The nutrients required by plants can be placed into three basic categories: primary nutrients, secondary nutrients and micro-nutrients (nutrients that the plant needs at small concentrations but that become toxic at higher concentrations). Once you get below a pH of 5.5 the micro-nutrient concentration can increase to dangerous levels, and the primary and secondary nutrient levels become less soluble and potentially decrease to levels of deficiency. Additionally, as the pH drops the solubility of toxic metals increases (such as Al and Mn). Once a pH of 4 is hit, there will be an excess of H+ ions which can start to damage the root membranes. Therefore, maintaining the appropriate pH for a particular plant is very important. When plants do not receive the nutrients they require they can start to decline in health and exhibit a variety of symptoms.

Symptoms of acidic soil: decreased growth.

Deficiencies – Phosphorous (reddish-purple leaves), Nitrogen (yellowing from the tip of the leaf down the middle (main vein), Magnesium (whitish strips along the veins), Potassium (orange-to-yellow-to-green leaves, from tip to center; and the leaves on the lower levels of the plant die off), Calcium (necrosis, premature death of living cells, often a dark brown colour; curling leaves), Sulfur (pale yellow or light green leaves)



Determining nutrient deficiencies by appearance (Big Picture Agriculture, n.d)

Saline treatment

Although salt is important in small quantities, it can be toxic at higher concentrations. If there is too much salt in soil, the water potential can be decreased making it difficult for the plant to take up water with its roots. This causes drought-like conditions within the plant, even if water is readily available. You may see salt stress on the trees in your neighbourhood due to road salt.

Symptoms of salt stress: *see drought symptoms

Teaching Notes

1. Seedlings must be planted, allowed to germinate and thinned to two plants per pot before commencing treatments. This can be done in advance of the students' experiment if class time is limited.
2. Ensure that the greenhouse soil mixture consists of peatmoss, vermiculite and potting soil.
3. Two types of seeds will be used in this experiment. Peas do best in a pH of 6.0-7.5 and soybeans do better between 5.5 and 6.0. Because the two plant species prefer different pH levels, we will be able to see if the pH preference of a plant plays a role in their tolerance for acidic soils. Although tree seeds are preferable, seeds of forest trees are usually difficult to obtain and prepare for germination.
4. Following planting, pots should be placed in an area with a lot of light (a combination of fluorescent and incandescent lights or 'grow' lights is preferable). Use the school greenhouse facility, if available. If 60 pots cannot be accommodated, the experiment can be reduced in size (see List of Possible Treatments). You may choose to plant only three replicates of each treatment or increase the replicates to 10 for a larger class. To simplify things, you may wish to plant only one sensitive species, such as soybean.

5. Plants will receive treatments for a period of four to six weeks after germination. The List of Possible Treatments should be posted on a wall near the pots for reference. The students can inspect and treat their plants at the beginning of the classroom period and then move on to other projects. Treatment should only take a few minutes. Make sure someone is responsible for extra watering and care between periods. Note that if the plants receive two or three exposures to the acidic or saline solution per week, then those treatments may end earlier. As well, after a certain point, the plants may become pot-bound and the results of the experiment will be influenced by and nutrient depletion.

At the conclusion of the experiment, weighing and measuring the plants will take one laboratory or classroom period. In order to avoid biasing the results, consider having students analyze a treatment other than the one that they were responsible for planting. Compile the data and distribute it for discussion in a subsequent period.

Advance Preparation

1. Copy and distribute the Instruction Sheet and the List of Possible Treatments.
2. Divide the class into groups - for example, five groups with each group responsible for planting 12 pots.
3. Prepare the acidic and saline solutions ahead of time for your students. Ensure that students observe all safety precautions when using these solutions. Make sure that students wear eye goggles and plastic gloves when spraying the acidic solution, even though accidental exposure will not immediately cause acid burns.

Activity - Instruction Sheet

1. Plant the seeds

a) Ensure that all plastic pots have adequate drainage holes in the bottom to prevent waterlog (for treatment 3, it is recommended to block some of the drainage holes after germination to better mimic a flooded situation).

b) Refer to the List of Possible Treatments for the pots you will be planting.

c) Begin by labelling each pot using a waterproof marking pen and sticky tape (or wooden sticks if tape is not available). Include the treatment name and species of plant.

d) Fill each pot three-quarters of the way with soil.

e) Be sure to add the same amount of soil to each pot. You can use a calibrated paper cup for this purpose.

f) Moisten the soil.

g) Plant four seeds on the soil surface in each pot. Be sure to space the seeds evenly and avoid the edges of the pot.

h) Add enough soil to cover the seeds, as per planting instructions (refer to seed envelope).

i) Water the soil until the excess water drains out the holes in the bottom of the pot. Be sure to water gently to avoid moving the buried seeds.

j) Design and follow a plan for accommodating all the groups of pots in the greenhouse or on the growth bench.

2. Weigh and measure the seedlings

To evaluate the effects of the various treatments, use fresh weights of both the shoot and root portions of the seedlings. In scientific research, it is a common practice to measure oven-dry weights of plants, but this procedure is more time-consuming and requires the use of a drying oven. If time allows, you can also measure the height of the plants from the soil line to the tip of the growing apex. This can be done prior to harvesting. Design a table to record your data. Your table should include a column to record observations concerning the appearance of leaves. Note any abnormal colouration or necrotic spots or lesions (areas of dead cells) that have developed as a result of the treatments.

a) After measuring the height of the seedlings, cut off the (green) shoot portion of the plant using scissors (or a scalpel/razor blade, as mentioned above).

b) Weigh the shoot on a top-loading balance, to the nearest tenth of a gram (more decimal places maybe used, depending on the precision of the balance).

c) Empty the pot, soil, and root portion into an enamel tray. Shake the soil loose from around the roots. A soft paint brush may be useful for cleaning soil particles that adhere to the roots. You will not have enough time to do a really thorough job. If soil is particularly sticky, you may have to wash the roots in a very gentle stream of tap water. Excess water should be dried off.

d) Weigh the root portion of the plants on the top-loading balance (see above).

e) Record your data and calculate the average values (mean of 5 replicate pots) for each treatment.

List of Possible Treatments

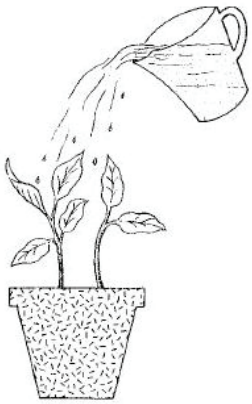
Treatment	Description
1. No Treatment	This is the control group, which receives no treatments. Pots should be watered daily with distilled water, which will be approximately pH 7.0. After watering the soil should be moist but not waterlogged.
2. Drought Stress	This group receives infrequent watering. Pots should be watered every three days or at the point of wilting. Young seedlings will need to be watered somewhat more frequently or they will die, especially if they are grown in a greenhouse environment.
3. Flood Stress	This group does not receive any less water than the other groups (omitting treatment 2). However, they will have the drainage holes at the bottom of the pot blocked off so that excess water cannot drain out. If the water is still there the next day it is not necessary to water it again. It is only to maintain the flooded soil conditions.
4. Fertilizer Amended	This group of pots will receive extra nutrients. You will test what effect fertilizer has on the plants. Once seedlings are established, fertilize once per week or according to product directions. Avoid over-fertilizing, as this may burn the foliage.
5. Acidic treatment	Using distilled water; adjust the pH to 4 using dilute sulfuric acid. Wear eye goggles and plastic gloves when spraying this solution, even though accidental exposure will not immediately cause acid burns. Water with acidic solution two or three times per week. Spray the solution directly into the soil; try not to get any on the plant tissue.
6. Saline treatment	Make a 10% salt water solution using NaCl, as it is commonly used as road salt. To make a 10% salt water solution, you must first make a 100% salt water solution Heat up a jar of distilled water to just above room temperature. Slowly add salt tablespoons one at a time. Ensure the salt completely dissolves before adding another tablespoon. Once the salt does not dissolve, your solution is ready. To make your 10% salt water solution, you must add 1 part 100% salt water solution to 9 parts distilled water. Spray the solution directly into the soil; try to avoid getting any on the plant.

Summary of Treatments

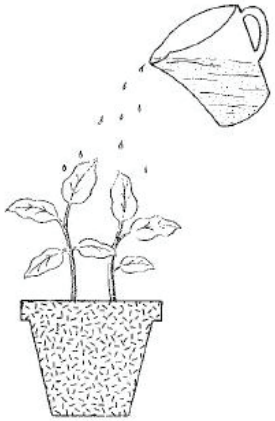
Treatments	Soil Type	Plant Species
• **No Treatment** • **Drought** • **Flood** • **Fertilizer** • **Acidic** • **Saline**	• Greenhouse Mixture	• Pea • Bean

Total number of treatments

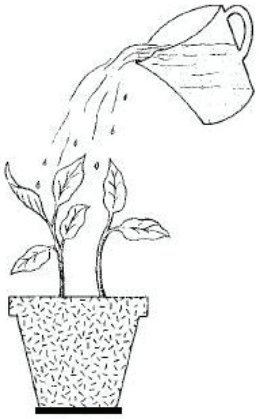
6 treatments x 1 soil type x 2 plant species = 12 groups
12 groups x 5 replicates per group = 60 pots



Treatment # 1
(pH 7.0)



Treatment # 2
(Infrequent watering)



Treatment # 3
(Water not drained)

Treatment # 4
(Fertilized)

Treatment # 5
(Low pH)

Treatment # 6
(Saline)

Extension: Discussion Questions

After the experiment, ask the students to answer the following discussion questions.
This can be done as a class or in groups.

1. Based on the results of this experiment, discuss the advantages and disadvantages of using a bioassay technique to investigate scientific hypotheses. How applicable are these data to real life situations?
2. Which of the treatment combinations had the most (positive or negative) effect on seedling growth and development? Rank the stresses that you studied in this experiment according to degree of severity. Did either plant species show extreme sensitivity to one of the treatments?
3. How did the plants respond to the addition of fertilizer? Are there any practical benefits that you can see to fertilizing trees in natural field situations? Any problems?
4. Based on the data from your experiment, make suggestions for future research on tree decline in your area.