Soil Fertility Protocol

Purpose

To measure the amounts of nitrogen (N), phosphorus (P), and potassium (K) in each horizon in a soil profile

Overview

Using a NPK test kit, students mix a dry, sieved soil sample into a solution and chemically extract the N, P, and K as nitrate, phosphate, and potassium. The N, P, and K amounts in the sample are determined by comparing the solution to a color chart. Students describe the N, P, K amounts as high, medium, low, or none. These measurements are conducted three times for each horizon.

Student Outcomes

Students will be able to measure the nitrate nitrogen, phosphate phosphorus and potassium contents of soils.

Students will be able to relate soil fertility to the physical and chemical properties of the soil.

Science Concepts

Earth and Space Sciences

- Soils store nutrients in different amounts depending on the type of nutrient and the soil properties.
- Soils have properties of color, texture, structure, consistence, density, pH, fertility; they support the growth of many types of plants.
- The surface of Earth changes.
- Soils are often found in layers, with each having a different chemical composition and texture.
- Soils consist of minerals (less than 2 mm), organic material, air and water.
- Water circulates through soil changing the properties of both the soil and the water.

Physical Sciences

- Objects have observable properties.
- Chemical reactions take place in every part of the environment.

Life Sciences

- Atoms and molecules cycle among the living and nonliving components of the ecosystem.

Scientific Inquiry Abilities

- Identify answerable questions.
- Design and conduct an investigation.
- Use appropriate tools and techniques including mathematics to gather, analyze, and interpret data.
- Develop descriptions and explanations, predictions and models using evidence.
- Communicate procedures and explanations.

Time

One 45-minute class period for three groups of students to analyze one horizon.

Level

Middle and Secondary

Frequency

Once for each soil profile

Materials and Tools

- Oven-dried, sieved soil (sieved with a Number 10 sieve with 2 mm mesh attached to a frame)
- GLOBE (or equivalent) NPK kit
- Distilled water
- Beaker
- Teaspoon
- Clock or stopwatch
- *Soil Fertility Data Sheet* (more than one *Data Sheet* may be needed for each profile)
- Latex gloves
- Goggles

Preparation

Obtain dry, sieved soil samples.

Collect required equipment.

Spread out newspapers or other cover on table to keep area clean.

Prerequisites

Soil Characterization Protocol

Soil Fertility Protocol – Introduction

In order to grow, plants require sunlight, water, air, heat, and nutrients. Table SO-FE-1 lists the *macronutrients* (nutrients required in large amounts) and *micronutrients* (nutrients required in smaller quantities) required for plant growth. The fertility of a soil indicates the availability of these nutrients for plants to grow.

Table SO-FE-1

Macronutrients	Micronutrients
Nitrogen (N)	Iron (Fe)
Phosphorus (P)	Zinc (Zn)
Potassium (K)	Manganese (Mn)
Sulfur (S)	Copper (Cu)
Calcium (Ca)	Boron (B)
Magnesium (Mg)	Molybdenum (Mo)
	Chlorine (Cl)

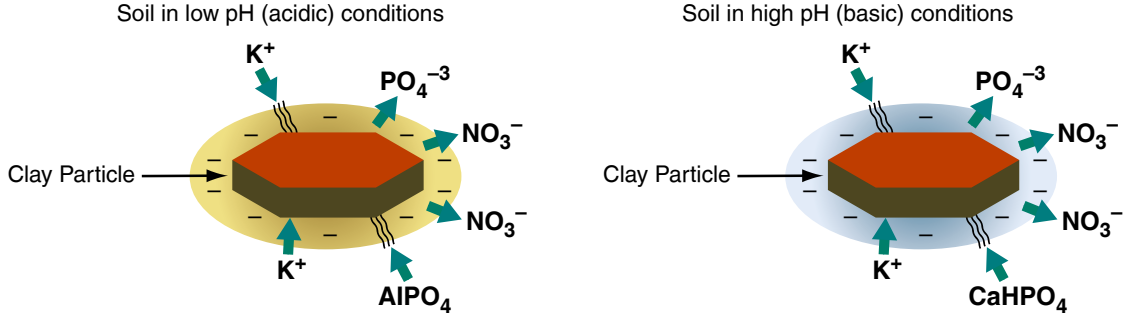
Some soil nutrients are positively charged, while other nutrients are negatively charged. Nutrients that are positively charged, such as potassium, calcium, and magnesium, are held by negatively charged soil particles. These nutrients are removed from the soil by plants or by weathering processes. Negatively charged particles, such as nitrogen (in the common form of nitrate), phosphorus (in the common form of phosphate) and sulfur (in the common form of sulfate) are not held by negatively charged soil particles. These nutrients are more easily leached and removed from the soil. When a soil loses its nutrients or does not have the nutrients needed for plant growth, farmers and gardeners replenish nutrients by adding fertilizers to soils.

The *Soil Fertility Protocol* measures the abundance of three nutrients: nitrate (nitrogen), phosphate (phosphorus), and potassium, in each horizon of a soil profile to determine if the soil is fertile for plant growth.

Nitrogen (N) is an element found in high concentrations in the atmosphere, but relatively low concentrations in soil. For nitrogen to be used by most living things, the N_2 molecules must be broken apart. In soil and water, this usable nitrogen takes the form of nitrate (NO_3), nitrite (NO_2) and ammonium (NH_4), with nitrate being the most common. In general, these forms of nitrogen are rapidly taken up by plants and are an important component of plant proteins. Nitrate (NO_3-), because of its negative charge, is not held by negatively charged soil particles and is easily removed *(leached)* from the soil as water passes through it. Nitrate can also be converted to nitrogen gas (N_2) or ammonia (NH_3) and be *volatilized (evaporated or removed as a gas)* out of the soil. Therefore, it is important that farmers and gardeners add nitrogen fertilizers when plants need the nutrient the most and can absorb it before it is removed from the soil by leaching. When nitrogen is added to the soil in the form of organic matter, it is stored longer because it becomes available to plants slowly, as the organic matter decomposes.

Phosphorus (P) is used as part of the energy pathway in the plant. Plants use phosphorus in the form of phosphate (PO_4^{-3}). Because of its negative charge, phosphate is easily *leached* from the soil. Plants are only able to take up phosphate when soils are at neutral soil pH values of 5.0-8.0. At low pH values (<5.0), phosphate combines with iron (Fe) and aluminum (Al) to form phosphates that are not soluble and cannot be taken up by plants. At high pH values (>8.0), phosphate combines with calcium

Figure SO-FE-1



(Ca) to form calcium phosphate, which is neither soluble nor available for plants to take up from the soil. When phosphate occurs in one of these insoluble compounds, it becomes easy to remove from the soil when the soil particles are eroded. Like nitrogen, phosphorus is also more slowly and easily available to plants when it is added as part of decomposing organic matter.

Potassium (K) plays the role of activating cell enzymes in plants. It is readily available to plants in its elemental state (K+), and because of its positive charge, is easily stored on negatively charged soil particles. The largest source of potassium is from the decomposition of potassium containing minerals, such as mica.

Teacher Support

Preparation

Make sure students understand the importance of each nutrient they are measuring before they conduct the *Soil Fertility Protocol*.

Have students review the NPK kit instructions before conducting the *Soil Fertility Protocol*.

Managing Materials

To measure soil fertility, students may use a GLOBE soil test kit or an equivalent product that produces a relative value for nitrate, phosphate, and potassium.

Measurement Procedures

The basic method for measuring soil fertility consists of mixing a soil sample with water and chemically extracting the N, P, and K as nitrate, phosphate, and potassium. The N, P, and K amounts in the sample are determined by comparing the solution to a color chart.

Using the GLOBE soil test kit to determine nitrogen (N), students compare the extraction solution with a pink color chart. To determine phosphorus (P), students compare the extraction with a blue color chart. To determine potassium (K), the students place the tube containing the extraction solution over a column of black boxes, and the amount of the blackness that can be observed through the cloudiness of the solution is compared with the column next to the tube.

Students should wait no more than 10 minutes to read the color change in each tube. Waiting longer may give erroneous results.

Based on previous experience with the GLOBE soil test kit, almost all readings for nitrate nitrogen result in values of none or low. This may be due to the rapid removal of nitrate from the soil once it has been added (either by plant uptake or leaching) or due to the lack of sensitivity of the kit to measure nitrate.

With some soil samples, especially those high in clay, students will need to repeat the extraction procedure more than once to obtain enough solution for the N, P, and K analysis.

Managing Students

In order to complete the analysis within a class period, have different students do the analysis for N, P, and K simultaneously after the extraction solution has been made.

Safety Procedures

1. Students should wear gloves when handling chemicals and the water sample.
2. Students should wear goggles when working with chemicals. They should also wear surgical masks when opening powdered reagents.
3. School authorities should be consulted on the proper disposal of used chemicals.

Questions for Further Investigation

How might natural changes affect the fertility of a horizon?

What differences between locations could affect the fertility of a horizon?

How does the soil fertility affect the types of vegetation that can grow on a soil?

How does the soil particle size distribution affect the nutrient content of a horizon?

How does climate affect the nutrient content of a horizon?

How does the type of vegetation growing on the soil affect the nutrient content of the soil?

Soil Fertility Protocol
Lab Guide

Task

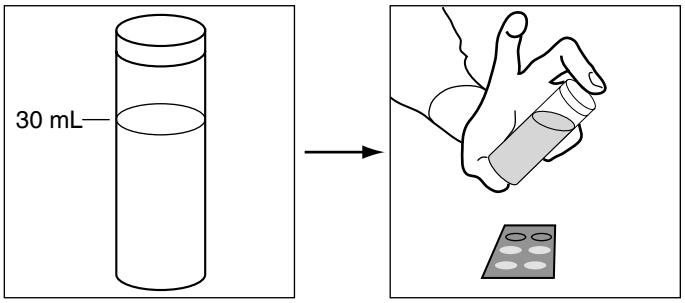
To obtain three soil fertility readings for every horizon in a soil profile

What You Need

- ❑ Dried sieved soil
- ❑ *Soil Fertility Data Sheet*
- ❑ Plastic teaspoon
- ❑ GLOBE NPK test kit or equivalent kit (that measures the relative amount of nitrate, phosphate, and potassium in a soil sample)
- ❑ Distilled water
- ❑ Pencil or pen
- ❑ Latex gloves
- ❑ Goggles

Part 1. Nutrient Extraction:

1. Fill the extraction tube from your Soil Test Kit to the 30 mL line with distilled water.

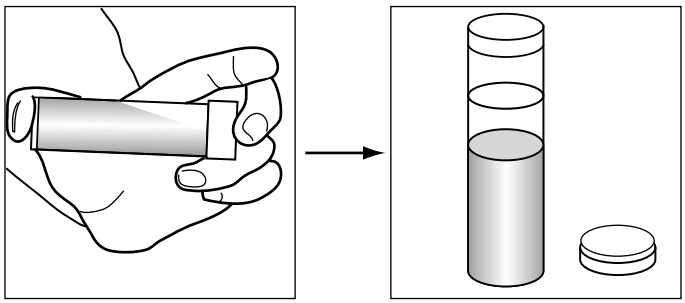


2. Add 2 Floc-Ex tablets. Cap the tube and mix well until both tablets have disintegrated.

3. Remove the cap and add one heaping spoonful of dry, sieved soil.

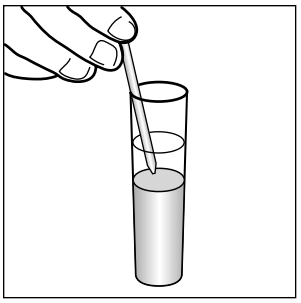
4. Cap the tube and shake for one minute.

5. Let the tube stand until the soil settles out (usually about 5 minutes). The clear solution above the soil will be used for the nitrate nitrogen (N), phosphate phosphorus (P), and potassium (K) tests.

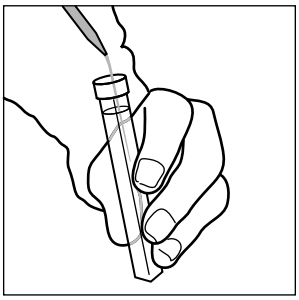


Note: For some soils, especially those high in clay, there may not be enough clear solution extracted. If more clear solution is needed, repeat steps 1-5.

Part 2. Testing for Nitrate Nitrogen:

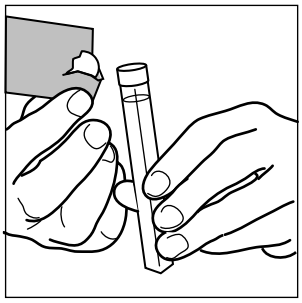


Use the pipette to transfer the clear solution above the soil to one of the test tubes in the Soil Test Kit until the tube is filled to the shoulder. (If more solution is needed, repeat Part 1).

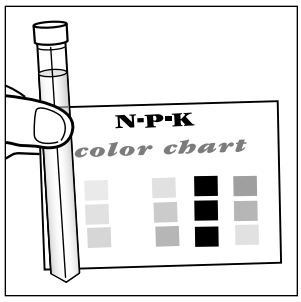


1. Add one Nitrate WR CTA Tablet. Be sure that all of the pieces of the tablet are added to the test tube and try not to touch the tablet as you place it into the tube.

2. Cap and mix until the tablet disintegrates.



3. Rest the test tube in a cup or beaker. Wait 5 minutes for color to develop. (Do not wait longer than 10 minutes).



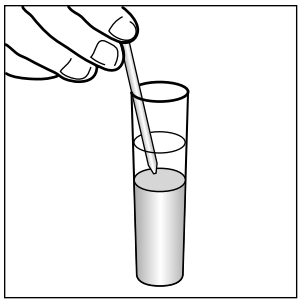
4. Compare the pink color of the solution to the Nitrogen Color Chart in the Soil Test Kit.

5. Record your results (High, Medium, Low, or None) on the *Soil Fertility Data Sheet*.

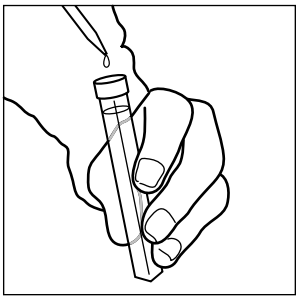
6. Discard the solution and wash the tube and the pipette with distilled water.

7. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after they are used.

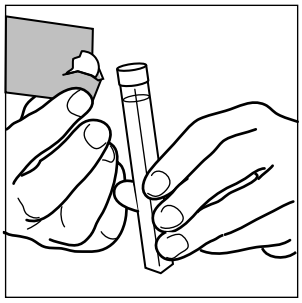
Part 3. Testing for Phosphate Phosphorus:



1. Use the clean pipette to transfer 25 drops of the clear solution above the soil to a clean test tube. (If more solution is needed, repeat Part 1).

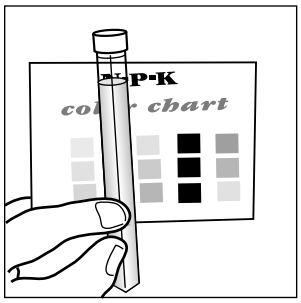


2. Fill the tube to the shoulder with distilled water.



3. Add one Phosphorus Tablet to the tube and cap it. Be sure that all the pieces of the tablet are added to the test tube.

4. Mix until the tablet disintegrates.



5. Rest the test tube in a cup or beaker. Wait 5 minutes (but no more than 10 minutes) for color to develop.

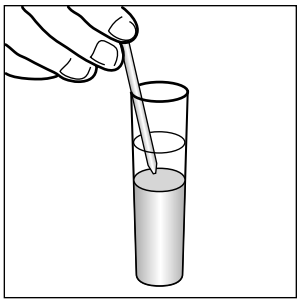
6. Compare the blue color of the solution to Phosphorus on the color chart in the Soil Test Kit.

7. Record your results (High, Medium, Low, or None) on the *Soil Fertility Data Sheet*

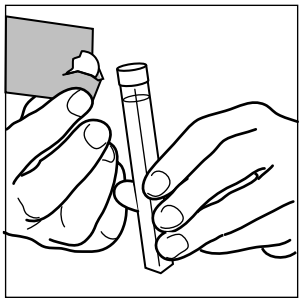
8. Discard the solution and wash the tube and the pipette with distilled water.

9. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after they are used.

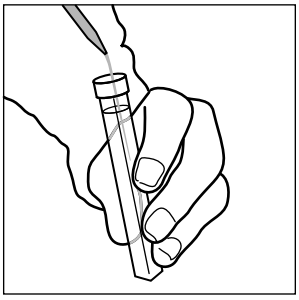
Part 4. Testing for Potassium:

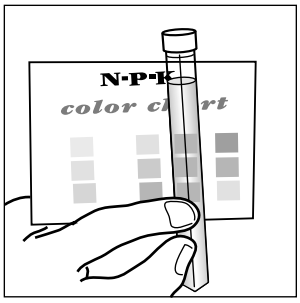


1. Use the clean pipette to transfer the clear solution above the soil to a clean test tube until it is filled to the shoulder. If more solution is needed, repeat Part 1.



2. Add one Potassium Soil Tablet to the tube. Be sure that all the pieces of the tablet are added to the test tube. Cap and mix until the tablet disintegrates.





3. Hold the tube over the black boxes in the left column of the K portion of the color chart. Look through the "cloudiness" of the solution in the test tube and compare it to the shaded boxes in the right column. Record your results (High, Medium, Low, or None) on the *Soil Fertility Data Sheet.*

4. Discard the solution and wash the tube and the pipette with distilled water.

5. Repeat this procedure with the liquid from each of the soil samples. Be sure to rinse the pipette and tube with distilled water after they are used.

Soil Fertility Protocol – Looking at the Data

Are the data reasonable?

Nitrogen (N):
The soil test kit used in GLOBE measures nitrogen in the form of nitrate (NO_3). Because nitrate has a negative charge, it is not attracted to the negatively charged surfaces of the soil. As a result, any nitrate added to the soil is quickly taken up by plants, washed out with water passing through the soil, or removed (volatilized) as nitrogen gas. Therefore, nitrate values may be low or none for most soil samples. If the soil has recently been fertilized, or if there is a steadily available source of nitrogen, such as from the addition of organic material from compost or manure, the levels of nitrogen may be higher.

Phosphorus (P):
GLOBE soil test kits measure phosphate (PO_4^{-3}), the form of phosphorus that is most easily taken up by plants. Soil test kit readings of phosphate should be low if the soil pH is less than 5.0 or greater than 8.0. This is because at low and high pH levels, phosphate forms compounds with other elements in the soil making it difficult for plants to use. For example, when the soil pH is low and iron is present (making the soil look red), iron phosphate is formed which holds the phosphate very tightly, not freeing it for plants to use. At neutral pH levels (around pH 7), phosphate is more easily taken up by plants and usually shows up as a medium or high phosphate reading with the soil test kit.

Potassium (K):
The amount of potassium present in the soil depends on the availability of potassium minerals in the parent material of the soil. The largest natural sources of potassium are potassium rich minerals such as micas, which release potassium into the soil through weathering. Potassium can also be added to the soil as a fertilizer. Since potassium is a positively charged ion, it is attracted and held to the negatively charged soil surface. The fertility test kits will show medium or high readings for potassium for many soils. A low potassium reading may be an indication of an extremely weathered soil.

What do people look for in these data?

Knowing the relative amounts of nitrogen, phosphorus, and potassium in the soil helps scientists to recommend the type and amount of fertilizers or other nutrients farmers and gardeners should add to their soils for plant growth. For example, they may recommend adding fertilizers, composts or manure to make a soil more fertile. N, P, K measurements also help scientists to better understand other soil properties, such as the number of negatively charged soil surfaces, the amount of iron and organic matter in the soil and the degree to which a soil has been weathered. N, P, K measurements can also help scientists determine the type of parent material from which the soil formed.