Course	Agricultural Science II
Unit	Soil Science
Lesson	Soil Chemical Properties
Estimated Time	50 minutes

Student Outcome

Explain how plants exchange anions for cations.

Learning Objectives

1. Explain the importance of cation exchange capacity (CEC).
2. Explain what CEC is.
3. Explain how CEC is calculated.
4. Identify the soil properties which affect CEC.
5. Explain what soil pH is.
6. Explain how pH relates to productivity.
7. Explain the factors which cause pH to change.
8. Explain how soil pH can be adjusted.

Grade Level Expectations

SC/ME/1/B/09-11/b SC/ME/1/E/09-11/a SC/ME/1/E/09-11/c

SC/ME/1/F/09-11/c

Resources, Supplies & Equipment, and Supplemental Information

Resources

1. PowerPoint Slides
   - PPt 1 – Negatively Charged Clay Particle (Micelle)
   - PPt 2 – pH Scale
   - PPt 3 – How Soil pH Governs Nutrient Release
2. Minor, Paul E. *Soil Science* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1995.
3. *Soil Science Curriculum Enhancement.* University of Missouri-Columbia: Instructional Materials Laboratory, 2003.

Supplemental Information

1. Internet Sites
   - Chemical Properties of Soil. Tree Fruit Soil and Nutrition, Tree Fruit Research and Extension Center, Washington State University. Accessed May 16, 2008, from http://soils.tfrec.wsu.edu/mg/chemical.htm.
   - Soils Basics: Part II – Chemical Properties of Soil. University of Massachusetts Extension. Accessed May 16, 2008, from http://www.umassvegetable.org/soil_crop_pest_mgt/soil_nutrient_mgt/soil_basics_II.html.
   - Soil and Water Publications. University of Missouri Extension. Accessed May 16, 2008, from http://extension.missouri.edu/explore/agguides/soils/.

2. Print

- Ashman, Mark R., and Geeta Puri. *Essential Soil Science: A Clear and Concise Introduction to Soil Science.* Malden, MA: Blackwell Publishing, 2002.
- Brady, Nyle C., and Ray R. Weil. *The Nature and Properties of Soils.* 14th ed. Upper Saddle River, NJ: Prentice Hall, Inc., 2007.
- Coyne, Mark S., and James A. Thompson. *Fundamental Soil Science.* Clifton Park, NY: Delmar CENGAGE Learning, 2005.
- Donahue, Roy L., and Roy Hunter Follett. *Our Soils and Their Management*. Danville, IL: Interstate Publishers, Inc. 1990.
- Plaster, J. Edward. *Soil Science and Management.* 2nd ed. Albany, NY: Delmar Publishers, Inc., 1992.
- White, Robert E. *Principles and Practice of Soil Science: The Soil as a Natural Resource.* 4th ed. Malden, MA: Blackwell Publishing, 2005.

Interest Approach

Why are some soils more productive than others? Use the bank account approach to illustrate this. As the plants grow they draw checks from the bank. Thus, if the total amount of calcium carbonate (lime) in the soil was 1200 lbs per acre and if alfalfa removed 120 lbs each year, there would be enough lime to last 10 years.

Communicate the Learning Objectives

1. Explain the importance of cation exchange capacity (CEC).
2. Explain what CEC is.
3. Explain how CEC is calculated.
4. Identify the soil properties which affect CEC.
5. Explain what soil pH is.
6. Explain how pH relates to productivity.
7. Explain the factors which cause pH to change.
8. Explain how soil pH can be adjusted.

Instructor Directions	Content Outline
Objective 1 *Ask students why soils with high CEC (cation exchange capacity) are more fertile than low CEC soils. Discuss the importance of soil chemistry and its effect on crop yields.*	**Explain the importance of cation exchange capacity (CEC).** 1. Soil chemistry has a significant effect on crop yields. 2. Soil chemistry involves the relationship between clay minerals, water, and other elements in the soil. 3. Quantity and balance of nutrient elements are important factors in soil fertility. 4. CEC of the soil determines what amounts of plant nutrients are needed.
Objective 2 *Use PPt 1 to illustrate how cations are exchangeable. Use magnets to reinforce the fact that like charges repel. Discuss how this compares to soil's capacity to hold essential nutrients.* PPt 1 – Negatively Charged Clay Particle (Micelle)	**Explain what CEC is.** 1. CEC is the soil's capacity to hold and exchange essential cations. Oxygen, silicon, and aluminum make up about 85% of the earth's crust, and greatly affect the CEC of the soil. 2. Essential soil elements are made up of atoms. Atoms are the smallest portion of an element that can take part in a chemical reaction. 3. Atoms that have become electrically charged are called ions. a. Postively charged ions are called cations. b. Negatively charged ions are called anions. c. Ions usually have from one to four positive or negative charges. 4. In chemical systems, there is always an equal balance of positive and negative charges.

Instructor Directions	Content Outline
	a. For example, two positively charged hydrogen ions attract one oxygen ion, which has two negative charges. b. Negatively charged clay minerals attract and hold positively charged ions of elements. c. The phenomenon of cations being attracted and held by the soil particle surfaces is called adsorption. 5. Bases tend to make the soil alkaline (Ca^{++}, Mg^{++}, K^{+}, and Na^{+}). 6. Acid cations tend to make the soil acidic (H^{+} and Al^{+++}). 7. The very small soil particles are not ions but have several negative charges per particle. a. Micelle is a term used for a negatively charged solid particle composed of clay or organic matter. b. Colloid is a term used to describe clay particles. c. Water surrounding micelles contains many positive charges. 8. Cation exchange is the process of micelles and plant roots exchanging ions. a. Micelles exchange acid H^{+} ions for Ca^{++}, Mg^{++}, and K^{+} base ions. The chemical attraction of the bases is much greater than the attraction of hydrogen H^{+} ions. b. Plant roots exchange H^{+} acid ions for Ca^{++}, Mg^{++}, and K^{+} base ions. These bases are some of the most important plant nutrients.
Objective 3 *Have students use the soil test data to calculate the CEC of the soil and determine the amount of fertilizer needed. Use Tables 7.1, 7.3, 7.4, and 7.5 of the student reference to assist in explaining and figuring CEC of the soil.*	**Explain how CEC is calculated.** 1. Obtain the results of a soil test. Soil contains various amounts of each of the exchangeable cations. 2. Add the milliequivalent weights of only K, Mg, Ca (bases) with H and Al (neutralizable acids or NA). a. Determine how many grams of each cation are contained in 100 g of soil (milliequivalent) by dividing its atomic weight by the number of positive charges on each ion. b. Calculations used in determining the CEC are based on the upper 7 inches of the surface layer of earth (which weighs about 2,000,000 lbs per acre).

Instructor Directions	Content Outline
	3. CEC is the total of these cations in milliequivalents. The sum of the bases divided by the total sum of the cations is the percent of base saturation.
Objective 4 *Discuss how texture affects the exchange capacity of the soil. Discuss the importance of organic matter in the exchange capacity of the soil.*	**Identify the soil properties which affect CEC.** 1. Amount of clay a. Low clay content indicates low CEC (sand or sandy loam). b. High clay content indicates high CEC. 2. Kind of clay: Montmorillonite clay has a larger CEC than kaolinite. 3. Organic matter content: Average organic matter content has medium CEC (loam and silt loam). 4. Textural differences a. Severely eroded soils have more clay and a higher CEC. – Contain less organic matter – Poorer tilth – Lower available water capacity b. Organic matter has good exchange capacity. – Soils containing 4% organic matter may have as much as 8 meq per 100 g of soil. – Silt loam with high organic matter content is most ideal. – Loam and silt loam have a high available water capacity.
Objective 5 *Have students discuss the meaning of pH. Refer to PPt 2 as pH is discussed.* PPt 2 – pH Scale	**Explain what soil pH is.** 1. pH is a scale from 0 to 14 that measures acidity to alkalinity. The pH increases 10 times between each unit of the scale. 2. Neutral pH of 7 on the scale is neither acid nor alkaline. It occurs when the concentration of H^+ ions and OH^- ions are equal (in pure water at 75° F). a. Pure water at 75° F contains 1.0×10^{-7} g of H^+ or 0.0000001N. b. The pH scale simplifies the -7 exponent to pH 7. 3. Acid or lower pH occurs when the concentration of H^+ ions increases. 4. Alkaline or higher pH occurs when the concentration of OH^- ions increases.

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	5. Two methods are used to determine soil pH a. Water pH (pH_w): a measure of the H^+ ions in the soil solution and the H^+ ions that were attached to soil particles. b. Salt pH (pH_s) – More precise method – About 1/2 unit lower than water pH – Reflection of neutralizable acidity (NA) – Calcium chloride releases the H^+ ions from the soil particles so they can be measured
Objective 6 *Discuss the effect of pH on plants. Ask the students how pH affects the nutrient availability of soil. Discuss the relationship of pH and soil organisms. Use PPt 3 to illustrate the pH range in which crops will grow best.* PPt 3 – How Soil pH Governs Nutrient Release	**Explain how pH relates to productivity.** 1. Soil pH governs relative nutrient availability. It indicates balance between plant nutrient elements (K, Mg, and Ca) and non-nutrient elements (H and Al). 2. Strongly acidic soils have low amounts of CEC occupied by K, Mg, and Ca. 3. Soil pH, CEC, and the neutralizable acidity (NA) value indicate the need for agricultural lime (Ca) for a particular crop. a. Legumes require more neutral soils of pH_w 6.8–7.3. b. Corn, small grain, and grass need pH_w of 6.0–6.8. c. Blueberries require acid soil to grow best. d. Trees grow better in soils below pH_w of 7.0. 4. Soil pH_w may also change the effect of pesticides and herbicides may become overactive and burn crops.
Objective 7 *Discuss with the students the factors that change soil pH.*	**Explain the factors which cause pH to change.** 1. Depletion of Ca causes increased acidity 2. Leaching – removal of bases by water 3. Absorption – removal of bases by growing plants
Objective 8 *Discuss with the students how pH can be adjusted by adding Ca back into the soil through the use of lime.*	**Explain how soil pH can be adjusted.** 1. Lime application can raise soil pH to a desirable level. a. Lime causes the H^+ on micelles surface to be replaced by Ca^{++}.

Instructor Directions	Content Outline
	– H^+ and CO^3 ions form carbonic acid, which further breaks down to carbon dioxide gas and water. b. Lime helps release other non-base plant nutrients.
Application	Other activities: 1. Use pH paper to test a number of household solutions, such as tap water, ammonia, vinegar, and lemon juice. 2. Check a soil sample for pH by mixing 20 g of soil with 20 ml of distilled water. Mix the sample well and let stand for 15 minutes. Use pH paper to determine the pH. 3. Place a few drops of a strong acid on a piece of limestone rock and observe the fizz. Discuss this reaction with the students. 4. Perform a cation exchange experiment. Place a filter paper in a funnel, add several grams of soil, then pour a solution of ammonium acetate through the soil. Catch the filtrate in a container and run a test for magnesium, calcium, potassium, sodium, and hydrogen. The filtrate should contain at least traces of all the cations. The ammonium acetate replaced the calcium, magnesium, potassium, sodium, and hydrogen ions on the surface of the clay crystals and humus particles. These cations were released to the soil solution and were moved down into the filtrate. 5. Have students bring in actual soil tests for CEC evaluation.
Closure/Summary	Soil chemistry and the cation exchange capacity (CEC) are important to crop yields. Soil chemistry involves the relationship between minerals, water, and other soil elements. CEC is the soil's capacity to hold and exchange essential nutrients with plants. The surfaces of clay minerals attract and hold positively charged ions, called cations, in exchange for negatively charged ions, called anions. Soil pH gives an estimate of the balance between plant nutrient elements (bases) and non-nutrient elements (acids). The two kinds of soil tests for pH are water (pH_w) and salt (pH_s). The pH values indicate the need for agricultural lime, but the exact quantity required is a function of CEC. Each crop has its own level

Instructor Directions	Content Outline
	of pH for good production. After nutrients have been used by plants, they need to be replenished by fertilization to maintain a high level of production.
Evaluation: Quiz	Answers: 1. b 2. c 3. i 4. e 5. g 6. d 7. h 8. f 9. a 10. K = 0.5 11. Mg = 1.5 12. Ca = 6.0 13. NA = 4.0 14. Total CEC = 12 15. K = 240 16. Mg = 288 17. Ca = 3600 18. No additional K needed 19. No additional Mg needed 20. 1200 lbs/A of additional Ca is needed