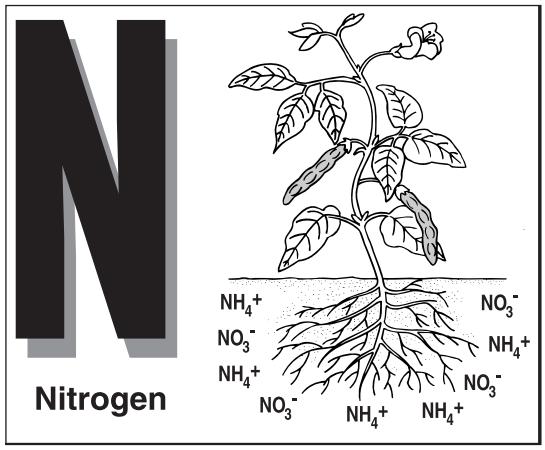
Natural Resources Fact Sheet

Plant Nutrients–Nitrogen

Information compiled by the Western Plant Health Association

Plant Utilization – Nitrogen is one of the 17 chemical elements required for plant growth and reproduction. Nitrogen is in chlorophyll, a green chemical which allows plants to capture energy from the sun and make food for themselves in a process called photosynthesis. It is also the basic element of plant and animal proteins, including the genetic material DNA and RNA, and is important in all phases of plant growth.



Production – Nitrogen is an abundant element on and around Earth. Approximately 78 percent of the Earth's atmosphere is nitrogen gas (N_2). As with all plant nutrients, however, nitrogen must be in specific forms to be utilized by plants. Converting N_2 into nitrogen plants can use is called nitrogen fixation. Most often, nitrogen gas is converted into plant available nitrogen by using complex chemical processes or nitrogen-fixing bacteria.

Most manufactured nitrogen fertilizers begin as ammonia. At temperatures of 400ºC - 500ºC and great pressure, nitrogen from the air and hydrogen from natural gas combine to produce ammonia. The ammonia can be used directly or further processed into other nitrogen fertilizers. Legumes, such as beans and alfalfa, grow specialized nodules on their roots. *Rhizobia*, nitrogen-fixing bacteria, live in these root nodules and convert atmospheric nitrogen into nitrogen plants can use. Farmers take advantage of this unique symbiotic relationship by periodically growing legumes in nitrogen-deficient soil to naturally boost nutrient levels.

Forms – In the soil, nitrogen exists in different forms, which interact with one another and with plants, animals and microorganisms. Most crops use nitrogen rapidly, therefore, farmers and home gardeners often supply nitrogen to the plants in a variety of ways, including the application of manufactured fertilizers, applying composts and manures, and growing legumes in rotation with other crops.

Plants absorb nitrogen in the forms of nitrate (NO_3^-) or ammonium (NH_4^+) ions, both of which are water-soluble. Nitrate ions are absorbed quickly by plant roots, but leach easily. Ammonium ions are attracted to soil particles and move slowly through the soil to plant roots. Commercial fertilizers, both dry and liquid, are available with various combinations of nitrate and ammonium ions, enabling farmers to manage their nitrogen application. Crop advisors monitor crops to ensure the crops receive optimum amounts of nitrogen.

History – Americans have fertilized their crops with nitrogen for centuries. Early colonists used animal manure, fish scrap, cottonseed meal, and tobacco stems as nitrogen fertilizer. Later, Americans imported nitrate of soda from Chile, rotated crops with legumes and used ammonium sulfate, a by-product of steel production. Many of these are still used today.

The process of synthesizing ammonia is considered one of the greatest chemical engineering feats. The process was first demonstrated in the laboratory in 1884, but it was not commercially feasible until 1913 in Germany. The first American ammonia plant was built in 1921. Nitrogen fertilizer production was minimal until after World War II, when the demand for food increased with an increase in human population. Improved nitrogen management is the focus of intensive research at both public and private research facilities.

Top Producing Regions – China is the world's largest producer of nitrogen and phosphate fertilizers and Canada produces more potash fertilizer than any other country. Although the U.S. is the third largest producer of nitrogen fertilizers, we still import more nitrogen fertilizer than any other country. Natural gas is a major feedstock for production of ammonia. During this same period 27 U.S. ammonia plants closed. Since 2008, four new ammonia plants have opened but the U.S. remains dependent on nitrogen imports. More than 60% of imported anhydrous ammonia is from Trinidad. Globally, wheat receives the largest share of nitrogen fertilizer at 18.1 percent, however, in the U.S. nearly half (49 percent) of all nitrogen fertilizer is applied to corn.

Economic Value – The economic value of the nitrogen industry is difficult to assess. Many people have businesses associated with replenishing agricultural soils with nitrogen, including those whose livelihoods depend on providing compost bins, soil amendments, and tools. Ammonia production adds $4 billion to the United States economy annually.

For additional information:
California Fertilizer Foundation
(916) 574-9744
Website: www.calfertilizer.org

California Fertilizer Foundation

04/17

This is one in a series of fact sheets composed by the California Foundation for Agriculture in the Classroom (CFAITC). For additional educational materials: CFAITC, 2300 River Plaza Drive, Sacramento, CA 95833-3293 (916) 561-5625 ✣ (800) 700-AITC ✣ Fax: (916) 561-5697
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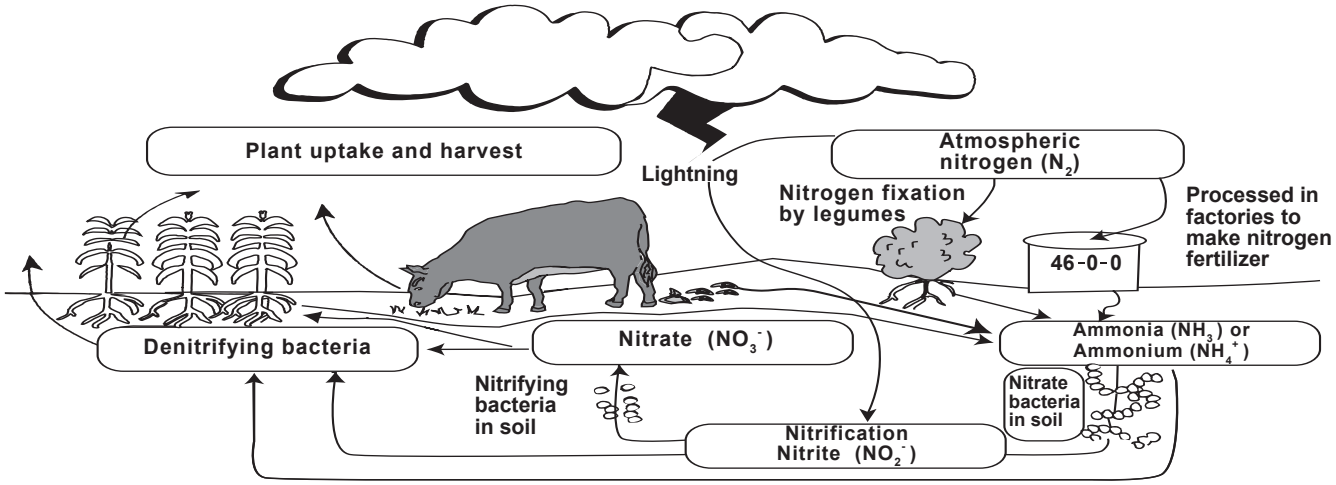
Nitrogen Activity Sheet



Lesson Ideas

- Compare and contrast the nitrogen and water cycles.
- Make a poster of the nitrogen cycle using magazine pictures.
- Chart and compare the growth of plants which are fertilized with varying amounts of nitrogen fertilizer.
- Compare fertilizer labels for nitrogen content.
- Make compost at your school using garden, fruit, and vegetable lunch waste.
- Identify plants which are legumes. Research how these plants make nitrogen available to other plants.
- Draw a picture of a plant and the plant's need for nitrogen.
- Research the procedures and chemical equations used in ammonia fertilizer production.
- Compare and contrast the nitrogen content of various organic fertilizers, including steer manure, chicken manure, and fish emulsion.
- Locate nitrogen on the periodic table of elements. Learn about its physical and chemical properties.

Fantastic Facts

1. Ammonia is the basic chemical ingredient in commercial nitrogen fertilizer production.
2. The color green is associated with plants which contain a sufficient amount of nitrogen.
3. Legumes, such as beans and alfalfa, contain microorganisms in their roots that convert nitrogen into a form other plants can use.
4. NO_3- and NH_4+ are the two forms of nitrogen that plants can absorb through their roots.
5. The United States is the world's top importer of nitrogen.
6. Nitrate (NO_{3-}) is a form of nitrogen that can leach rapidly, depending on environmental factors.

Lesson Plan: Let's Make Manure Tea

Introduction: Substances added to improve the nutrient content of soils are called fertilizers. Fertilizers can be natural or man-made (synthetic). Animal waste is sometimes used as a natural fertilizer.

Objective: Students will make a liquid fertilizer called "manure tea" from steer manure. Students will design and perform an experiment to determine the optimum dilution of this nitrogen-rich fertilizer.

California Standards: NGSS: 3-5-ETS1-3, MS-LS1-5, MS-ETS1-3

Materials: Store-bought steer manure (3 or 4 cups), coffee filter, five-gallon bucket with lid, water, string, index cards cut in half, stapler, tablespoon, corn seedlings and other supplies for student-designed experiment.

Procedure:

1. Write the term "manure tea" on the board. Obtain student ideas for its definition. Also discuss that plants need certain nutrients for successful growth and reproduction.
2. Have each student make a manure tea bag by placing two tablespoons of manure into a coffee filter and stapling it shut. Staple a string to one end and 1/2 of an index card to the other end of the string. Have students create and draw labels for their "brands" of tea on the index cards.
3. Hang the tea bags in a covered five-gallon bucket that is full of water. Let the bags steep overnight. Record observations.
4. Design and perform a class experiment that will determine the optimum manure tea concentration for growing corn. Brainstorm variables to control and potential failure points.
5. At the conclusion of the experiment, compare and identify the most successful design solutions. Discuss how their newly-gained knowledge can relate to large-scale agriculture.

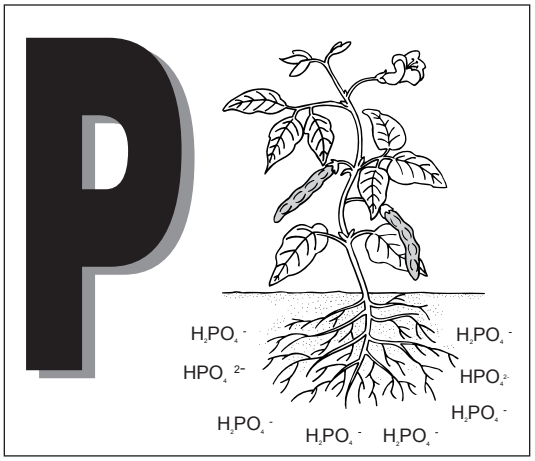
04/17 This Fact and Activity Sheet was developed by California Foundation for Agriculture in the Classroom in conjunction with California educators and meets the required education standards of the California Department of Education.

Natural Resources Fact Sheet

Plant Nutrients–Phosphorus

Information compiled by the Western Plant Health Association

Plant Utilization – Phosphorus, one of the 17 chemical elements required for plant growth and reproduction, is often referred to as the "energizer" since it helps store and transfer energy during photosynthesis. It is also part of the genetic material of all cells—DNA and ATP.



All plants require phosphorus during all phases of growth. Most annual plants (plants that grow, reproduce, and die in one year) require large amounts of phosphorus as they begin to grow. Plants grown in cold weather which have limited roots and rapid top growth, such as lettuce, are high phosphorus users. Legumes also require plentiful amounts of phosphorus. Established plants such as trees, shrubs, and vines, especially those grown in warm climates with long summers, require the least amounts of phosphorus fertilizer.

Production – In the soil, phosphorus is often found in chemical forms that cannot immediately be absorbed by plants, so farmers commonly apply phosphorus to the soil. The common source for commercial phosphorus fertilizer is rock phosphate, a calcium phosphate ore found in deposits within the earth. Rock phosphate is usually strip mined and then pulverized. The resulting material is treated with sulfuric, phosphoric, or nitric acid to produce various soluble phosphates that can be used as fertilizers such as monoammonium phosphates, diammonium phosphates, and super-phosphates.

Forms – All plants require phosphorus. Plants most often absorb phosphorus in the form of phosphate ions $H_2PO_4^-$ and sometimes as HPO_4^{2-}. These phosphate ions react readily with the soil and become part of the soil particles in a process called "fixation." Fixation prevents the leaching of phosphorus, but also changes it to a form that plants cannot use. The challenge in agriculture is to provide plants with the proper amount of phosphorus, in the proper form, at a time when the roots will absorb it.

The phosphorus concentration in fertilizer is reported as P_2O_5 and is represented by the middle number of the three numbers listed on the label. Manufactured fertilizers come in liquid and granular forms. Organic fertilizers, such as manure, contain phosphorus in limited quantities. Growers usually apply phosphorus directly near the root zone. This is called banding and makes the phosphorus available for immediate absorption by the roots. Growers often mix phosphorus in soil when planting seedlings or transplanting trees, shrubs, or vines.

History – Early American farmers used ground bones as fertilizers, however, very little of the phosphorus in the bones was available to the plants. In 1808, Sir James Murray of Ireland produced the first effective phosphorus fertilizer. Murray treated bones with sulfuric acid, converting the phosphorus to phosphate, a form of phosphorus plants can absorb. Murray later discovered that rock phosphate could be used in this same process.

Super phosphate production began in the United States in South Carolina in 1849. In 1851, John Jay Mapes of Long Island, New York, built the first phosphate manufacturing plant in the United States. Thus, he earned the title of "Father of the American Fertilizer Industry." By 1889, America produced 90 percent of the world's phosphate fertilizer and continues to produce 30 percent of the fertilizer produced today.

Top Producing Regions – In 2008, China led the world in phosphate production with 35 million tons, followed by the U.S. with 31 million tons, and Morocco/Tunisia with 28 million tons. The U.S. remains the leading exporter of phosphate fertilizers. In 2009, China led all countries in annual phosphate fertilizer consumption with 10 million metric tons followed by India which consumed more than five million tons and the U.S. with more than four million tons.

In 2007, Florida and North Carolina accounted for 85 percent of the total domestic output of phosphate rock. Production also occurs in Idaho and Utah. India and China are the major destinations for United States exports of phosphate fertilizers.

Economic Value – The economic value of the phosphate industry is difficult to assess. The fertilizer value alone is more than $3.5 billion, but the additional value associated with this industry for mining and food production greatly exceeds this value.

For additional information:
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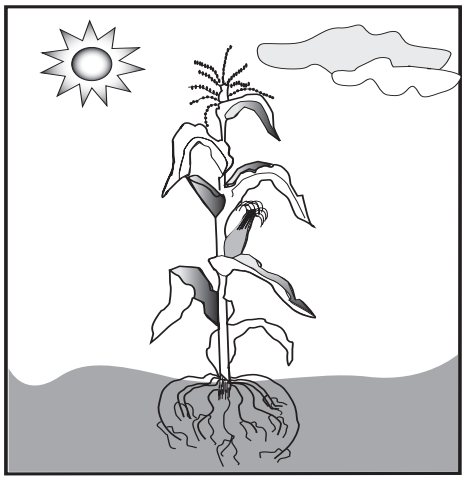
Phosphorus Activity Sheet

How Phosphorus Functions in Plants

- *Stimulates early growth and root formation and growth.*
- *Necessary for cell division and DNA and RNA formation.*
- *Improves the ability of plants to absorb water and other nutrients.*



- *Stimulates flower blooms and seed development.*
- *Improves plant strength and the ability to tolerate unfavorable environmental conditions.*
- *Aids in photosynthesis and food formation.*

Lesson Ideas

- On a United States map, color the states yellow that mine rock phosphate.
- Learn about the physical and chemical properties of phosphorus.
- Research and list foods high in phosphorus and learn how phosphorus is used in the human body.
- Interview a nursery or greenhouse worker and ask when and how phosphorus should be applied to your favorite plants.
- On a world map, color the major phosphorus producers one color and the major phosphorus importers another.
- Research how phosphorus rock is processed into phosphate fertilizer.
- Invite farmers into your class to discuss how plant nutrients are added to their particular crops.
- Create a comic strip whose main character is “Phosphorus—the Energizer.”

Fantastic Facts

1. Plants require the most phosphorus at the beginning of life and during periods of rapid growth.
2. The largest phosphorus producer is China.
3. Plants that have small root systems and significant above ground growth require plentiful amounts of phosphorus fertilizer.
4. Before rock phosphate, ground bones mixed with dilute sulfuric acid provided plants with phosphorus.
5. Florida and North Carolina produce the most rock phosphate in America.
6. P is the symbol for the element phosphorus.
7. The middle number on a fertilizer label represents the amount of phosphorus it contains.

Lesson Plan: Read the Label

Introduction: Fertilizer labels have a standard format which lists three numbers. Each number represents the quantity of a nutrient in the fertilizer. The first number represents the percentage of nitrogen (N) in the particular fertilizer. The second number represents the percentage of phosphorus (P_2O_5), and the third number represents the percentage of potassium (K_2O) in the fertilizer.

Objective: Students will examine fertilizer labels, research the nutrient needs of an agricultural crop, and create a fertilizer label for that crop.

California Standards: CC ELA: SL.3-12.3; NGSS: 5-LS1-1, MS-LS1-5

Materials: Fertilizer labels, white paper, markers, reference books.

Procedure:

1. Distribute sample fertilizer labels. In groups, have students examine the labels. As a class, create a template for a standard fertilizer package. Discuss what the three numbers mean on the front label.
2. Have each student select a crop for which they will find out its nutrient requirements. They may use encyclopedias, the Internet, a local agricultural commissioner’s office, or information from the University of California Cooperative Extension.
3. Have students create fertilizer labels that would meet the nutritional needs for their crop. Students may need to specify the time frame for application, such as “at planting.”
4. As a class, compare the fertilizer labels the students developed. Could one fertilizer be used for more than one commodity? Discuss what other factors might be considered when determining what fertilizer to purchase—price per unit, package size, soil type, climate, availability of composts and manures.
5. Invite an agronomist or fertilizer manufacturing representative to your class to discuss the uses and sales of fertilizers. After the presentation, identify the speaker’s claims, point of view, and reasoning.

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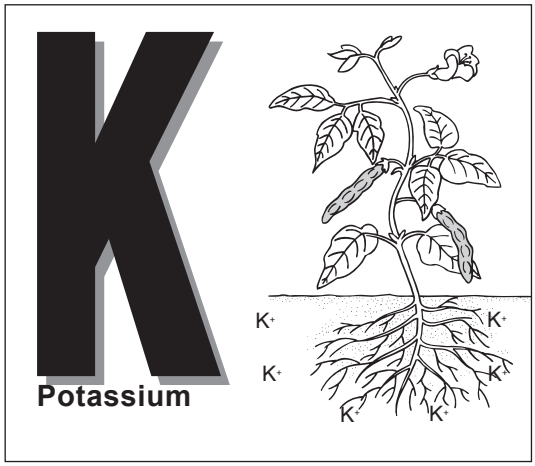
Natural Resources Fact Sheet

Plant Nutrients–Potassium

Information compiled by the Western Plant Health Association

Plant Utilization – Potassium, one of the 17 chemical elements required for plant growth and reproduction, is often referred to as the "the regulator" since it is involved with more than 60 different enzyme systems in plants. Potassium helps plants to resist drought and effects from excessive temperatures. It also increases crop resistance to disease. Potassium aids plants in the production of starches, controls root growth, and regulates the opening and closing of pores in plant cells (called stomata), which is important for efficient water use.



All plants require potassium, especially crops high in carbohydrates, like potatoes. Studies have shown that adequate amounts of potassium may promote the growth of long, strong cotton fibers; increase the shelf life of fruits; increase the stem length and quantity of roses; enhance the green color and growth of turf grass; and increase the size and quality of fruits, grains, and vegetables.

Production – Potassium is the seventh most abundant element in the Earth's crust, yet only one to two percent is available to plants. The rest is incorporated in the structure of the rocks and unavailable to plants. Farmers often apply potassium fertilizer for optimum plant growth.

Most potassium is mined from underground deposits and is shaft mined, like coal. Some shafts are drilled as deep as 3,000 feet. In some cases, solution mining is also used in which case water is pumped into the shaft to dissolve the ore. The solution is extracted and allowed to evaporate, leaving behind potassium salts. Some potassium comes from the evaporation of water from natural salt lakes, such as the Great Salt Lake in Utah, and the Dead Sea in Israel and Jordan. Tobacco stems, wood ash, wool waste, sugar beet factory waste, and flue dust also contain potassium, but their use as a fertilizer is limited.

Forms – Potassium is symbolized as K_2O on fertilizer labels and is the third number on the label. Plants absorb potassium in the form of the ion K^+ which dissolves readily in water.

Ninety-five percent of all potassium fertilizers come in the form of muriate of potash, also known as potassium chloride. For crops unable to tolerate chloride, potassium sulfate, potassium nitrate, and other chloride-free salts are used. Potassium comes in both liquid and granular form and is usually mixed in the soil or placed directly near the root zones of plants. Application of chloride-free foliar sprays are sometimes used on certain crops.

History – The letter K, used to symbolize potassium, comes from the German word kalium. Before the industrial era, people burned wood and other organic matter in pots to manufacture soap. The ashes were rinsed and the water was allowed to evaporate, leaving a residue of potassium salts. People called the residue "pot ashes" or potash. These salts were boiled with animal fat to produce soap.

In 1868, Samuel William Jackson, a botanist in Connecticut, burned plants and analyzed the ash. Jackson found plants consisted of large amounts of potassium, and other minerals. His work led to the use of fertilizers to promote an increase in crop yields. The very first US patent issued by the United States government was for an improved method of potash production.

Top Producing Regions – Canada leads the world potash fertilizer production and exports, producing nearly 8 million tons in 2009. Russia, Belarus and Germany are also top producers of potash. U.S. production has been stable with most domestic production occurring in New Mexico. Lesser amounts are produced in Utah and Michigan. The price of potash fertilizer has increased significantly in the past few years, causing mining companies to seek new sources of the raw material throughout the world.

China is the world's leading potash consumer, using 8 million tons in 2009. The U.S. and India are the next leading consumers of potash. Approximately 20 percent of the 6.5 million tons of potash used in the U.S. is domestically produced.

Economic Value – United States farmers pay $900 million annually for potassium fertilizers, with California farmers paying, approximately $30 million each year.

For additional information:
California Fertilizer Foundation
(916) 574-9744
Website: www.calfertilizer.org

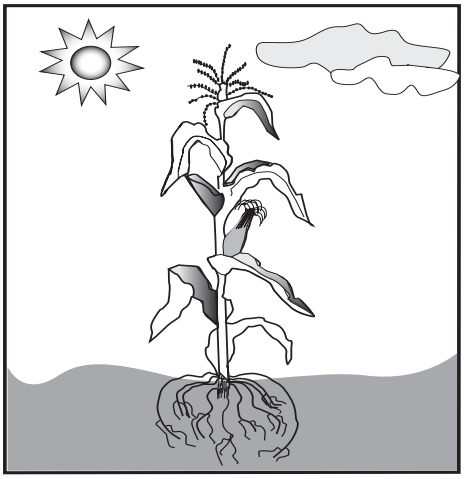
California Fertilizer Foundation

04/17

Potassium Activity Sheet

How Potassium Functions in Plants

- *Helps retard crop diseases.*
- *Builds cellulose needed for stalk and stem strength.*
- *Aids in photosynthesis and food function.*
- *Increases root growth and improves drought resistance.*



- *Produces grain rich in starch.*
- *Necessary for plant protein formation.*
- *Reduces water loss and wilting.*
- *Assists many enzyme actions.*

Lesson Ideas

- On a world map, color the major potassium exporters blue and the major importers red.
- On a map of North America, locate and color the areas where potassium is mined.
- Research how humans utilize potassium and find out what foods are high in potassium.
- Make a poster illustrating the various roles potassium plays in plant growth and health.
- Locate potassium on the periodic table of elements. Learn about its physical and chemical properties.
- Find two points that are 3,000 feet apart so students can appreciate the depth of some potassium mine shafts.
- Research the Colonial soap-making process and the various uses of potash.
- Find out how agronomists determine the potassium content of soils.

Fantastic Facts

1. Canada is the world's leading exporter of potassium.
2. Potassium is obtained by underground mining.
3. Potassium is sometimes called "the regulator" because it controls many plant enzyme systems.
4. Potassium helps plants by aiding protein and starch formation, stimulating root growth, providing winter hardiness, and opening and closing cell pores called stomata.
5. New Mexico processes the most potassium in the United States.
6. Historically, potassium was called "potash" because it was sourced from the residue found in wood ashes.
7. California is the largest importer of potassium.
8. Some potassium is obtained from The Great Salt Lake in Utah.
9. The very first US patent issued was for an improved method of potash production.

Lesson Plan: The World of Potassium

Introduction: Potassium is an essential nutrient for plants and animals. It also has many other uses, depending on its chemical formulation.

Objective: Students will research potassium and its various uses. They will create a wall-length mural that depicts their findings.

California Standards: CC ELA: W.3-12.7; RI.3.5; RI.4-5.9; RST.6-10.2, 7

Materials: Reference materials, including encyclopedias, human nutrition books, plant nutrient requirement books, butcher paper, paint or markers, glue.

Procedure:

1. Write the following phrases on index cards: plants which produce fibers for clothing; annual crops, such as celery; forage crops, such as alfalfa; tubers, such as potatoes; disinfectant; human nutrition; component in soap; plant guard cells; potassium forms which are usable by plants; agricultural by-products which contain potassium; roses and other flowers.
2. Divide the students into groups of three or four and distribute one index card to each group.
3. Each group is responsible for researching how potassium relates to the key words on the index card. After they gather the details, the group is to decide how they will depict their knowledge on a wall mural called "The World of Potassium."
4. In a class discussion, determine what the class mural will look like so that all aspects of potassium use will be displayed.
5. Have each group create their graphics and text for the mural and then place it on the mural.
6. Display the mural at a science night or in the library. This may be displayed with other murals made for other elements, such as nitrogen and phosphorus.

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