

Unit D: pH of Soil

Lesson 2: Identifying pH Connection With Plant Growth

TERMS

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

- 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.

- 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.

- 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.

- 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.

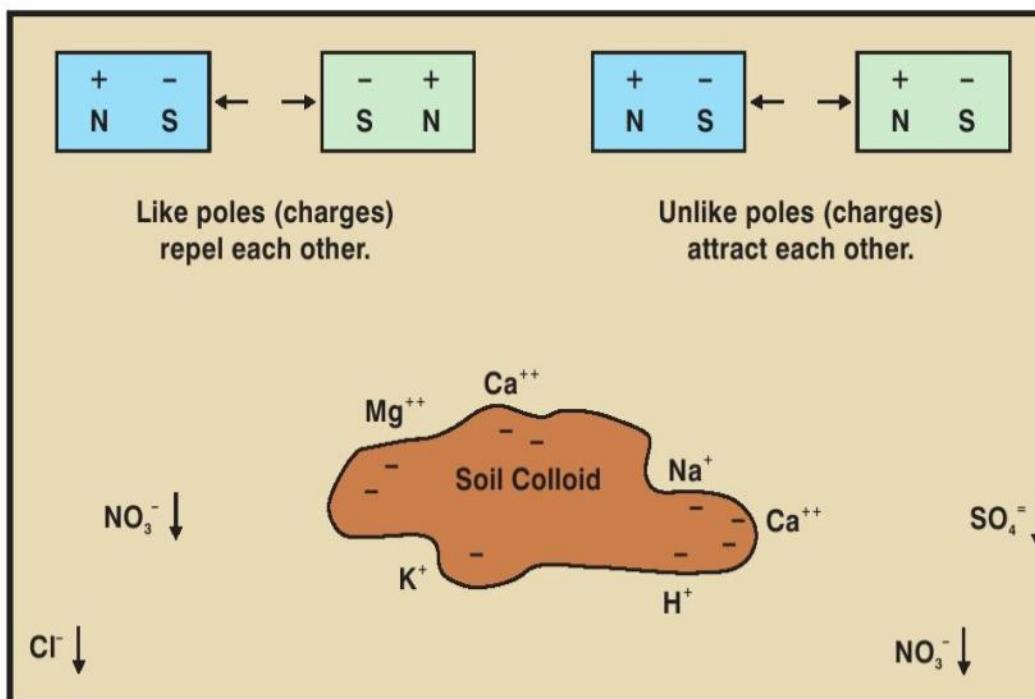
- E. The idea is that certain nutrient ratios or balances are needed to insure proper uptake by the crop for optimum yields.
 - 1. Research has shown that cation saturation ranges and ratios have little or no utility in a vast majority of agricultural soils.
 - 2. Under field conditions, ranges of nutrients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

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 ₂ PO ₄ ⁻

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.



SOME PRACTICAL APPLICATIONS

Soils with CEC 11–50 Range	Soils with CEC 1–10 Range
<ul style="list-style-type: none">• 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	<ul style="list-style-type: none">• 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

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



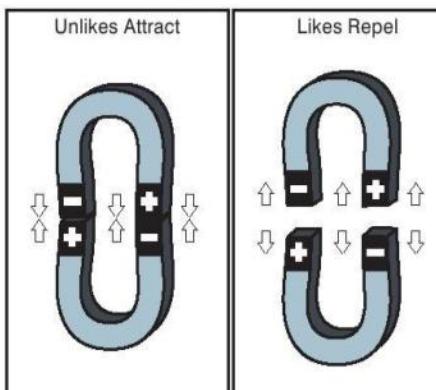
Cations (NH_4^+ , K^+ , Ca^{2+} , Mg^{2+}) have a positive charge.

Cations are held on clay and organic matter particles by magnetic attraction.

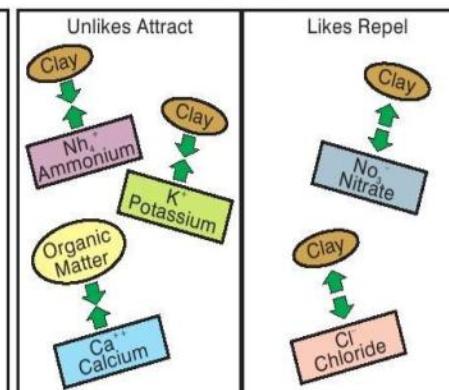
Unlike poles attract — like poles repel.

This is the same principle that holds cations to the clay and organic matter particles.

WITH A MAGNET



IN THE SOIL



- 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.

- 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, gravelly layers, and accumulations of soluble salts are extremely difficult to correct.

- 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.

- 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.

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.

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

Soil Slope (%)	Relative Productivity (%) ¹	
	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.

REVIEW/SUMMARY

- How does organic matter affect soil productivity?
- What does CEC stand for and why is it important to soil?
- What is a cation?
- What is an anion?
- What is the relationship with clay and organic matter with CEC?