Nutrient retention in soil

How does soil chemistry affect the availability of nutrients in the soil?

Background

Soils are composed mainly of sand, silt, clay, and organic matter which attract some of the nutrient chemicals required by plants to grow. The makeup of particles in the soil determines its ability to attract these nutrients for plant use. Electrostatic forces of the soil particles cause the particles to attract or repel the nutrients found within the soil. Sand, silt and clay are all negatively charged particles and attract nutrients with positive charges. The more negatively charged a soil is, and the more surface area it has, the more cations it can hold. The amount of cations (positively charged particles) that a soil can attract is called its **cation exchange capacity (CEC).**

Some nutrients are anions or neutral particles. In these cases, the soil particles will not be attracted to these ions and may even repel these nutrients. As a result, the anions can be removed from the soil by water if not absorbed by the plant quickly. Consequently, nutrients may need to be applied to the soil more frequently in lower concentrations, as they are available to plants for a shorter period of time.

Farmers measure the cation exchange capacity of a soil so they can best distribute fertilizer. If CEC is compared to a drinking glass, then soils with a high CEC can absorb large amounts of fertilizer, similar to a large drinking glass. They may not need to be fertilized as often, as they are able to retain more nutrients for longer periods of time. Soils with lower CECs cannot retain as much fertilizer. Excess fertilizer will be mobilized in water and potentially lost to runoff. These soils may benefit from lower concentrations of fertilizer that are distributed more frequently. This is similar to using a smaller drinking glass, but filling it more often to achieve the same volume of water as a larger glass. Farmers match their fertilizer usage with their soil chemistry in order to retain the highest amounts of applied nutrients for plant use.

How do plants absorb nutrients from the soil? Plants exchange hydrogen ions (H+) for nutrient cations of equal charge. For example, a plant exchanges one hydrogen ion (H+) for one potassium ion (K+). For an ion like calcium with a charge of two plus (Ca 2+), the plant must release two hydrogen ions into the soil to make the exchange. The more positively charged an ion is, the more tightly it is held by negatively charged soils and the more difficult it is to exchange and absorb.

Nutrient chart

Nutrient cations	Nutrient anions	Neutral
Potassium (K^+)	Nitrate (NO_3^-)	Phosphorus pentoxide (P_2O_5)
Ammonium ($NH4^+$)	Sulfate (SO_4^{2-})	
Calcium (Ca^{2+})	Orthophosphates (HPO_4^{2-})	
Iron (Fe^{3+})		

Soil chemistry chart

Soil type	Overall charge	Relative surface area	Relative charge of the particle
Sand	Negatively charged	Least	−1
Silt	Negatively charged	Moderate	−2
Clay	Highly negatively charged	Most	−4

Materials

- Particle images
- Soil diagram
- Sketch space

Instructions

Cut out the Particle Images. Sort them into groups of the same particles (there should be multiple copies of each particle). Locate your Soil Diagram and Sketch Space.

Activity 1

1. Consider a soil made mostly of silt that is rich in calcium and has been treated with nitrates. Using the Particle Images, place the correct soil particles on your Soil Diagram. Place the appropriate nutrient particles among your soil particles. Model how the nutrient and soil particles would interact with one another and how the plant might uptake some of these nutrients. Use your model to complete step 2 below.
2. Create a diagram on your Sketch Space page in the Activity 1 box showing the following:
3. Use arrows to show the attractive or repulsive forces between soil and nutrient particles.
4. Show what particles the plant root would exchange for certain nutrient particles. Include the number of ions to be exchanged for each nutrient particle. Use arrows to indicate which particles would be exiting the plant and which would be entering in exchange for them.
5. Label the relative Cation Exchange Capacity of this soil (high, moderate, or low).

Activity 2

1. A corn crop has been cultivated in clay soil. It has been enriched with potassium and sulfates. Place the appropriate nutrient and soil particles on your Soil Diagram. Model how these nutrients would interact with the soil particles.
2. Consider what would happen to the nutrients in this soil if a heavy rain occurred. Create a diagram on your Sketch Space page in the Activity 2 box. Show what might occur to each of the nutrients as the rain washed through the clay-based soil. Include the presence of correct soil and nutrient particles and the presence of rain in your diagram. Use arrows to indicate the movement (if any) of nutrient particles.
3. Include a brief note at the bottom of your diagram summarizing the nutrient availability to plants in this soil after it has rained.

Activity 3

1. Create your own soil and nutrient scenario. Select at least 2 nutrients to add to your soil as fertilizer for your crop. Create a diagram on your Sketch Space page in the Activity 3 box showing items a-c from Activity 1.

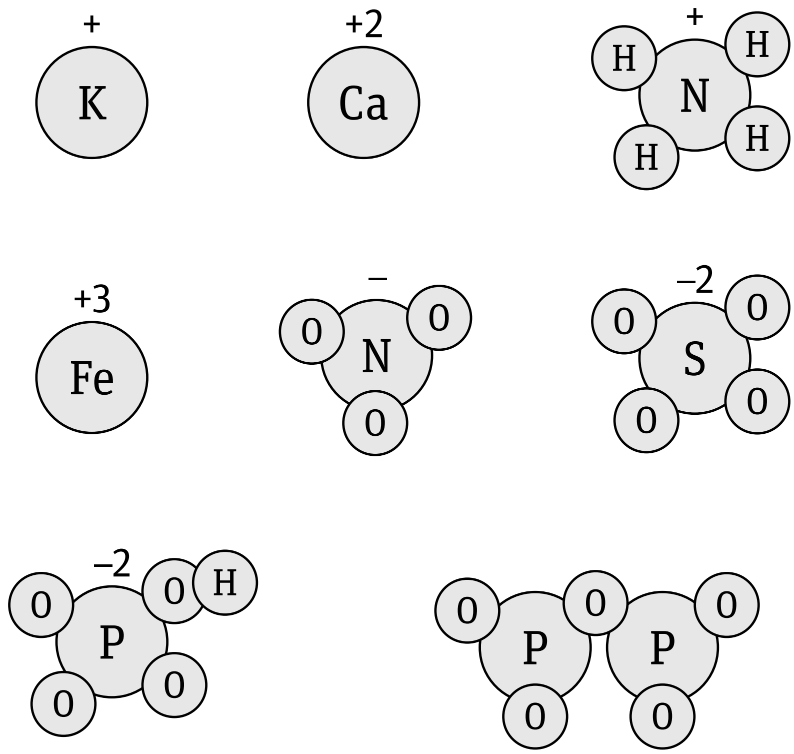
Reflection

1. Explain how the Cation Exchange Capacity of a soil impacts its ability to attract or repel cations and anions. Include an example in your explanation.
2. Farmers place fertilizer in the soil at times when they are most likely to be absorbed by crops. If a farmer is planting crops in a soil with a low CEC, would you recommend a fertilization plan involving high volumes of fertilizer administered less frequently, or smaller volumes of fertilizer administered at more frequent intervals? Create a diagram that illustrates your answer in the Reflection box on your Sketch Page. Below the sketch, justify why you chose this fertilization plan.

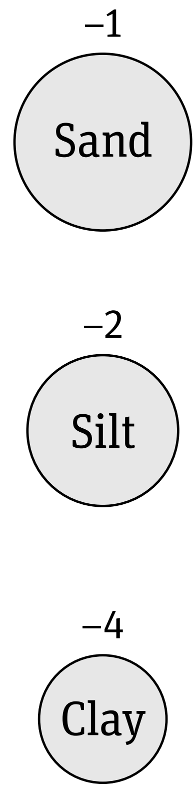
Particle images

Note: The nutrient and soil particles shown here are not accurately sized relative to one another.

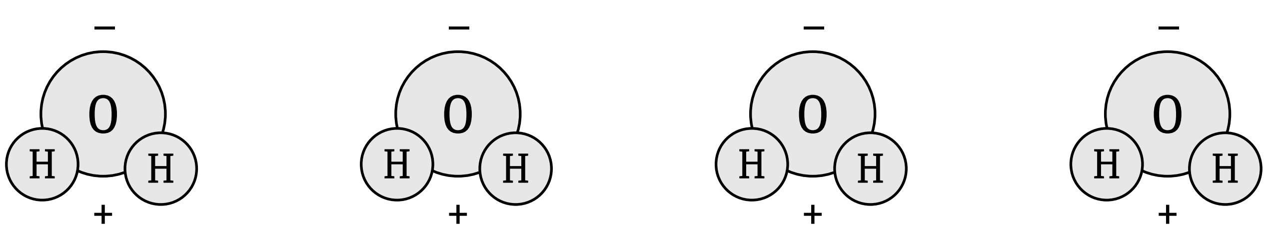
Nutrient particles



Soil particles



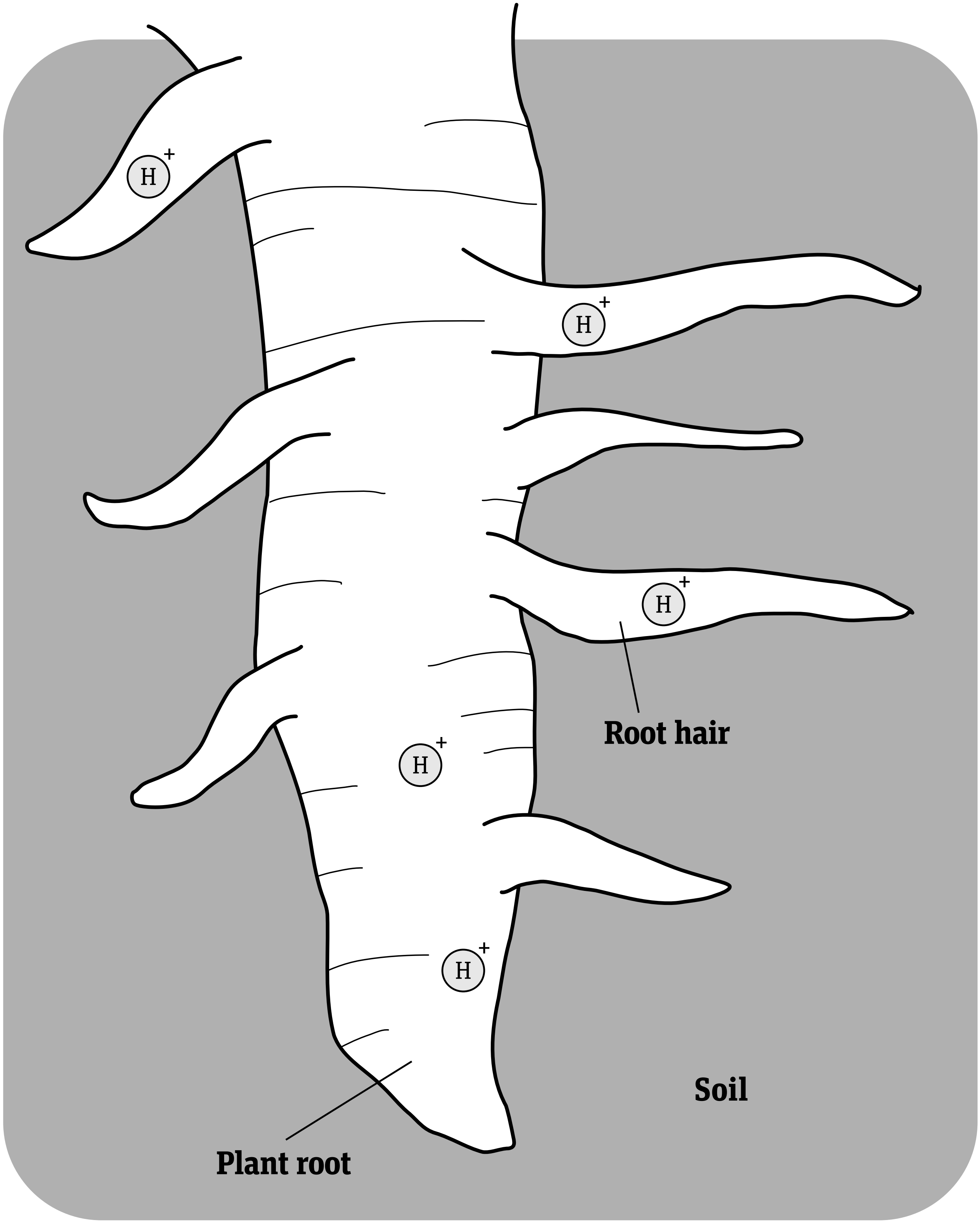
Water particles



Feed the World

Content designed by educationprojects.org on behalf of Ohio Corn & Wheat.

Soil diagram



Sketch space

Activity 1	Activity 2
Activity 3	**Reflection**