Unit D: pH of Soil

Lesson 2: Identifying pH Connection With Plant Growth

Student Learning Objectives: Instruction in this lesson should result in the students achieving the following objectives:

1. Explain the role of soil colloids, ions, and the cation exchange capacity (CEC) in soil chemistry.
2. Explain the role of organic matter, soil depth, surface slope, soil organisms, and nutrient balance in soil productivity.

Recommended Teaching Time: 2 Hours

Recommended Resources: The following resources may be useful in teaching this lesson

- A PowerPoint has been provided

List of Equipment, Tools, Supplies, and Facilities:

Writing surface
PowerPoint Projector
PowerPoint Slides
Different strength magnets
Different metals, including aluminum, iron, bronze, etc.
Soil samples

Terms: The following terms are presented in this lesson (shown in italics and on PowerPoint Slide 2)

- Colloids
- Ion
- Cation
- Anion
- Cation Exchange Capacity
- Soil Organic Matter
- Soil Depth

Interest Approach: Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

Using a magnet and a piece of metal, demonstrate the attraction the magnet has for the metal piece. Explain to the students that the soil, plant roots, and plant nutrients are very similar to the magnet and metal, in that there is an attraction between the soil and plant roots for the plant nutrients. Use this illustration to

lead into a discussion of Objective 1 and how chemistry takes place in the soil as plants try to get nutrients for growth and development.

Summary of Content and Teaching Strategies

Objective 1: Explain the role of soil colloids, ions, and the cation exchange capacity (CEC) in soil chemistry.

(PowerPoint Slide 3)

I. As soils are formed during the weathering process, some minerals and organic matter are broken down to extremely small particles.
   A. Chemical changes further reduce these particles until they cannot be seen with the naked eye, the very smallest are called ***colloids***.
      1. Colloids are primarily responsible for the chemical reactivity in soils.
      2. Mineral clay colloids are plate-like in structure and crystalline in nature. In most soils, clay colloids exceed organic colloids in amount.
      3. The kind of parent material and the degree of weathering determine the kinds of clays present in the soil.
      4. Each colloid, clay and organic, has a negative (-) charge, developed during the formation process. It can attract and hold positively (+) charged particles, as unlike poles of a magnet attract each other. Colloids repel other negatively charged particles, as like poles of a magnet repel each other.

(PowerPoint Slide 4)

   B. An element with an electrical charge is called an ***ion.***
      1. Ions with positive charges are called ***cations***. They are written in the ionic form. Examples are potassium (K^+), sodium (Na^+), hydrogen (H^+), calcium (Ca^+), and magnesium (Mg^{++}).
      2. Ions with a negative charge are called ***anions***. Examples are chlorine (Cl^-), nitrate ($NO_3{}^-$), sulfate ($SO_4{}^=$), phosphate ($H_2PO_4{}^-$).
      3. Negatively charged colloids attract cations and hold them like a magnet holding small pieces of metal.
      4. This characteristic explains why nitrate (N) is more easily leached from the soil than ammonium nitrate. Nitrate has a negative charge like the soil colloids, so it is not held by the soil but remains as a free ion in the soil water to be leached through the soil profile in some soils under certain rainfall conditions.

(PowerPoint Slide 5)

   C. Cations held by soils can be replaced by other cations. This means they are exchangeable. The total number of exchangeable cations a soil can hold (the amount of its negative charge) is called its ***cation exchange capacity*** or ***CEC***.
      1. The higher a soils CEC, the more cations it can retain.
      2. The CEC depends on amounts and kinds of clay and organic matter present.

3. A high-clay soil can hold more exchangeable cations than a low-clay soil.
4. CEC increases as organic matter increases. CEC of a soil is expressed in terms of milligram equivalents per 100 grams of soil and is written as meq/100g.

(PowerPoint Slide 6)

D. Clay minerals usually range from 10 to 150 meq/100g in CEC values.
   1. Organic matter ranges from 200 to 400 meq/100g.
   2. Clay soils with high CEC can retain large amounts of cations against potential loss by leaching.
      a. Leaching is the loss or removal of materials from the soil.
   3. Sandy soils with low CEC retain smaller quantities.
   4. Percent base saturation, the percent of the total CEC occupied by the major cations, has been used to develop fertilizer programs.

(PowerPoint Slide 7)

E. The idea is that certain nutrient ratios or balances are needed to insure proper uptake by the crop for optimum yields.
   1. Research has shown that cation saturation ranges and ratios have little or no utility in a vast majority of agricultural soils.
   2. Under field conditions, ranges of nutrients vary widely with no detrimental effects, as long as individual nutrients are present in sufficient levels in the soil to support optimum plant growth.

Use PowerPoint Slide 8 and/or provide students with a copy of TM: D2-1. Explain how the Ions are the specific ones found in the soil. Now give each student a copy of TM: D2-2 or use PowerPoint Slide 9. Explain how this is the connection between ions and the soil particles. Split the students into groups of four. Give each group different strength magnets and different pieces of metal. Have the students try to figure out which metals will be attracted to what strength magnets. Then have them try to put the magnets together. Have the student share their findings.

Give each student a copy of TM: D2-3 and/or use PowerPoint Slide 10. While the students are looking at this paper or slide, ask them what kind of CEC different soil textures would have. They should be able to look at the information and tell you approximately whether it is a higher CEC or lower CEC. Take some of the different chemicals from TM: D2-1 or PowerPoint Slide 8 and ask different students if that chemical would be attracted or repelled by clay and organic matter. Give each student a copy of TM: D2-4 and/or use PowerPoint Slide11 and have the students look at the different soil textures and their percentages of clay as a reinforcement and summary of what you have discussed so far in this lesson.

Objective 2: Explain the role of organic matter, soil depth, surface slope, soil organisms, and nutrient balance in soil productivity.

(PowerPoint Slide 12)

II. Soil productivity can be affected by organic matter, soil depth, surface slope, soil organisms, and nutrient balance.

A. ***Soil organic matter*** consists of plant, animal, and microbial residues in various stages of decay.

1. Adequate organic matter levels benefit soil in many ways such as: improves the physical condition and tilth, increases water infiltration, decreases erosion losses, and supplies plant nutrients.
2. Organic matter contains about 5 percent nitrogen, so it serves as a storehouse for reserve N. But the nitrogen in organic matter is in organic compounds and is not immediately available for plant use, since decomposition usually occurs slowly.
3. Fertilizer N is needed to assure non-legume crops an adequate source of readily available N.
4. Soil organic matter contains other essential plant elements. Plant and animal residues contain variable amounts of mineral elements such as phosphorus, magnesium, calcium, sulfur, and the micronutrients.

(PowerPoint Slide 13)

B. ***Soil depth*** may be defined as that depth of soil material favorable for plant root penetration.

1. Deep, well-drained soils of desirable texture and structure are favorable to crop production.
2. Plants need plenty of depth for roots to grow and secure nutrients and water.
3. Roots will extend .9 to 2.7 meters or more when soil permits. Rooting depth can be limited by physical and chemical barriers as well as by high water tables.
4. Hardpans, shade beds, gravely layers, and accumulations of soluble salts are extremely difficult to correct.

(PowerPoint Slide 14)

C. Land topography or surface slope largely determines the amount of runoff and erosion.

1. It also dictates irrigation methods, drainage, conservation measures, and other best management practices (BMPs) needed to conserve soil and water.
2. The steeper the land, the more management is needed, increasing labor and equipment costs.
3. At certain slopes, soil becomes unsatisfactory for row crop production.
4. The ease with which surface soils erode, along with percent slope, is a determining factor in a soil’s potential productivity.

(PowerPoint Slide 15)

D. Many groups of organisms live in the soil. Soil organisms range in size from microscopic (bacteria, fungi, and nematodes) to those readily visible to the naked eye (earthworms and insect larvae).

   1. Most soil organisms depend on organic matter for food and energy, and are usually found in the upper foot of soil.
   2. Factors that affect the abundance of soil organisms include: moisture, temperature, aeration, nutrient supply, soil pH, and the crop being grown.
   3. Some of the microscopic organisms cause many favorable soil reactions, such as the decay of plant and animal residues. They help to speed nutrient cycling.
   4. Other reactions can be injurious, such as the development of organisms that cause plant and animal diseases.

(PowerPoint Slide 16)

E. Nutrient balance is a vital concept in soil fertility and crop production.

   1. Nitrogen may be the first limiting nutrient in non-legumes. But without adequate amounts of the other nutrients, N cannot do its best.
   2. As Nitrogen fertilization raises yields, the crop demands more of the other nutrients.

Give every student a copy of TM: D2-5 and/or use PowerPoint Slide 17. Have students discuss with the person next to them about why it is important to have deep productive soil. Have them discuss different ways to increase productivity of soil. If they cannot think of any as a pair, discuss this as a group. They should be able to come up with adding compost to soil for organic matter and the impact slopping land that is easily eroded can have on soil productivity.

Have students go outside. Have them dig a hole as deep as they can with a shovel. Have them dig it large enough to see how deep the roots go. Have them look at the color of the soil. They should be able to decide if the soil has a lot of organic matter, if it is very deep, and if it is a good slope to be productive. Have the students look at TM: D2-5 and decide what kind of productivity this soil has.

Review/Summary: Use the student learning objectives to summarize the lesson. Student responses to the questions on **PowerPoint Slide 18** can be used to determine which objectives need to be reviewed.

Application: Have soil samples available for students. The students should look at the soil, decide whether it is high in organic matter or not. Then they should texture it and see if it is high or low in clay content. Have example slopes and depths for each sample. The students should combine all of these attributes and come to a conclusion on how high the CEC is and how productive the soil is. Use LS: D2-1 for the students to complete.

Evaluation: Evaluation should focus on student achievement of this lesson's objectives. A sample test has been provided.

Answers to Sample Test:

Part One: Matching

1=d, 2=a, 3=e, 4=c, 5=f, 6=b, 7=g

Part Two: Completion

1. Cation Exchange Capacity
2. Depth, Slope, Texture
3. Clay, Organic Matter

Sample Test Name________________________________

Test

Unit D Lesson 2: Identifying pH Connection With Plant Growth

Part One: Matching

Instructions. Match the term with the correct response. Write the letter of the term by the definition.

a. Colloids	**d**. Cation	**f**. Cation Exchange Capacity	**g**. Soil Organic Matter
b. Ion	**e**. Anion		
c. Soil Depth			

_______ 1. A particle with a positive charge.

_______ 2. The smallest of all particles.

_______ 3. A negatively charged particle.

_______ 4. The distance into the soil that has favorable material for plant growth.

_______ 5. The total number of replaceable positive charges that a soil can hold.

_______ 6. An element with an electrical charge.

________7. Decaying plant and animal material.

Part Two: Completion

Instructions. Complete the following statements.

1. ______________________ is the amount of cations a soil can hold at a time.
2. The productivity of soil is determined by organic matter, soil __________, soil __________, and soil __________.
3. _________ and __________ ___________ attract cations and repel anions.

LS: D2-1

Is this Soil Productive?

NAME:_______________________

Complete the following questions using the soil samples provided and the handouts provided during this lesson.

1. soil color _______
soil texture _______
soil depth _______
soil slope _______
overall soil productivity _______

2. soil color _______
soil texture _______
soil depth _______
soil slope _______
overall soil productivity _______

3. soil color _______
soil texture _______
soil depth _______
soil slope _______
overall soil productivity _______

4. soil color _______
soil texture _______
soil depth _______
soil slope _______
overall soil productivity _______

5. soil color _______
soil texture _______
soil depth _______
soil slope _______
overall soil productivity _______

6. soil color _______
soil texture _______
soil depth _______
soil slope _______
overall soil productivity _______

7. soil color _______
soil texture _______
soil depth _______
soil slope _______
overall soil productivity _______

8. soil color _______
soil texture _______
soil depth _______
soil slope _______
overall soil productivity _______

9. soil color _______
soil texture _______
soil depth _______
soil slope _______
overall soil productivity _______

10. soil color _______
soil texture _______
soil depth _______
soil slope _______
overall soil productivity _______

TM: D2-1

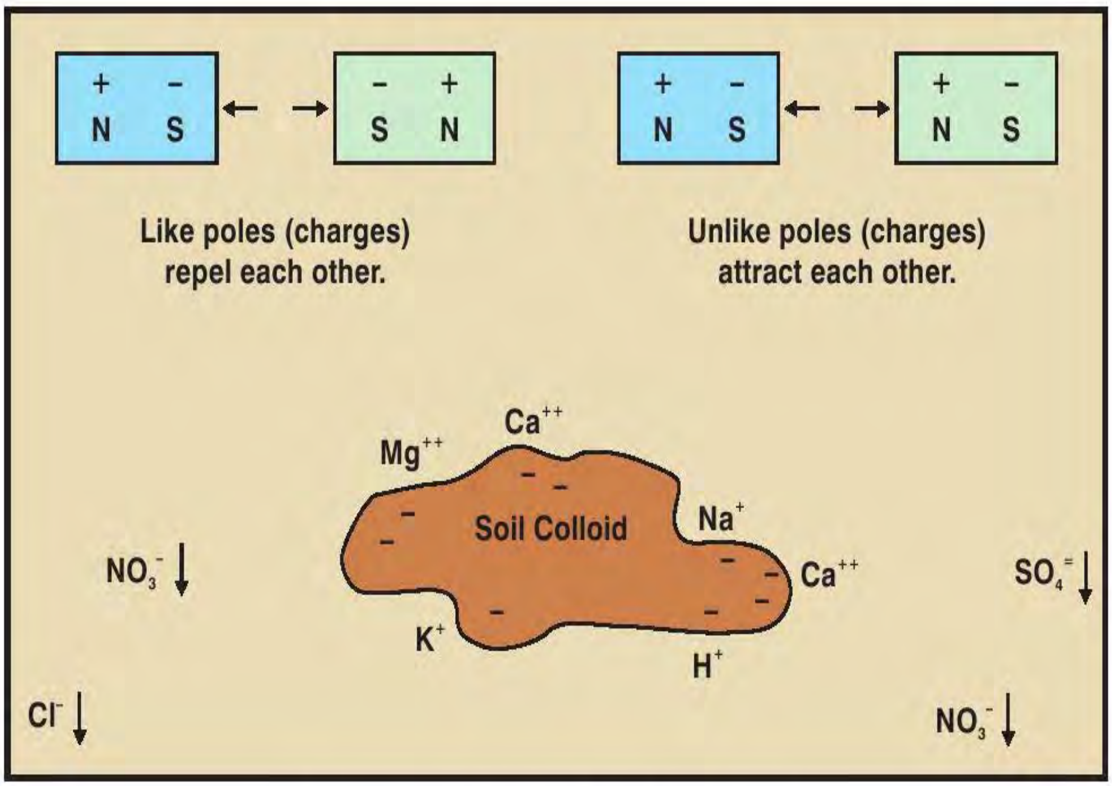
CHEMICAL SYMBOLS AND IONIC FORMS FOR COMMON SOIL CATIONS AND ANIONS

Common Soil Cations, Their Chemical Symbols, and Ionic Forms		
Cation	**Chemical Symbol**	**Ionic Form**
Potassium	K	K^{+}
Sodium	Na	Na^{+}
Hydrogen	H	H^{+}
Calcium	Ca	Ca^{++}
Magnesium	Mg	Mg^{++}

Common Soil Anions, Their Chemical Symbols, and Ionic Forms		
Anion	**Chemical Symbol**	**Ionic Form**
Chloride	Cl	Cl^{-}
Nitrate	N	NO_3^{-}
Sulfate	S	SO_4^{-}
Phosphate	P	$H_2PO_4^{-}$

TM: D2-2

LIKE AND UNLIKE POLES IN RELATIONSHIP TO CATIONS AND ANIONS



Cations are attracted to soil clays and organic matter; anions are repelled.

CATION EXCHANGE CAPACITY

Cations are the positively charged nutrient ions and molecules: Calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), hydrogen (H), and ammonium (Nh_4).

Clay particles are the negatively charged constituents of soils. These negatively charged particles (clay) attract, hold, and release positively charged nutrient particles (cations). Organic matter particles also have a negative charge to attract positively charged cations. Sand particles carry little or no charge and do not react.

Cation exchange capacity (CEC) is the soil's capacity to hold and exchange cations. The strength of a cation's positive charge varies, enabling one cation to replace another on a negatively charged soil particle.

50 CEC (Heavy Clay) ← **Common CEC Range** → **0 CEC** (Sand)

SOME PRACTICAL APPLICATIONS

Soils with CEC 11–50 Range	Soils with CEC 1–10 Range
• High clay content • More lime required to correct a given pH • Greater capacity to hold nutrients in a given soil depth • Physical ramifications of a soil with a high clay content • High water-holding capacity	• High sand content • Nitrogen and potassium leaching more likely • Less lime required to correct a given pH • Physical ramifications of a soil with a high sand content • Low water-holding capacity

TM: D2-4

CLAY AND ORGANIC MATTER PARTICLES

Soil Texture	Percent Clay
Loamy Sand	5
Sandy Loam	10
Silt Loam	20
Silty Clay Loam	30
Clay Loam	35
Clay	45

To understand nutrient behavior in the soil, we must understand the role of clay and organic matter particles. All farm soils contain some clay and some organic matter. Typical clay contents of major soil classes are shown in the table.

The diagram below explains: (1) how cations are held by clay and organic matter to resist leaching and (2) how anions are repelled.

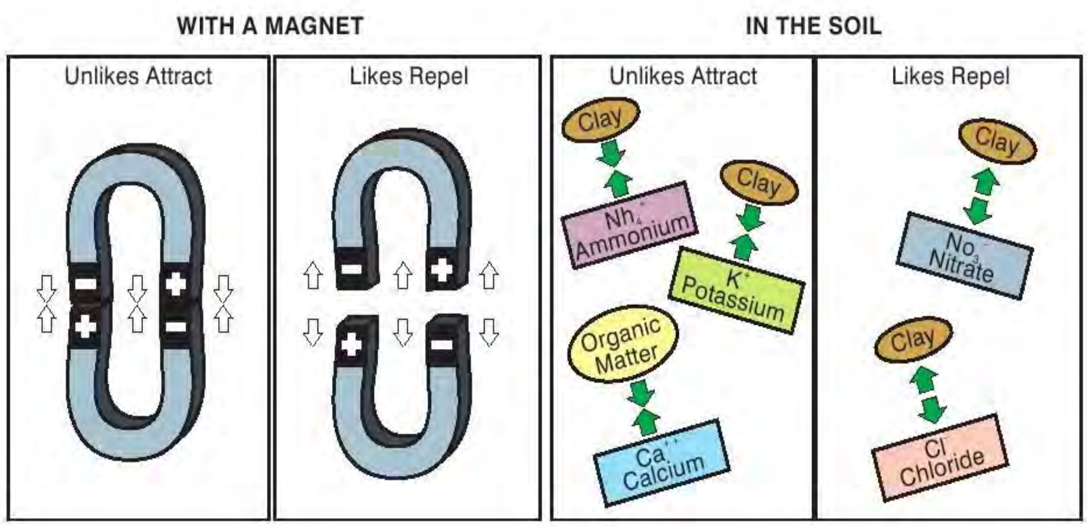
NEGATIVE

Clay and organic matter particles carry a negative charge.

POSITIVE

Cations (Nh_4, K, Ca, Mg) have a positive charge.

Cations are held on clay and organic matter particles by magnetic attraction.
Unlike poles attract — like poles repel.
This is the same principle that holds cations to the clay and organic matter particles.



INFLUENCE OF SOIL DEPTH AND SOIL SLOPE ON RELATIVE PRODUCTIVITY

Influence of Soil Depth in Relative Productivity	
Soil Depth Usable by Crop Roots (meter)	Relative Productivity (percent)
.30	35
.61	60
.91	75
1.2	85
1.5	95
1.8	100

Influence of Soil Slope on Relative Productivity		
	Relative Productivity (%)[1]	
Soil Slope (%)	Soil Not Easily Eroded	Soil Easily Eroded
0–1	100	95
1–3	90	75
3–5	80	50
5–8	60	30
Conservation tillage helps reduce the detrimental effects of slopes.		