TEACHING KATE

TEACHING KIDS ABOUT THE ENVIRONMENT

TO BEAN OR NOT TO BEAN
(EFFECTS OF SOIL COMPOSITION OF PLANT GROWTH)

Grade Level: 9-12 **Time Required:**

SC Science Standards

This lesson plan was correlated with only the grade level specified unless otherwise noted.

I. A. 1, 2
I. B. 1, 2, 10
IV. C. 3. a. 1, 2

Note: This activity also applies to the 7th and 8th grade standards.

Grade 7:
I. A. 1. a. 1
I. A. 2. b, f, h
I. A. 3. a
I. A. 5. a, b, c
I. A. 7. a
III. A. 2. a, b
III. A. 7. a

Grade 8:
I. A. 1. c. 1. a
I. A. 1. d. 1
I. A. 2. d, f, h
I. A. 3. a
I. A. 5. a, b, c
I. A. 7. a

Purpose

Students shall demonstrate the effects of soil composition, or soil texture, on plant growth. They shall determine pH of soils using soil pH test kit. Students shall examine root structure and determine how soil composition affects root structure.

Skills

Deduction, interpretation, measurement, observation, record keeping.

Concepts

Pore space in soil, clay as the active ingredient in soil, determinants of soil texture, germination and growth of plants.

Materials Needed

Soil pH Test Kit	Rubber Bands
Seeds (bean or other legume)	Observation/Record Sheets
3-inch Squares of Netting	Sand
Rulers	Silt (if available) 50-ml Graduated Cylinders
Loam	Plastic Wrap
Plastic Pots Approximately 4" Deep	Plant Cart With Grow-Light or Sunny Window
Dissecting Probes, or Pencils and Toothpicks	Clay

Plastic Bags to Serve as "Runoff Collectors" Under Pots
Soils Mixed From Different Proportions of Sand, Silt, and Clay

Definitions of Terms

<u>Soil Texture</u>	Relative proportions of the three particle sizes – sand, silt, and clay – in the soil.
<u>Sand</u>	Soil particles measuring 0.05-2.0 mm.
<u>Silt</u>	Soil particles measuring 0.002-0.05 mm.
<u>Clay</u>	Soil particles measuring less than 0.002 mm; most active soil component.
<u>Nutrient</u>	Substance required by organisms for normal growth and activity.
<u>Pore Space</u>	Spaces between soil particles.
<u>Soil Permeability</u>	The rate at which water and air move from upper to lower soil layers.
<u>pH</u>	Numeric value that indicates the relative acidity or alkalinity of a substance on a scale of 0 to 14, with the neutral point at 7. Acid solutions have pH values lower than 7; and basic, or alkaline, solutions have pH values greater than 7. The pH scale is based on the concentration of H^+ (hydrogen) ions in an acid and OH^- (hydroxyl) ions in a base.

Water Holding Capacity — A function of pore size and permeability of soil, indicating the amount of water present in saturated soil.

Cation — Positively charged ion.

Anion — Negatively charged ion.

Before the Session

Before this activity students should be given an explanation of pH. Define pH and explain that the pH scale is a logarithmic scale. For example, a solution of pH 6 has ten times more hydrogen ions per liter than a solution of pH 7. Using a pH meter, the teacher may demonstrate how the pH of an acid (ex: vinegar) differs from that of a base (ex: bleach). Students should be exposed to a discussion of soil composition, porosity and permeability. Students should also be involved in a discussion of why most plants require soil or other necessities for growth such as: nutrients, anchoring for plant, water.

Background Information

Soils vary in color, content, pore space, acidity (pH) and depth. Most plants are grown in soil, and thus provided with the water and nutrients required. Plant nutrients include nitrogen, carbon and other elements such as phosphorus, potassium and magnesium, as well as assorted trace minerals.

Soil texture is determined by the content of different sized particles. Soil particles fall into three size groups: sand (0.05-2.0 mm), silt (0.002-0.05 mm) and clay (less than 0.002 mm). Mixing the particles in different proportions yields soils with textures described as sand, clay or loams. (See worksheet: Soil Triangle). Loams contain some of each of the three basic soil particle types.

The soil texture "helps determine soil porosity - a measure of the volume of pores per volume of soil and the average distances between these spaces. A soil with a high porosity can hold more water and air than one with a lower porosity. The average pore size determines soil permeability: the rate at which water and air move from upper to lower soil layers. Soil porosity is also influenced by soil structure: how the particles that make up a soil are organized and clumped together." Tyler, 268.

Sandy soils have less pore space, larger pores, and higher permeability than other types of soil; therefore water flows through quickly. This means that sandy soils have low water holding capacity.

Clay particles are the smallest, have more pore space per volume of soil, and greater water-holding capacity than sandy soils. However, because the pore sizes are so small, clays have low permeability. Because of the low permeability, water moves very slowly through to lower levels and upper layers easily become waterlogged.

Clay is the most active component of soil, responsible for the majority of chemical activity in the soil. Clay particles are multi-layered, with many different elements in them, mostly silicon and aluminum oxides, making approximately twenty-one layers. Other components are held within those layers.

"Soil clays ordinarily carry electronegative charges, which are the result of one or more of several different reactions." Tan, 160. Some of the reactions involve substitution of atoms in the crystal structure for other atoms without affecting the crystal structure. This process occurs only between atoms of almost equal sizes and when the difference in valence does not exceed one unit.

Other reactions in clays are dissociation reactions that release protons (H^+). The dissociation reactions depend on the soil pH. Reaction rates generally increase as pH increases and decreases as pH decreases. Most plants grow best in soils with a slightly acid pH. However, some plants grow best at pH values ten times as acid as where most other plants grow. In the pH range of 6.0 to 7.0, nearly all plant nutrients are available in optimum amounts. Soils with a pH below 6.0 will have a lower nutrient availability. Some plants, such as blueberries and cranberries, prefer and actually grow best at the lower pH (more aidic) values. These plants interact with their environment and obtain all the nutrients they need.

The particles exchanged by clays in substitution reactions are very often cations. "Cation exchange is of great importance in 1) soil fertility, 2) fertilizer application, 3) nutrient uptake and 4) environmental quality." Tan, 165. Under natural conditions the most common cations in soil are H^+, Ca_2+ , Mg_2+, K^+, and Na^+. These cations replace each other depending on soil conditions. When H^+ is replaced or released, the soil becomes more acidic.

"The exchangeable cations serve as storage for large quantities of available nutrients for plant growth. Plant roots obtain the adsorbed cations by cation exchange. The exchanged material used by roots is H^+." Tan, 166.

"The presence of clays with their cation exchange capacity provides a buffering capacity. Because of the electrical charge and high surface area, clays adsorb a variety of chemical compounds entering the soils as products of microbial reactions, as organic waste, gas, heavy metals, and other pollutants. By adsorption to clay surfaces, many toxic metals are immobilized and/or precipitated into less harmful solid compounds. The clay will intercept a variety of pollutants trickling down the soil with the percolating water. These pollutants will be removed by clay because of cation exchange before they reach the ground water. Consequently, clay acts as a purifying agent in nature and increases the quality of soil and ground water." Tan, 166.

Suggested Lesson Plan

1. Divide class into groups of two or three. Have groups pick a group name that pertains to soil in some way. Assign each group a soil type to work with.

2. Each group will obtain 2 Group Lab Sheets, one pot, 3 or 4 bean seeds, a graduated cylinder, and a piece of netting. Place the netting in the bottom of the empty pot to prevent the soil from falling out.

3. With assigned type of soil, they will fill pot to a depth of 3 inches, tapping pot gently on table top to settle the soil. Students will test soil type to determine its pH, following the test kit instructions and record pH on lab sheet.

4. Have students plant the bean seeds approximately 0.75 inch deep, and at least 1 inch apart.

5. Groups will place pot in plastic bag and use a rubber band to attach the bag under the top rim of the pot. This will serve as a "runoff collector."

6. Instruct them to add 50 ml water to the pot, being careful not to displace the soil. Allow excess water to drain from pot, overnight if possible. Some soils will take several hours to wet.

7. Groups will measure the water in the runoff collector by pouring the water into the graduated cylinder. Record your results on your lab sheet. Then pour the water back into the pot.

8. Instruct students to cover pot with plastic wrap and place in the plant cart or a sunny window. Check the pot every 2 days to be sure soil stays moist until the seeds germinate. As soon as the seeds have germinated, remove the plasticwrap from the pot. Groups should be careful not to allow plastic wrap to remain on pots too long, as this will encourage some disease problems.

9. These instructions should be followed by groups every Monday, Wednesday and Friday for the duration of the experiment (30-45 days).

    a. Add 50 ml of water, let excess water drain for 5 minutes, and measure runoff. Pour runoff in the sink.

    b. Measure and record the height of the plant.

    c. Note other observations about plant (color, condition, etc.)

Note

The amount of water added may need to be adjusted if plants begin to wilt too quickly or there is no runoff. If so, notify all students so that all plants are exposed to the same amount of water.

10. At the end of 30-45 days students will:

    a. Observe all plants grown by the class. Make notes of your observations on the Class Data Sheet you receive.

    b. Cover table top with newspaper.

    c. Dump any water in the runoff collector in the sink.

    d. VERY CAREFULLY, turn pot sideways and tap on tabletop to remove plant and soil.

    e. Using a dissecting probe or toothpick, begin to remove soil from the plant roots. Try to remove as much soil as possible without tearing the roots. **BE CAREFUL!**

    f. Observe the root structure.

       (1). Sketch the roots.
       (2). Write a description of the root structure (is there a pattern?).

    g. Observe root structures of plants grown by other groups.

    h. Clean up table, throwing away soil and plant material. Rinse pot and place where directed.

11. Instruct each student to record the data from all groups including his/her own on the Class Data Sheet. Answer the discussion questions.

Application

Most plants grow best in a loamy soil, whether they are grown as agricultural crops or potted house plants. Students may apply what they learn when caring for a vegetable garden, flower beds, potted plants or their own lawn.

Gardeners may have their soil tested for pH and nutrient levels by their county extension service. With the results of those tests, they can decide what needs to be added to the soil to maximize crop yield. Different crops require different nutrient mixes. Flower beds are similar to garden crops in this respect. Home owners who are planting a lawn or have problems with their lawn may also benefit from having their soil tested. The test results will help them decide what type fertilizer is needed, or if an application of lime is called for to raise the pH.

People growing house plants can mix their own potting soil using different proportions of sand, clay, and silt instead of purchasing commercial potting soil.

Resources Available

Cox, Keith. July, 1994. Latta High School, Latta, SC.

Felder, Rick. July, 1994. South Carolina Department of Natural Resources.

Kessler, Dr. George D. July, 1994. Clemson University Cooperative Extension Service.

Environmental Science: Sustaining the Earth. 1991. G. T. Miller. Wadsworth.

Environmental Soil Science. 1994. K. H. Tan. Marcel Dekker.

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DISCUSSION QUESTIONS

Name: Date: Group:

I. List 3 plant nutrients.

II. Which soil type has the most pore space?

least pore space?

III. Which soil type has the largest water holding capacity?

lowest water holding capacity?

IV. Rank the soil types from most acidic to most basic.

V. Is there a correlation between the list in IV and the growth patterns of the plants? Write a hypothesis explaining your answer.

VI. List the soil particles in order from largest to smallest.

VII. In which soil type did plants grow the most? Why?

VIII. In which soil type did plants grow least? Why?

IX. In which soil type did the plant have the —

most extensive root system?

least extensive root system?

Why do you think this occurred?

X. "Clay is the most chemically active soil ingredient because it is responsible for most ion exchange." Relate your indings to the statement above. Is the statement true?

XI. If you were going to plant and raise beans as a cash crop, what soil factors would you consider in looking for suitable land?

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SOIL TEXTURE

Name: Date: Group:

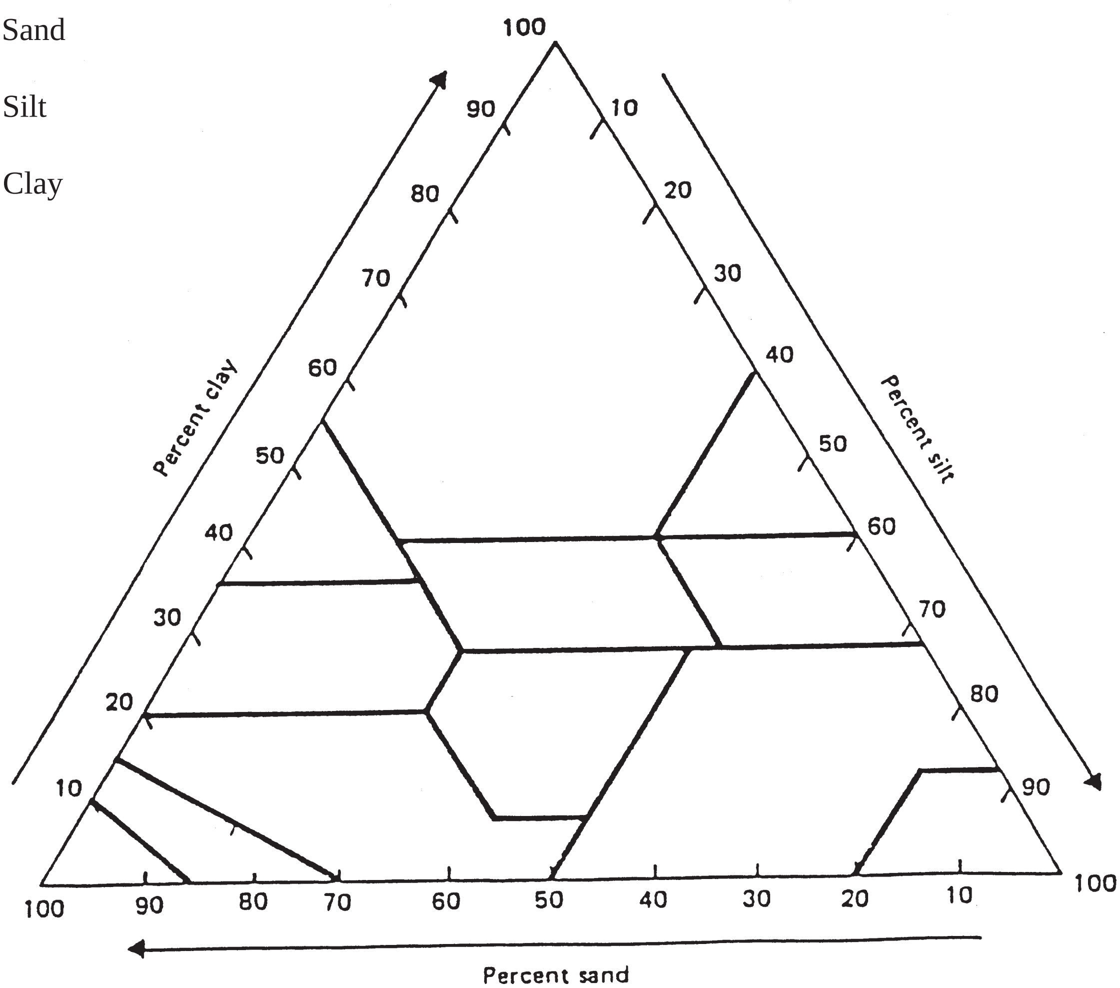
I. Label all of the following:

A. All Loams

B. Sand

C. Silt

D. Clay



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SOIL TEXTURE
TEACHER'S GUIDE

Name: Date: Group:

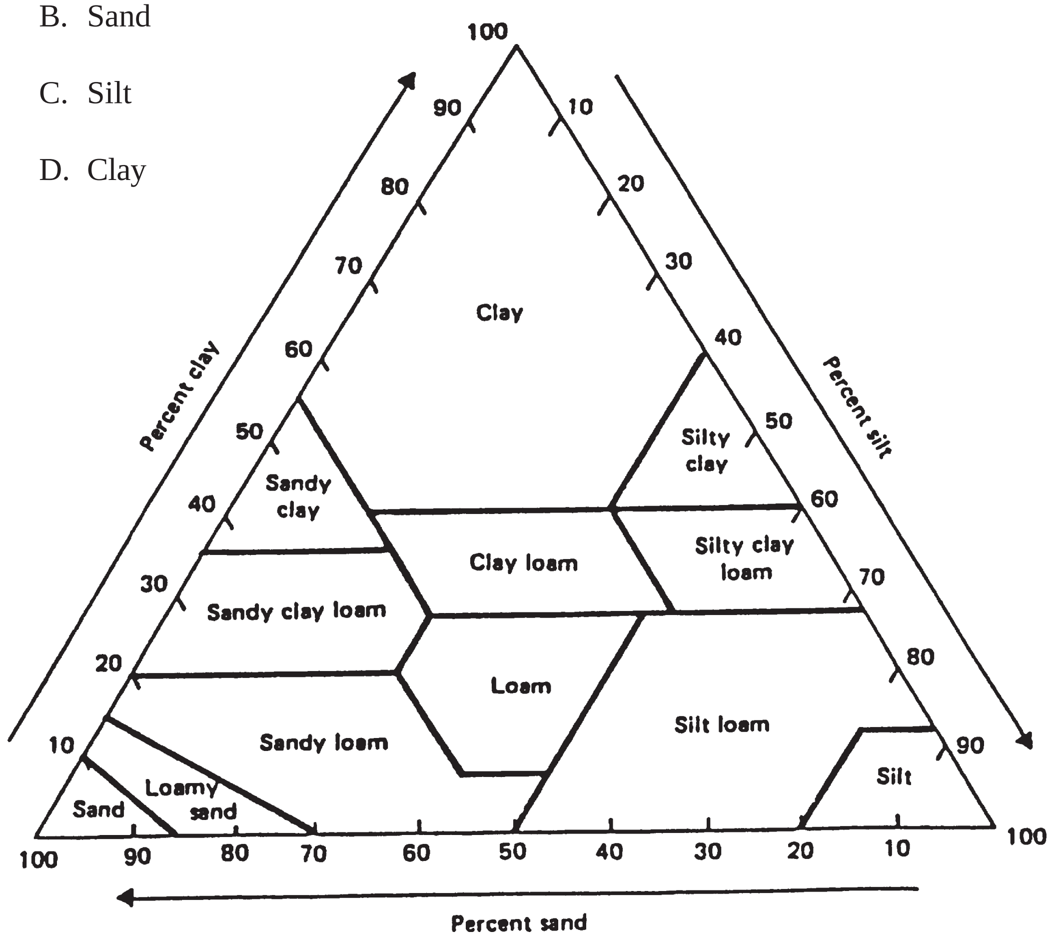
I. Label all of the following:

A. All Loams

B. Sand

C. Silt

D. Clay



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GROUP LAB SHEET

Name: Date: Group:

I. Soil Type________________________________

II. Soil pH

A. Wet____________________ B. Dry_____________________

III. Data Collected.

Date	Runoff Water (ml)	Plant Height (cm)	Increase in Plant Height (cm)	Other Observations

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GROUP LAB SHEET (CONTINUED)

Name: Date: Group:

III. Data Collected. (continued)

Date	Runoff Water (ml)	Plant Height (cm)	Increase in Plant Height (cm)	Other Observations

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CLASS DATA SHEET

Name: Date: Group:

I. Data collected.

Group Name	Soil Type and pH	Average Runoff (ml)	Total Plant Height (cm)	Root System