Soil Chemistry: Plants' Soil pH Preferences

Principal concept:
This activity introduces the concept of pH, a measure of chemical activity in soil. Soil pH is an important factor in agricultural production.

Grade levels:
This activity is appropriate for grades 6 – 12.

Performance Standards:
This project meets the following Next Generation Science Standards:
MS-PS1-2: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
PS1.B: Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
LS1:B: Genetic factors as well as local conditions affect the growth of the adult plant.
MS-LS4-5: Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits of organisms.
LS4:B: In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.

Summary:
The Earth's surface varies greatly from place to place. About 70% is covered by water while the remaining 30% features landforms such as mountains, deserts, plains, plateaus, marshes, and valleys. Only a small portion, approximately 11%, of this land can be used for growing crops because of climate, topography, and soil quality issues. The chemical condition of soil is an important consideration for agriculture, and soil pH is one of the most important chemical properties.

The pH level in soil is a measurement of how basic or acidic soil is. pH is determined by the concentration of hydrogen ion, the term pH meaning *power of hydrogen.* Acids have a pH of 0 - 6 because they have excess H+ molecules, and bases have a pH of 8 - 14 because they have

excess OH- molecules. Pure water is considered neutral with a pH of 7 and is neither acidic nor basic. A pH scale provides a visual way of measuring acids and bases.
Indicators are used to measure pH because they change color in the presence of acids and bases. Some plant pigments found in, for example, red cabbage, hibiscus, and red grapes, are natural pH indicators. The indicator found in red cabbage is anthocyanin and this pigment reacts with both acids and bases. Strong acidic solutions turn the anthocyanin red, and strong bases turn it greenish-yellow. Weaker acids create a pinkish-purple color, and weaker bases create a deep blue color. Therefore, it is possible to determine the pH of a liquid based on the color it turns the anthocyanin in the red cabbage juice.

pH levels are of great interest in agriculture as plants are unable to grow successfully outside of a preferred pH range. In acidic soils, aluminum and manganese in the soil are dissolved by the acids. The dissolved metals bind with critical plant nutrients such as calcium and phosphate making them unavailable to the plants' root systems. Plants trying to grow in a soil with a high pH can also suffer; basic soils prevent vital nutrients from dissolving enough for plants to fully absorb them.

Acid soils limit crop production on 30 to 40% of the world's farmable land, and aluminum toxicity is the single most important factor. Although the aluminum problem can be improved through the surface application of agricultural lime, this is not practical in all parts of the world due to the expense of application. The combination of lime application and the development of more tolerant plants are the most effective strategies to combat acid soils.

Vocabulary:
soil, pH, acid, base, neutral, indicator, pH scale, physical properties, chemical properties

Prior knowledge:
Students need to be aware that plants require important nutrients that must be gathered through their roots. These nutrients are dissolved in water in the soil, thus any factors that prevent the absorption of the nutrients will harm the plants. Plants will not grow successfully if there are soil conditions that prevent the absorption of these dissolved nutrients.
Students need to be aware of the organization of a chemical reaction and know key terms such as reactants and products. Students should also be aware of the conservation of matter within chemical reactions by understanding that the atoms that make up the reactants side of the equation regroup to form the products. Students should understand that no matter is created nor destroyed in a chemical reaction.

Class time required:

45 minutes

- 5 minutes for scientist introduction and materials distribution.
- 5 minutes for students to prepare dirt, distilled water and cabbage juice mixture in vials.
- 15 minutes for lecture/PowerPoint while allowing the color reaction to occur in vials.
- 5 minutes for cleanup.
- 15 minutes for discussion and worksheet completion.

Materials: (per group of 3 to 4 students)

- 2-25 mL graduated cylinders
- 4 flat-bottomed vials
- 1 plastic bottle with squirt top containing 25 mL cabbage juice
- 1 plastic bottle with squirt top containing 100 mL of distilled water
- 4 plastic 3 oz. (88.7 mL) Dixie cups
- 4 coffee stirrers
- 4 small funnels
- 1 black mat
- 1 laminated student handout with pH scale and plant pH preference table
- Student analysis sheets (1 per student)
- 12 Crayola watercolor pencils
- Safety glasses

Materials for entire class:

- 4-4 oz (118 mL) plastic containers of soil samples containing 4 T (59 cc) of soil
- envelopes of premeasured chemicals clearly marked A, B, C, D stored in matching soil container
- 4 (5 mL) teaspoon scoops, one for each bag of soil

Preparations prior to class

1. On arrival in the classroom, empty the envelopes of pre-measured chemicals into the appropriate containers of soil. Replace the lid and vigorously shake for 15 seconds in order to distribute the chemicals throughout the soil. DO NOT mix ahead of time to avoid buffering.
2. Distribute the four containers in four separate locations in the room, creating stations.
3. Place one scoop beside each soil container.
4. Distribute the equipment bag, handouts, and worksheets to each group.

Procedure for students

1. Place a level scoop of each soil sample in the appropriate cup at each of the four stations.
2. Pour soil through the funnel into the matching vial.
3. Add 20 mL of distilled water to each of the vials.
4. Stir each vial with its own coffee stirrer for 5 seconds. Discard the stirrers and the Dixie cups.
5. Measure 5 mL of cabbage juice into each of the vials.
6. Observe the color changes (it may take up to 15 minutes for a complete color change).
7. View the PowerPoint.
8. Look at the order of colors on the pH scale on the handout and color in the blank scale on the worksheet showing the four observed colors in the vials.
9. Label each color with the letter of the soil that produced that color.
10. Complete the worksheet as directed by your teacher.
11. Obtain Exit Card #'s 1 and 2 to complete outside of class.
12. Return the laminated sheets to your teacher.

Assessment:

Students complete the worksheet:

- color and label the pH scale with their observations.
- complete the crop pH preference data table.
- respond to the short answer questions.

Teacher notes:

- Caution students to leave the vials undisturbed while the color reaction occurs.
- Slight variations in colors among the groups may occur. However, there should be a pink (pH 4), a purple (pH 6), a blue (pH 8), and a green (pH 10).
- The teacher will need to circulate around the room to assist with accurate measurement and careful handling of materials.
- During the PowerPoint, as you ask students various questions, allow time for discussion. For example, in slide 27, ask students about the different technologies that they have prior knowledge of that addresses how and why human influence

  If time permits, direct students to observe the soil layering at the bottom of the vial and the organic debris floating at the top. Allow students the opportunity to hypothesize why this layering effect is taking place. (The soil will layer by density with sand at the bottom, silt in the middle, and clay at the top. The sand and silt may not be clearly separated as the sand may pull the silt down with it.) Once adequate guessing occurs, you can verify their answers.

Kit preparation by Outreach personnel:

- Mark Dixie cups , 4 oz containers, envelopes, and vials with letters A, B, C, D corresponding to soil samples.
- Funnels will need to be relatively small with large outlets in order for soil to drop easily into vials.
- The measured chemicals need to be placed in small plastic envelopes that are stored in the appropriate containers of soil.
- The following chemical measurements are needed per 4 T (59 cc) of soil:
  - Soil sample A:
    - pH of 6: a pinch of sodium bisulfate.
  - Soil sample B:
    - pH of 8: no chemicals added.
  - Soil sample C:
    - pH of 10: 1/8 tsp. of sodium carbonate.
  - Soil sample D:
    - pH of 4: slightly less than ¼ tsp. of sodium bisulfate.
- To rehydrate red cabbage powder, mix 1 pinch into 200 mL of distilled water.
- Be sure to rinse all new plastic ware with distilled water before first use.