THE INTERRELATIONSHIPS OF SOIL, WATER AND FERTILIZERS AND HOW THEY AFFECT PLANT GROWTH

GRADES 9-12

written by
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This series of units includes:

*What Do Plants Need To Grow? for Grades 2-4
*How Much Is Too Much? How Little Is Too Little? for Grades 5-8
*The Interrelationships of Soil, Water and Fertilizers And How They Affect Plant Growth for Grades 9-12

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‘Denotes pilot testers
INTRODUCTION

Welcome to the wonderful world of science and agriculture!

Did you know California produces more agricultural products for the nation than any other state? Consequently, it has a great effect on all of the people living here. You can easily take the knowledge your students have, add science education through practical application, and give them an opportunity for some valuable fun in the classroom. After all, the Science Framework for California Public Schools emphasizes the need to make science education more meaningful to students so they can apply what they learn to their lives. The enclosed unit helps students connect what they learn in the classroom to daily living. They can see the relationship of science lessons to the food they eat and the clothes they wear.

As more rural areas become urbanized, and challenges exist to maintain and improve the quality of our planet and to feed the people of the world, it is extremely important to educate children about their environment and about agriculture. This science unit is another tool you can use to enlighten your students about the world in which they live.

'The Interrelationships of Soil, Water, and Fertilizer and How They Affect Plant Growth" is structured to encourage students and teachers to "construct" their own knowledge about plants and their environment. This means students become conscious of their own concepts concerning a topic, challenge those ideas through experimentation, and then apply their thoughts to a separate situation. There is a lot of room for creativity in this unit, yet enough guidance for success. Do not feel tied to using the handouts provided, teach the concepts in any order, grow plants and try new ideas. Encouraging your students to create experiments will help them confirm or disprove their ideas. If you provide well-managed labs and allow creativity at the same time, your students will appreciate the hands-on approach to learning science and will be encouraged to further their science education.

The California Foundation for Agriculture in the Classroom is dedicated to fostering a greater public knowledge of the agricultural industry. It seeks to enlighten students, educators, and leaders in the public and private sector about agriculture's vital, yet sometimes forgotten, role in American society and the effect all citizens have on agriculture's well being. Please contact the Foundation if we can assist you with the integration of agriculture into your curriculum.
UNIT OVERVIEW

BRIEF DESCRIPTION

The students will perform a series of experiments on soils and the nutrient requirements of plants and participate in a valuable role-play that will help them appreciate the complexity of human interactions with the planet. This unit can be incorporated into botany, earth science, and chemistry units of a general science course, or used in horticulture, earth science, and biology classes.

SCIENCE THEMES

- Systems and Interactions
- Stability
- Patterns of Change
- Energy

CONCEPTS

- Plants have basic requirements, including the need for 16 elements, as well as certain environmental conditions, such as appropriate temperature, humidity, light, and soil composition.
- There are many ways to maintain and/or improve the quality of soil so it can provide the nutrients and conditions needed for successful plant growth.
- Optimum water quality is critical to the survival of living things.
- Soils and waters vary; thus, they differ in the types and amounts of nutrients that are available to plants.
- There are advantages and disadvantages to using organic and commercial inorganic fertilizers.
- Many factors are important in maximizing the production of food and fiber.
- Average citizens, as well as political activists, have an impact on what legislation and policies are adopted by the government.

OBJECTIVES

The students will:

- Identify a variety of facts related to the nutrient requirements of plants, human population statistics, agriculture and water quality.
- Analyze various factors that affect plant growth.
- Record facts and opinions on class readings and discussions about various issues related to agriculture.
- Demonstrate knowledge of the quantitative measures of part per million and part per billion.
- Analyze the mechanics of water flow and the mechanics of pollution in groundwater.
- Analyze the contents of fertilizers.
- Determine how fertilizers, water types and soil types affect plant growth.
- Analyze water quantity and water quality conditions.
KEY VOCABULARY

- aquifer
- fertilizer
- nutrient
- potassium
- contamination
- groundwater
- organic
- part per billion
- public hearing
- decompose
- inorganic
- part per million
- quality
- depletion
- nitrate
- phosphorus
- quantity
- detection limit
- nitrogen
- soil management
- close
- nitrogen-fixing
- potash
- sustainable agriculture
- emulsion

SEQUENCE OF ACTIVITIES

These activities can be completed in a variety of sequences. Skim over the entire unit before beginning it with your students. Pick out a sequence which will work best for you. Make sure you plan ahead so that short term activities can occur between longer experiments. One sample sequence is listed below:

**LETS GET THE FACTS**
**READ ALL ABOUT IT- FACT/REACT JOURNAL**
**HOW TO READ A FERTILIZER LABEL**
**HOW SOILS, WATERS, AND FERTILIZERS AFFECT PLANT GROWTH- TEAM EXPERIMENTATION**
**WHAT'S A PPM? PPB?**
**GROUNDWATER**
**PLEASANTVILLE AND GROUNDWATER**

EVALUATION

There are many ways to evaluate student knowledge as they participate in this unit: class participation, written and oral answers to questions, completion of labs and personal interviews.

The impact of this unit may not be clear to the instructor because much of the material taught in this unit relates to the way students think about issues. One possible evaluation tool is described below and is a good follow-up lesson to the Pleasantville and Clear River role-play the students will perform.

Have each student represent an older member of the community whose family has lived in Pleasantville for generations. This person owns a farm or ranch and is getting ready to retire. S/he understands that times are changing and wants the family farm to continue to be modernized and successful. S/he also has great insight on how agriculture must co-exist with a rapidly growing population.

Pretending to be this person, each student writes a letter to a grandson who is attending college in another state, but will be returning to Pleasantville to run the family farm. The letter should include what has just happened at your public hearing as well as comments on what this young farmer should learn about while studying animal and crop science in college. (Remind the students that this letter will be used to evaluate their increase in knowledge and should clearly show that the student has learned something in this unit.)

EXTENSION ACTIVITIES

The following lesson ideas are included in the Teacher Resource section of this unit.

**WINOGRADSKY COLUMN**
**THINK ABOUT IT-SOIL**
**COMPOSTING WITH A WIGGLE**

**COMPOST COLUMNS**
**OUTDOOR COMPOST BIN**
TIME REQUIREMENTS

General Time Frame

This unit is designed to span 7-9 weeks. This allows time for plants to grow and for instructors to include other related topics. In actuality, approximately 20 fifty-minute sessions are needed to complete the lessons in this unit.

Let's Get The Facts

30 minutes--teacher preparation
1 fifty-minute session--activity

Read All About It!

Approximately 3-4 hours total
2-3 weeks of 2-3 readings per week

How To Read A Fertilizer Label

1-2 fifty-minute sessions--classroom activity

What's a ppm? ppb?

1 fifty-minute session--classroom activity

How Soils, Water, and Fertilizers Affect Plant Growth

4 fifty-minute sessions--introduction and set-up
4 weeks--growing of plants and observations
3 fifty-minute sessions--conclusions and presentations

Groundwater

2 fifty-minute sessions--classroom activity

Pleasantville and Clear River

3 fifty-minute sessions--research and preparation
2 fifty-minute sessions--public hearing
Specific quantities of materials are listed at the beginning of each individual lesson. The list below gives you an overview of what materials are necessary to complete the entire unit.

2-liter bottles
Article--supplied in this unit
Articles on current issues in agriculture
Baby food jars with lids
Bread wrapper, empty
Butcher or chart paper
Calculators
Car oil can, empty
Clay-like soil
Construction paper
Darkness, total--for plants to be stored
Dime
Eye droppers
Fertilizer
Fertilizer box, empty or fertilizer labels
File folders
Food coloring
Glass of water
Graduated cylinders
Hand shovel
Handouts--supplied in this unit
Knife
Labels
Light source
Markers
Masking tape
Newspapers and magazines
Nylon stockings, old
Overhead projector
Overhead transparencies
Paper towels
Pebbles
Pictures of farmers, people, forests, toilet, rainforest, wheat and rice fields, starving people and homes
Place to grow plants for 4-5 weeks
Planting pots--see ‘Growing Plants in the Classroom’ section of this unit
Pond water
‘Post-it” notes
Potting soil
Reference books--see “Background Reference” section of this unit
Rubber bands
Sand
Scotch tape
Seeds--beans, corn, radish and wheat
SEPUP trays--see Useful Organizations and Companies section of this unit
Stapler
Test tubes
Vermiculite
Water
GROWING PLANTS IN THE CLASSROOM

All Instructors should read this section before beginning this unit. There are many tips mentioned here that pertain specifically to the lessons in this handbook. Refer to this section, when necessary, as you complete the various activities with your students.

INTRODUCTION

There are a variety of ways to successfully grow plants in a classroom. If you already have a successful set-up, use it for this unit. If you have never grown plants in your classroom, experiment with the following guidelines and see what works best in your particular situation. You will find that your students can successfully grow plants indoors if they are given proper guidance and are able to learn from their mistakes. Remember, students (and teachers!) learn just as much, if not more, when an experiment does not turn out as expected!

OBTAINING MATERIALS FOR GROWING PLANTS

Growing plants with students can be a community project. There are many resource people in your community who can assist you with your efforts. You will be surprised how much assistance you will receive, financially, as well as physically, if you just ask. Local gardening clubs, garden and florist shops, University of California Cooperative Extension Master Gardeners, local farmers and 4-H and FFA organizations have knowledgeable personnel. Sometimes farming or gardening equipment that can be loaned out or donated. You might also ask various community clubs and organizations such as Kiwanis, Lions, your Chamber of Commerce and county Farm Bureaus for financial support. The California Foundation for Agriculture in the Classroom has a resource guide that can assist you in finding free or low cost educational resources. See the Teacher Resource section of this handbook for specific names and addresses of helpful organizations.

LIGHT SOURCES

Plants should have proper light for approximately 8-10 hours each day. Overhead classroom fluorescent lights provide enough light for starting seeds and growing small seedlings. However, they do not provide enough light for the rapidly growing phases of plant life. The following list mentions ways you can make sure your plants receive enough light.

- The best set-up is a light source of incandescent or fluorescent lights that is no higher than 2 feet above the growing plants. Desk lamps or simple grow-lights, purchased from a garden center, work well.

- Sunlight from sunny windows will provide enough light for bean plants, however, corn and wheat plants require more light. If necessary, students can take their plants outside in the morning and return them to the classroom in the afternoon. When the students are transporting them, make sure they are careful not to touch or break the plants and the plants are protected from high winds and other students.

- There are a variety of elaborate plant “grow labs” that can be purchased from scientific supply companies such as NASCO West, Carolina Biological Supply Company and Frey Scientific Company. If you are in an older school, you might even be able to find bits and pieces of old grow labs--use them to build a unique “grow-lab” of your own.
POTS

There are a variety of small planting pots (approximately 2-3 inches in diameter) that can be purchased at garden centers or from scientific supply companies. However, it is not necessary to use ‘true’ planting pots. Remember, plants require drainage so holes should be in the bottom or lower sides of any pot you use. Pots should be placed on jelly roll pans, aluminum pie plates or other water proof trays so that the overflow water will not spill onto unprotected areas. Use separate drainage pans for pots watered with different types of solutions. All pots should be washed thoroughly, with clean water, before each planting.

Suggestions for inexpensive pots:

- Well-rinsed school milk cartons with 2 holes poked in the bottom with a nail.
- 8-ounce wax-lined paper cups with 2 holes poked in the bottom with a nail.
- Donated cups from fast-food restaurants with holes poked in the bottom.
- 9 ounce clear plastic cups--instructors can make holes in the bottom of these cups by heating a nail over an open gas flame then placing the nail through the bottom of each cup.
- 4" pots gathered from neighbors and nurseries who have transplanted bedding plants. Be sure to wash the containers thoroughly before using them.

Peat pots are available at most garden centers. These pots cannot be re-used and should not be used for most experiments in this unit. The pots have nutrients in them and can alter your data and usually do not last longer than 2-3 weeks. However, peat pots are convenient to transplant seedlings into their own home gardens.

LABELS

All pots and solutions should be labeled clearly. Pencils, ball point pens, laundry pens and permanent markers can be used. Test the pens or pencils yourself, before having your students make labels.

Possible label ideas are listed below.

Masking tape--Students can place the masking tape on their tables, write the necessary items on the tape and then place it on the planting pot. Test the masking tape you would like to use before distributing it to students. Masking tapes vary--some may be too adhesive, others not adhesive enough, and some may not be easy to write on.

File folder labels--These can be purchased at most stationery and department stores. These are handy for experiments lasting no more than 1-2 weeks. These labels are not recommended for long term experiments or for use on clay pots.

Paper labels--Handmade labels can be made by using scrap pieces of construction or binder paper. Scotch tape can be placed over the labels to make them waterproof and to adhere the labels to the pots. The frosted-type is easier to remove than cellophane tape.

Grease pencils--The need for labels can sometimes be avoided if grease pencils are available. They can be purchased at stationery stores or from scientific supply companies. These pencils can be used for teacher demonstration labels, but are not recommended when students will be handling the pots frequently.
SOILS

There are many types of soils available at garden centers. The experiments in this unit require a variety of soils. Using soil gathered from local surroundings will be suitable for some experiments, however, more reliable laboratory results will occur if soil is purchased. Some garden centers will donate broken bags of soil to schools for student use. Ask your local garden center manager if this is the policy at the store. Landscape centers that sell large quantities of topsoil, sand and gravel may also donate small amounts of these items to your school.

Standard potting mix/soil--This is what should be used unless otherwise indicated. It contains the nutrients required for successful plant growth. Generic brands of potting soil will work fine. Potting soil should not be reused unless it has had a chance to dry out and has all old roots, seeds and plants removed. The molds and other organisms in used potting soils can often harm seeds and young seedlings. Used potting soil can be spread into school gardens, landscaped areas, or put into compost piles.

Vermiculite--This is expanded mica, grayish in color, and is used to sprout seeds that will later be transplanted. It can be found at garden centers. Vermiculite is gentle on root systems but does not contain a lot of nutrients.

Perlite--Perlite is expanded, volcanic ash and contains very little nutrient value. It is used in plant propagation to allow air flow and hold water and can be purchased in local garden centers.

Sand--Sand is a component of most soils. Sand, in its pure form, is made of quartz particles between 0.05 mm and 2.0 mm in size. It usually does not contain nutrients required by plants. When using sand in this unit, make sure that you rinse it well since small amounts of clay, silt or organic matter can alter your results. Sand from garden centers might be a little more pure than playground sand and require less rinsing.

Silt--Silt is a component of most soils. It consists of particles that are smaller than sand but larger than clay. Silt particles range from 0.02 mm and 0.05 mm in size. Silt is formed by the sedimentation of rock particles that exist due to wind or water erosion.

Clay-like soil--Clay is a component of most soils. It consists of very tiny particles no larger than 0.02 mm in size. Clay-like soils compact very easily and are hard for digging.

Pea gravel--Pea gravel is a mixture of small rocks about the size of peas. It can be purchased at most garden centers. Make sure the gravel is rinsed before using it in your experiments.

PLANTS AND SEEDS

A variety of seeds can be used in this unit.

Bean/Pea/Corn Seeds--To insure successful plant growth, purchase garden seeds that are produced for the current planting season. If you choose to use older seeds, discuss the likelihood of non-germination with your students and have them plant more than the suggested number of seeds in each pot. Sometimes the seeds are covered with a fungicide. If this is the case, make sure your students wash their hands after touching the seeds. Dried grocery store beans can be used for seed dissections but are not recommended for plant growth experiments.
Wheat Seeds—Wheat seeds, sometimes called wheat berries or grains of wheat, can be purchased in the grain section of health food stores or health food sections of some grocery stores. They are very inexpensive and generally grow quite well. Plant a few seeds yourself before doing an experiment with your students if you are not certain of their viability. Wheat seeds can also be purchased from livestock feed and grain stores.

Seedlings—A few experiments may take less time if seedlings are used. If you have the space, you may want to plant some extra bean seeds a couple of weeks before you will need them. Purchased seedlings can also be used for some experiments.

WATER AND WATERING

Water Types

Tap water—Generally, tap water can be used unless specific instructions tell you otherwise or if your water is too hard. Soft water also should not be used in this unit because it contains ions that can be harmful to plants.

Distilled water—Certain experiments require the use of distilled/de-ionized water. This water can be purchased inexpensively at a grocery store. Some hospitals and laboratories have plumbed distilled or de-ionized water and will donate some to you, if you provide the containers.

Appropriate Amounts of Water

Overwatering tends to be a major problem with students. There are many ways to prevent your students from overwatering and under watering their plants. Generally, you want the soil to be moist, not wet, after watering. You then let the soil dry out before the next watering. Excessive drainage from the pot or standing water are good indications of overwatering.

Suggestions are listed below.

- Show your students examples of soil that is ‘just right,’ ‘too wet’ and ‘too dry.’
- Monitor your students the first few times they water their plants. Discuss with each student what an appropriate amount of water would be.
- Use spray bottles or eye droppers for watering.
- Place a specific amount of water in a plastic cup for each group and explain that no more water than the specified amount should be necessary.

Water Storage Containers

Any sealable container can be used to store water. It is important to label all containers, especially when a container is being used for something other than its original use.

Ideas for water storage containers:

- 1-gallon plastic milk or water bottles with lids
- Baby food jars with lids
- 2-liter plastic soda bottles with lids
- Spray bottles
- Water pitchers
LABORATORY MANAGEMENT TIPS

The Science Framework for California Public Schools states: ‘Much has been written about the need for students to conduct hands-on investigations in learning science. The reasons are many, but they essentially fall into three major categories: (1) many students will not truly understand the science they are supposed to learn if the exposure is solely verbal; (2) students learn the processes and techniques of science through the replication of experiments; and (3) students will enjoy and retain the science they learn from a laboratory activity more than from a textbook.’

The statements above are legitimate and understandable. Teachers know they should be teaching science with hands-on activities, however, all teachers know that ideal situations do not always exist in the classroom. Classrooms are often overcrowded with students; there is not enough storage space; parents can no longer volunteer because they have to work, and supplies are limited.

This section of the booklet is dedicated to helping you and your students have positive experiences in laboratory science activities. Try several ideas and choose what works best for you.

ORGANIZING YOUR CLASSROOM

Science labs can be done in any classroom. One trick to making them work in your particular classroom is to have your room set up properly.

- Have your tables set up so there is a flat surface available for use by each student group. Desks might be clustered together or each group may have a particular shelf or counter they use around the room. If desks must be rearranged, train your students to move them. Make it a contest, if necessary, so that you can have your room arranged for science in 1 minute flat! Masking tape markers on the floor can help your students properly position tables.

- When not in use, keep your science supplies out of the reach of students. Curiosity often causes damage or loss of equipment. Allow the curious students to be your monitors and train them in handling and organizing your science supplies. Labeled copy paper boxes, shoe boxes, plastic storage crates and other containers can help keep materials organized. Some classroom teachers have built storage sheds somewhere at their school to hold science equipment.

- Water is a must in the teaching of science. If you have a sink, have your students follow a set of rules related to it. If you do not have a sink in your classroom, water from a local drinking fountain or restroom can be stored in 1-gallon water or milk bottles. Perhaps you can arrange to have your classroom located near an outside watering spigot.

- Mops, sponges, rags, empty buckets, brooms and dust pans should be made available for clean-up.

SCIENCE SUPPLIES

- Keep regularly used items such as colored pencils, scissors and markers in organized, ready-to-use bins.

- Check materials out to groups and make them responsible for returning the supplies in good condition: numbering the supplies and numbering the groups can help. Another successful process is to excuse the class only after all supplies have been returned to their proper locations.

- Do not have unnecessary supplies in the reach of students. They can know what you have available, but you should require them to check out the materials.
• At appropriate times, and well in advance, send lists home to parents requesting certain household items. Students can receive extra credit for bringing-in items you will need for experiments.

• Do not be afraid to ask local merchants for donations for your classroom: fast food restaurants might donate cups or straws, grocery stores may donate paper or plastic bags, shoe stores might donate shoe boxes, butchers might donate butcher paper or foam trays, etc. Some schools have one teacher coordinate the requests asked of local merchants so the merchants are not overwhelmed with requests. Perhaps you can be that person, or a classroom parent volunteer could assume the responsibility.

DISCIPLINE

You must have a working discipline program in effect before beginning lab activities. Start out slowly; do simple lab activities first and then build up to more complex activities. The key to positive experiences in laboratory science is organization, planning and the insistence of following safety procedures.

Discipline tips are listed below.

• Associate all lab rules with safety and responsibility. For example, there is no squirting of water bottles because people can slip and get hurt or get a harmful chemical in an eye; running in a lab setting could cause someone to spill a chemical that could be harmful to people or clothing, etc.

• Have all of the supplies ready for distribution so that you can spend class time with your students rather than worry about obtaining supplies or passing out papers.

• Think of potential horseplay scenarios that could happen with your equipment. Role-play these scenarios. Clearly explain to the students how the equipment should be used and discuss the consequences that will occur if students misuse the equipment or do not follow directions. (For example, a student who does not clean up his area will be responsible for cleaning the entire room after school.) It is best if you can make the consequence fit the problem and, if possible, clearly state all potential problems at the onset of the experiment.

• Have each student or group of students earn two grades for lab assignments—one grade for cooperation and one grade for work completed. Depending on the lab activity, group cooperation may be worth more of the grade than the actual work completed.

• if you are using cooperative groups, have the groups earn a grade on cooperation and following directions. This will encourage students to use peer pressure as a means of classroom control.

• Ask your principal or peers for names of people who manage laboratory activities in a positive and productive way and observe these successful teachers during lab activities. It helps to observe the same person at least twice and discuss his/her discipline program. It takes a while to develop a useful management program, and occasionally some management techniques are only used at the beginning of the year or are not obvious to an observer. It is amazing how many great tips you get through a peer observation program.
You should evaluate how well you think your labs are going. Immediately following a lab, write down problems, great ideas and trouble-shooting suggestions. Keep these notes with the teacher instructions of each lab; They will help you the next time you perform the activity. Revisions to labs are best made at the conclusion of a unit while your ideas are fresh in your mind.

Do not cancel all labs if one does not go well. Analyze the problems and use it as a learning experience. You and your students probably learned something even if you think a lab was not well managed.

You will find that students will want to do lab activities. They can be used as motivating tools and to promote cooperation. Putting trust in your students often encourages them to show you how well they can act.

Provide your students with a timeline. Explain how much time they have to complete the lesson. Throughout the period remind students of how much time they have remaining.

Have strategies for dealing with students who finish lab activities early. A well organized teacher always has other work for students to do upon completion of a lab (extension activities, reading assignments, puzzles, poster contests etc.).

Take a break from labs every once in a while. Labs are very active situations and can be tiring for both you and your students. When you and/or your students are feeling overwhelmed, do individual activities such as reading or writing assignments or watch an appropriate video. Pick up lab activities again once everyone is re-energized.

Train your students regarding what to do in case of a laboratory accident. Clearly explain how to inform the instructor and what steps should be followed. This avoids student embarrassment, classroom chaos, and further accidents. Discuss how horseplay can cause unnecessary accidents.

Hopefully, some of the preceding suggestions will help you have a positive experience with laboratory activities. Science is a very exciting subject and allows students to interact with one another on an intellectual level. Try an experiment or two with your students. You might be surprised how much fun it can be!
ORGANIZING STUDENT WORK

Throughout this unit, your students will be making many hypotheses, performing experiments to test their hypotheses and participating in many other activities. Each student will be required to write and draw pictures about their thoughts and record experimental data. It is important that your students have an organized place to keep their papers. Using ideas of your own and ideas listed below, decide how you would like your students to organize their work. Spend some time at the beginning of this unit to explain to your students how they will keep their records. Remember to allow organizational time throughout the unit. The more time you give students to organize their work, the more professional their final products will be.

SCIENCE NOTEBOOKS

- Science notebook contains any material you want your students to keep—hypotheses, lab write-ups, drawings, handouts, etc. Generally, science notebooks are organized in a standard way according to the instructor’s guidelines. Each student’s notebook will look similar to those of other classmates. A table of contents at the beginning of the notebook encourages students to keep their work organized. Teachers often post the table of contents on a wall so that students can have a model to follow.

JOURNALS

- This folder contains writing paper and any handouts you want your students to keep. Most often, journals are places where students can write their thoughts. They are usually dated, organized sequentially and allow students to comment freely on subjects. You should have your own requirements for journal writing and clearly explain those guidelines to your students. Some teachers require group journals rather than individual journals.

PORTFOLIOS

- Students keep a science folder of all lab activities, but at the end of the unit, they are required to make an individual “portfolio.” Portfolios include your students’ favorite/best work of his/her choosing. You should require your students’ portfolio to contain certain things. For example, you might require the students to include 2 labs, one writing assignment, 1 re-written laboratory assignment, one drawing and/or other items you think are appropriate; however, allow each student to pick the work that fits the criteria. Some students will need help organizing their final product. You will find that all students enjoy choosing what they want to go in their portfolios and that most will put extra effort into their papers they place in their “featured” work. Portfolios can be used as evaluation tools of student progress.

ACCORDION BOOKS

- Students keep folders with their materials and then make an accordion book of things they learn as they perform experiments and activities. The accordion books can be any size. The books are made by cutting pieces of butcher paper to the preferred lengths and widths and then folding them like an accordion. Students show what they learn in a sequential manner and enjoy looking at their work from previous lessons. Accordion books can also be used as evaluation tools of student progress.
MAKING FOLDERS

Possible folder ideas:

- Use manila file folders. Have each student write his/her name on the tab and keep it in a file folder box that is kept at school. This prevents students from losing and damaging papers. Papers can be stapled to the folder.

- Staple lined paper, blank paper, and/or combination sheets (master in the ‘Template’ section of this handbook) into a cover made from a 12” X 18” piece of construction paper.

- Make small booklets cut in the shape of a seed, plant, sun, fertilizer box, dirt pile, stream, etc.. Fill the booklets with blank paper and have the students fill it with predictions, data, conclusions, pictures and writing assignments. You may use one booklet for each scientific concept or experiment or different booklets for each concept or experiment.

- Spiral bound notebooks are a way of helping students keep all of their papers together. You can require your students to-staple or glue handouts in particular places.

- Report folders with 3 inner brads can be used as science folders. This allows students to keep papers organized but also allows for the addition of handouts.

OTHER IDEAS

- Have student groups or individuals make large posters that can be displayed in libraries and hallways.

- Flip books are a fun way of illustrating knowledge.

- For some lessons limit the number of words that can be used to express a hypothesis or thought. This encourages students to draw and allows artistic students to use their talents.
LET'S GET THE FACTS
(A SCAVENGER HUNT)

PURPOSE

Students will obtain factual information on issues within this unit as a basis for understanding the material that follows.

CONCEPTS

- Many factors are important in optimizing the production of food and fiber.
- Optimum water quality is critical to the survival of living things.
- There are advantages and disadvantages, both economic and scientific, to using organic and inorganic fertilizers?
- Humans can choose to change their behavior and plan to provide for the needs of future generations.

MATERIALS

For Entire Class:

- 1 copy of “N-Nitrogen” handout
- Article “How Nitrates Affect Health”--(included)
- Empty fertilizer box
- “Post-it” notes
- 1 dime
- 1 loaf bread or empty bread wrapper
- Glass of water
- Hand trowel, shovel, or rake
- Small amount of moist soil
- Marker
- Scotch tape or stapler
- Empty or unopened can of car oil
- Pictures of the following:
  Farmer--2 photos
  Crowd of people
  Starving children
  Homes built next to farmland
  Toilet
  Forest
  Rice or wheat field
  Rain forest

For Each Team of Two:

- 1 or 2 “Let’s Get the Facts” Worksheets
- Pen or pencil
TIME 30 minutes--teacher preparation
   1 forty-five-minute session

BACKGROUND INFORMATION

Science activities are more meaningful to students when they understand why they are performing them. This short activity provides students with facts about population growth, food and fiber production and environmental conditions. The information obtained from this activity should make the subsequent activities more meaningful.

PROCEDURE

1. Make up a scavenger hunt (or use the “Let’s Get the Facts’ student worksheet provided) about current issues that relate to agriculture, water and population dynamics.

2. Place the answers to the hunt in appropriate places around the classroom. You might even bring out special props for this activity. Suggestions are provided on the “Let’s Get the Facts teacher worksheet.

3. Explain the rules for the scavenger hunt. (Yours may vary.)
   - Only one team of students at a particular place in the room at a time.
   - No talking between teams, only between team members.
   - Do not write an answer on the team answer sheet unless all people agree to the answer. If this is not possible, write down both answers and explain the controversy on the answer sheet.
   - Remember where you found your answers so you can refer to the location during the class discussion.
   - Copying answers from other teams is unacceptable.

4. After telling them how much time they have to do the activity, have the students complete the scavenger hunt. If you wish, make this a contest. However, it may be difficult to determine a winner. Perhaps all students can be winners and receive a prize.

5. Discuss the answers to the scavenger hunt and how they relate to upcoming activities.

CONCLUSION

Just as the students looked for answers for the scavenger hunt, scientists and other people, today, are looking for solutions to solve many problems related to the same facts.

VARIATION

1. Have the students write their guesses down without providing clues around the room.

EXTENSION

1. Have students make up 2 additional scavenger hunt items related to current agricultural or water issues they read about in the local newspaper.
1. Contamination of water with this substance can cause "blue-baby" syndrome, a type of suffocation in infants.

2. This number represents the percentage of California residents living south of Sacramento and the percentage of rainfall north of Sacramento.

3. The 3 primary nutrients needed for plant growth.

4. The African population is predicted to do this between 1990 and 2020.

5. The percentage of the U.S. population that grows the food for all of the U.S.

6. This is reducing the amount of land available to farm on.

7. The reason farmers sell their land to developers.

8. The average number of gallons of water it takes to flush a household toilet.

9. Many commercial inorganic fertilizers require these substances for synthesis. These chemicals could be depleted if not used wisely.

10. U.S. farmers get this amount of each dollar spent on food in the U.S.

11. One loaf of bread requires this much water for production.

12. These people are often the worst abusers of commercial inorganic fertilizers--not because they deliberately try to misuse the substances but because they do not understand how or why to use the fertilizers properly.

13. These can be produced when groundwater is pumped to the surface of the earth and is not replenished.

14. The element that is in the human body which you eat approximately 10-13 grams of each day. It is in all nitrate minerals and is the major element of the air you breathe.

15. The estimated human population of the world.

16. One square mile of lush tropical forest can feed this many people per year.

17. One square mile of an agri-ecosystem (such as a rice field) can feed this many people per year.

18. One acre of this type of ecosystem is said to contain more species of living things than anywhere else on the planet.
<table>
<thead>
<tr>
<th>QUESTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
</tr>
<tr>
<td>QUESTION</td>
</tr>
<tr>
<td>ANSWER</td>
</tr>
<tr>
<td>DISPLAY SUGGESTION</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>1. Nitrates, although not a major problem in the United States.</td>
</tr>
<tr>
<td>Post the article &quot;How Nitrates Affect Health&quot; (copy provided)</td>
</tr>
<tr>
<td>2. 75%</td>
</tr>
<tr>
<td>A map of California with Sacramento northward shaded in and 75% rainfall written on it</td>
</tr>
<tr>
<td>3. Nitrogen, Phosphorus, Potassium</td>
</tr>
<tr>
<td>Have a fertilizer box on display</td>
</tr>
<tr>
<td>4. Double</td>
</tr>
<tr>
<td>Show a picture of hungry children: 1 child with 2 children underneath or 2 children with 4 children underneath</td>
</tr>
<tr>
<td>5. 1-2%</td>
</tr>
<tr>
<td>Post these numbers on a picture of a farmer</td>
</tr>
<tr>
<td>6. Increased population and urbanization of rural areas</td>
</tr>
<tr>
<td>Post a picture of new homes being built next to farmland</td>
</tr>
<tr>
<td>7. They will get more money for their land when they sell it than they will if they farm it</td>
</tr>
<tr>
<td>Make a statement bubble coming from a farmer's mouth that states this</td>
</tr>
<tr>
<td>8. 5-7 gallons</td>
</tr>
<tr>
<td>Post a picture of a toilet with 5-7 gallons written on it</td>
</tr>
<tr>
<td>9. Fossil fuels-methane gas, oil, and coal are used as energy sources to create compounds. Some are also used in the chemical reactions of fertilizer synthesis</td>
</tr>
<tr>
<td>Put this information on a can of crude or car engine oil</td>
</tr>
<tr>
<td>10. 10 cents</td>
</tr>
<tr>
<td>Have a dime being given to a farmer</td>
</tr>
<tr>
<td>11. 150 gallons</td>
</tr>
<tr>
<td>Display a loaf of bread or a bread wrapper with 150 gallons written on the wrapper</td>
</tr>
<tr>
<td>12. Home gardeners</td>
</tr>
<tr>
<td>Hand trowel with &quot;home gardener&quot; written on it</td>
</tr>
<tr>
<td>13. Sinkholes</td>
</tr>
<tr>
<td>Create a sinkhole by pressing the bottom of a beaker into moist soil. Label it a &quot;sinkhole&quot;</td>
</tr>
<tr>
<td>14. Nitrogen</td>
</tr>
<tr>
<td>Write a big letter N with a short statement about its properties underneath, or use the handout provided</td>
</tr>
<tr>
<td>15. 5,000,000,000 people estimated to be 6,119,000,000 in the year 2000</td>
</tr>
<tr>
<td>A picture of a mass of people with &quot;5,000,000,000 people&quot; written underneath it</td>
</tr>
<tr>
<td>16. 1-2 people per year</td>
</tr>
<tr>
<td>A picture of a forest with '1-2 people per year' written on it</td>
</tr>
<tr>
<td>17. 1000 people per year</td>
</tr>
<tr>
<td>A picture of a rice or wheat field with the statement, &quot;1000 people per year&quot; written on it</td>
</tr>
<tr>
<td>18. Rainforest</td>
</tr>
<tr>
<td>A picture of the rainforest with the word 'rainforest' written underneath it</td>
</tr>
</tbody>
</table>
How Nitrates Affect Health

California Farmer • March 2, 1991

In a nation where half the drinking water comes from groundwater, nitrate contamination has to be considered a serious potential health threat. In rural areas, up to 85 percent of residents depend on groundwater.

High levels of nitrates are known to have adverse health effects, the most infamous of which is methemoglobinemia, also known as “blue baby syndrome.” It occurs when infants six months or younger directly ingest nitrate. Because infants’ stomachs are immature, the nitrate forms a blood molecule called methemoglobin that prevents blood from carrying sufficient oxygen to support the baby. Affected infants can die; indeed, “blue baby” was a serious threat earlier this century. Today, however, it is both treatable and rare.

To avoid any impact on infants, the U.S. Public Health Service has established the standard for nitrates in drinking water at 10 ppm, according to The Fertilizer Institute. No cases of blue baby syndrome have been reported in the United States in areas where drinking water contained less than 45 ppm of nitrate, the limit set by California and Federal law.

Two other health effects, cancer and birth defects, have been loosely attributed to high nitrate water. CDFA says investigation on nitrates converting to carcinogenic N-nitrosamines in the stomach have been conducted in the Midwest, Europe, and Asia, and have been inconclusive. Further studies are under way.

-Caroline Mufford

(Reprinted with permission from the California Farmer Magazine.)
'N-Nitrogen' Handout

7

N

14.0067
PURPOSE

The purpose of this activity is for students to gain background knowledge on current issues related to the following:

- Food and Fiber Production
- Groundwater Quality
- Organic Fertilizers
- Soil Management/Quality
- Loss of Farmland
- Human Population Statistics and Growth
- Plant Nutrient Requirements
- inorganic Fertilizers
- Endangered Species

CONCEPTS

- Many factors are important in optimizing the production of food and fiber.
- There are many ways to maintain and/or improve the quality of soil so it can provide the nutrients and conditions needed for successful plant growth.
- Optimum water quality and quantity is critical to the survival of living things.
- There are advantages and disadvantages to using organic and inorganic fertilizers.
- Humans use air, fresh water, soil, minerals, fossil fuels and other sources of energy from the earth.

MATERIALS

For entire class:

- 1 copy of each article you will read aloud to students

For each student:

- Copy of articles students will read individually
- 2-3 recent newspapers from various sources and dates

TIME: Approximately 3-4 hours throughout 2-3 weeks to include 2-3 assigned readings each week

BACKGROUND INFORMATION

Many factors affect the quality of life Americans have today. With the industrial revolution and increased technology, Americans have more time for recreational activities since less is spent growing food, washing clothes, keeping the house warm or cool, and additional necessary functions.

Recently, people have realized that the leisurely life that we lead has brought some challenges with it. The concerns about the quality of the environment, as well as people’s quality of life, is a positive one. People are taking steps to maintain or improve water, soil and air quality so that future generations can enjoy the planet.
The series of articles you have your students read should be from a variety of viewpoints so they are encouraged to determine their own feelings on a subject after looking at all sides of an issue.

PROCEDURE

This activity should be spread out over the entire 4-6 week unit. The students should be required to read and to react to no more than 2-3 reading assignments each week. You want to encourage your students to read but not require them to read so many articles that it begins to become monotonous. Perhaps you can require some of the reading to be done at home so class time can be spent performing experiments.

1. Obtain various readings on the topics mentioned above and any other topics that relate to this unit. Some readings are included in the selected Student Reading Section of this unit. Others can be obtained from newspapers and magazines.

2. Have the students make up some sort of journal or lab book that they will use for this activity. One sample page of the journal is shown below:

3. Using methods appropriate for your students, have them read the material or listen to the material being read. As the material is read, they are to write down things they learned or heard in the ‘FACT’ column of their paper. After they are done with the reading, give the students an opportunity to react to what they’ve heard or read. Their reactions will go in the ‘REACT’ column. This process takes some practice. At various times throughout the unit, have students react to things you think are important and should think about.

Here are some suggestions for handling the material in a non-threatening way.

- Read to your students, 3-4 minutes at the beginning of each class period, part of an article or story.
- Have the students read certain articles at home for homework and complete the FACT/REACT Journal at home.
- Use the ‘jigsaw’ cooperative reading approach to obtaining information.
- Save newspapers and magazines for about a month before beginning this unit. During one class period, have the students look through the newspapers and find articles related to the unit. Have them share what they learned with the rest of the class or a small group.
- Cut out comic strips that relate to lessons you are teaching. Copy them onto various class handouts and have students react to them.

4. Periodically, have your students look back into their journals for various information. This will help them remember what they have read and connect what they are learning in lab to information written by others.
CONCLUSION

Many challenging issues face society today and there are many sides to one particular issue. In order to make intelligent decisions that affect society and the planet, students must weigh the pros and cons of possible decisions and choose what they think is best.

VARIATION

1. Have students clip current articles about the topics described in the purposes. Organize the articles in some way before having your students read them. For example, students might read about fertilizers first, groundwater second, how fertilizer affects groundwater third, how plant growth is affected by groundwater fourth, and finally, how society is affected by all of the factors. This may provide some continuity to the readings.
SELECTED STUDENT READINGS’

This list provides you with literature selections on a limited number of topics. Customize this list by adding articles that relate to your students and community.

- Appropriate selections from *The Western Fertilizer Handbook* from the Soil Improvement Committee and the California Fertilizer Association.
- “Surprising Facts About Organic Fertilizers” by Florence Bellis; *Gardening and Beyond*, Timber Press.
- ‘Improving Plant Production For Human Health and Environmental Quality” Pamphlets by the Potash and Phosphate Institute.
- “They’re Worming Their Way Into Your Yard” by Yvonne Savio and Steven Zen; *The Sacramento Bee*; November 21, 1992.
- “How Plants Grow” and “Fertilizing Your Garden” sections of the *New Western Garden Book*, Sunset.

A complete bibliography, along with ordering information, is located in the Background References section of this unit.

* Copies of these articles are included in the “Teacher Resources’ section of this unit.
HOW TO READ A FERTILIZER LABEL

PURPOSE

The purpose of this activity is for students to learn how to read a fertilizer label, to understand the components of fertilizers, and to compare • natural and • man-made fertilizers.

CONCEPTS

• Fertilizers are substances added to soils or water to increase the nutrients available to plants.
• Fertilizers come in a variety of forms, yet labels clearly identify what the fertilizers contain.
• Humans use a variety of substances from the earth to enhance plant growth.

MATERIALS

For the Class:
• commercial fertilizer labels (optional)

For Each Student:
• How to Read a Fertilizer Label worksheet
• calculator

TIME: 1 forty-minute session--set up and label explanation
      1 forty-minute session--calculations and conclusion

BACKGROUND INFORMATION

A fertilizer is any type of substance added to the soil or water to increase the nutrients available to plants. All commercial fertilizers are monitored by the California Department of Food and Agriculture and are required to follow specific label guidelines. The three numbers on the fertilizer package represent the percentages of nitrogen, phosphorus, and potassium, in that order. There is no particular reason why nitrogen is always listed first. An arbitrary standard was set, years ago, to avoid consumer confusion.

Manures and commercial inorganic fertilizers are compared so that students can reflect on the pros and cons of each of two basic types of fertilizers. The issues revolving around fertilizer use are very complex and this activity clearly illustrates some of the key concerns--manures do not contain as high percentages of N, P, and K as do commercial, inorganic fertilizers: commercial, inorganic fertilizers require mining and the use of fossil fuels for manufacturing; commercial inorganic fertilizers are generally easier to apply than manure and composts; manures provide the organic matter needed to increase the absorption and aeration of soils, etc.

Discuss with your students the importance of continuing research in the area of providing plants with the nutrients in such a manner that people can be fed while the environment is protected.
PROCEDURE

1. Complete the worksheet with your students.

CONCLUSION

Fertilizers are substances added to soils and water so required nutrients are available to plants. Standards for fertilizer labels are set so that consumers understand what they are purchasing. The issues surrounding fertilizer use are legitimate and very complex. Consumers need to be knowledgeable about the use and limitations of fertilizers, as well as the differences between fertilizers, for home use and commercial production.
HOW TO READ A FERTILIZER LABEL

INTRODUCTION

For healthy growth, all plants require certain nutrients that normally come from the soil. The three primary nutrients are nitrogen, whose symbol is N; phosphorus, whose symbol is P; and potassium, whose symbol is K. There are 13 other elements that plants need. The oxygen, carbon, and hydrogen come from air and water. The others come from the soil or water around the soil. Since plants use up some of the nutrients in the soil, people often put nutrients back by using fertilizers.

Any type of substance that is added to soil or water to increase the nutrients available to plants is considered a fertilizer. Fertilizers can be in the forms of solids, such as houseplant fertilizer stakes or pellets; liquids, such as "Schultz's Houseplant Food;" or gases, such as anhydrous ammonia, which is injected into fields.

Soil nutrients can be replenished by organic or inorganic substances. For example, ground lobster shells and animal manure are good sources of nitrogen, potato skins and bananas are good sources of potassium and animal bone meal is a good source of phosphorus. By performing certain chemical reactions, nitrogen gas from the air can be converted into a form of nitrogen plants can use. Phosphate rock can be mined and converted to a usable source of phosphorus. Potash, a source of potassium, is mined or gathered from salt deposits like those in the Great Salt Lake in Utah. Farmers and scientists are continually looking for new ways to replenish soils with nutrients so that the environment is protected. Today you will learn how to read a fertilizer label. This will help you understand the labels when you purchase a fertilizer for your lawn or garden.

1. Name the 3 major elements that come from the soil that plants must have.

2. Name 2 elements plants get from water or air.

3. What is the general name for a substance used to put nutrients back into the soil?

4. Explain one other item of information you learned from the reading above.
PROCEDURE

1. Fertilizer labels are set up in a standard way so consumers do not get confused. The California Department of Food and Agriculture and the United States Department of Food and Agriculture (USDA) make sure that the rules are followed for labeling all foods, fertilizers, pesticides and other substances.

There are 3 numbers on the front of any fertilizer box, bottle, or bag. The first number represents the percentage of nitrogen (N) there is in that particular fertilizer. The second number represents the percentage of phosphorus (P₂O₅), and the third number represents the percentage of potash or potassium (K₂O). Other substances are also part of fertilizers. Look at the labels below.

a. What percentage of the fertilizer is nitrogen in the citrus-avocado fertilizer? ___________ Houseplant fertilizer? ___________

b. Which of the 2 fertilizers has more phosphorus? __________________________

2. Farmers and gardeners use different fertilizers for a variety of reasons. Certain crops require more nitrogen than others. If this is the case, they use a fertilizer high in the first number. If the soil is low in phosphorus, they might pick a fertilizer high in the second number. Fertilizers are also available with single nutrients so they can be custom-blended to meet the exact needs of certain plants. Farmers and gardeners must realize that if they use too much of a fertilizer, they are wasting money and could harm their crops and the environment. Farmers and home gardeners should avoid overusing fertilizers.

a. State one reason fertilizers do not all contain the same percentages of nitrogen, phosphorus, and potassium.

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3. Look at the General Guaranteed Fertilizer Analysis Statements of the three fertilizer labels on the attached page. This statement must appear on each container of fertilizer.

a. According to the three labels listed, which type of plant requires the most:

   nitrogen? __________________________________________

   phosphoric acid? __________________________________________

   potash? __________________________________________
b. Name 2 othersubstances, besides nitrogen, phosphoric acid and potash that can be found in fertilizers?  


c. Out of the three samples, which fertilizer contains the most iron?  

4. Trees, field crops, and houseplants are all different in their nutrient requirements. For convenience, fertilizer companies have developed plant-specific fertilizers. For example, if you go to the local nursery you can purchase rose fertilizer, violet fertilizer, fruit tree fertilizer, etc. The nutrients contained in each of the fertilizers are the same. The only difference is in the amount of each nutrient. Tomatoes, for instance, require more nitrogen to grow than legumes, such as beans. Therefore, a tomato fertilizer contains more nitrogen than a bean fertilizer. Compare the three different fertilizers.

a. Suppose you have the three fertilizers, whose labels are shown, stored carefully in your garage. You planted tomatoes in your garden and expect a large crop. You have been applying “Hardy and Healthy” fertilizer to your tomato plants and have been watering them appropriately. You are very disappointed when large brown spots appear on the base of each red tomato. The owner of the local nursery says your plants are lacking calcium. Do you need to purchase a new fertilizer called “Veggie Plus,” or can you use one of your fertilizers from the garage? Explain.

5. All fertilizer labels have a “warning” or “caution” section. These sections tell you whether or not protective clothing (gloves, dust mask, respirators, coveralls, etc.) is required and inform you of other precautions you must take for proper storage and handling of fertilizers.

a. What do all of the three sample fertilizers state in the warning section?
Guaranteed Fertilizer Analysis Statement

Total N: ........................................... 8%
  5.6% Ammoniac N
  1.1% Urea N
  1.3% Water Insoluble N
Available Phosphoric Acid ($P_{2}O_{5}$) ........... 12%
Soluble Potash (K20) ............................ 4%
Calcium (Ca) ..................................... 8.0%
Magnesium (Mg) .................................. 3.0%
Sulfur (S) .......................................... 4.0%
Boron (B) ........................................... 0.02%
Iron (Fe) ........................................... 0.4%
Manganese (Mn) .................................. 0.05%
Molybdenum (Mo) ................................. 0.0008%
Zinc (Zn) ........................................... 0.05%

Guaranteed Fertilizer Analysis Statement

Total N: ........................................... 17%
  4.1% Ammoniac N
  8.9% Urea N
  4.0% Water Insoluble N
Available Phosphoric Acid ($P_{2}O_{5}$) ........... 23%
Soluble Potash (K20) ............................ 6%

Derived from: Monoammonium phosphate, urea, methytene ureas, muriate of potash

Guaranteed Fertilizer Analysis Statement

Total N: ........................................... 12%
  12% Urea N
Available Phosphoric Acid ($P_{2}O_{5}$) ........... 6%
Soluble Potash (K20) ............................ 6%
Iron (Fe) .......................................... 0.5%
Zinc (Zn) .......................................... 0.1%

Primary Nutrients from Urea and Potassium Phosphate
Trace Nutrients from Iron Sulfate and Zinc Sulfate

Directions: Add 1 Tablespoon per gallon of water. Apply to foliage and soil. Repeat monthly. Do not apply during heat of day.

Warning: Keep out of reach of children.

Caution: Keep out of reach of children. Harmful if swallowed.

WARNING: Harmful or fatal if swallowed. Keep out of Reach of Children.

Disposal: Container will not contain toxic residues if empty. Remove any additional fertilizer before disposal.
Store in cool, dry place. Product will lose nutrient value over time.

Warning: Keep out of reach of children.

Caution: Keep out of reach of children. Harmful if swallowed.
Natural fertilizers are also used commercially. Animal manures are one type of natural fertilizer. Manures not only add nutrients to the soil, but they also add organic matter which allows the soil to make more water and air available to plant roots. The following list shows how many pounds of each nutrient are in one ton of animal manure.

a. After looking at the formula below, complete the table by calculating the percentage of each nutrient in the manure.

\[
\text{% of fertilizer in manure} = \frac{\text{lbs nutrient}}{2000 \text{ lbs/ton}} \times 100\%
\]

<table>
<thead>
<tr>
<th>Type of Manure</th>
<th>Lbs N</th>
<th>% N</th>
<th>Lbs P₂O₅</th>
<th>% P₂O₅</th>
<th>Lbs K₂O</th>
<th>% K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicken</td>
<td>31</td>
<td>18</td>
<td>8</td>
<td>8</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Dairy Cow</td>
<td>11</td>
<td>5</td>
<td>40</td>
<td>40</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Turkey</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Swine (pig)</td>
<td>10</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Steer</td>
<td>4</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Review the chart above. Which type(s) of animal manure contains the most:
- Nitrogen (N)
- Phosphorus (P₂O₅)
- Potassium (K₂O)

c. If you were to buy a bag of chicken manure, what would the three numbers on the label be? _____ What would the three numbers be on a bag of steer manure? _____

7. When buying any item—a car, shirt, bag of potato chips, or fertilizer, consumers can save a lot of money if they know how to do a quick cost comparison of similar products. A knowledgeable home gardener can spend a few dollars to purchase enough fertilizer to supply the houseplants, trees, shrubs, and lawn around the home for a year. However, a farmer with hundreds of acres of crop land can spend hundreds or even thousands of dollars per year on fertilizers. It is important for home gardeners and farmers to be knowledgeable about the nutrient requirements of their plants, as well as the fertilizers available, so that money is not wasted on purchasing and applying unnecessary nutrients. Applying appropriate amounts of fertilizer is also important in protecting the environment and producing high quality food.

One way to become a knowledgeable fertilizer consumer is to calculate the cost of each nutrient in the fertilizer. Let’s use the tree and shrub fertilizer as an example.
The cost of the 2 lb package of fertilizer is $5.99. Since the fertilizer contains 12 percent Nitrogen, we can calculate the cost of nitrogen through multiplication.

\[ 0.12 \times 0.12 \times \text{cost of product} = 0.7188 \]

We can round this off to 72 cents. Of the $5.99 we paid for the fertilizer, only 72 cents is for the Nitrogen in the product.

a. Calculate the cost of each nutrient for the three fertilizers listed above:

<table>
<thead>
<tr>
<th>Type of Fertilizer</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>Ca</th>
<th>S</th>
<th>Mg</th>
<th>Zn</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree and Shrub</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>Lawn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houseplant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. If a home gardener needed to fertilize a couple rows of corn that require lots of nitrogen, which fertilizer might be the best value? Why?

c. Does the total cost for all the nutrients add up to the price of the fertilizer?

d. Can you explain the difference between the total cost and the price?

e. List at least three other factors that might influence the price of the fertilizer.

f. Although the price of the fertilizers listed above does not seem high, a farmer would have to buy a tremendous amount of each package to fertilize a 100 acre field. Assuming that each package of fertilizer can fertilize 1000 square feet, and one acre is approximately 43,560 square feet, calculate the cost of each fertilizer for a 100 acre field. (Show how you arrived at your answers.)

Tree and Shrub Fertilizer: $
Lawn Fertilizer: $
Houseplant Fertilizer: $
Remember that manures are also fertilizers. The cost of manures vary. For a farmer in a diversified operation (dairy/wheat), the cost may be very little, but for the farmers who must purchase manure from distant places, transportation and sterilization costs must be considered. For the sake of comparison, let's assume that one ton of manure costs $15.00 and can fertilize \( \frac{1}{3} \) of an acre. How much would it cost for a farmer to fertilize a 100 acre field with manure? (Show your calculations)

Compare the cost and nutrient value of the tree and shrub fertilizer, lawn fertilizer, houseplant fertilizer, and turkey manure.

CONCLUSION

1. In your own words, describe what a fertilizer is:

2. Why must home gardeners and farmers apply fertilizers to their land?

3. List at least two advantages of using animal manure instead of chemical fertilizers.
   a. 
   b. 

4. List at least two disadvantages of using animal manure instead of chemical fertilizers.
   a. 
   b. 
5 List two possible problems with overusing fertilizers?

a. 

b. 

6. In one well written paragraph, describe how fertilizers affect your life.
WHAT'S A PPM? PPB?

PURPOSE

The purpose of this activity is for students to understand the meaning of parts per million and parts per billion. These terms are frequently used in science and are often not understood.

CONCEPTS

- Measurement is one tool that can be used to determine how various factors affect plant growth and water quality.
- Optimum water quality is critical to the survival of living things.

MATERIALS

For Every Two Teams:

- 1 bottle of food coloring

For Each Team of Two:

- 1 CEPUP tray or equivalent (micro-chemistry trays or plastic trays with at least ten wells that can hold about 2 milliliters of liquid each)
- eye dropper
- 1 sheet of white typing paper
- 1-2 paper towels
- water (about 20 ml)

For Each Student:

- 1 “What is a ppm? ppb?” handout

TIME: 1 fifty-minute session

BACKGROUND INFORMATION

With advancements in technology, it is becoming possible to detect more and more substances at minute levels. It is a reality that 99.99% of the substances on this planet are not “pure.” When people first conceptualize this fact, they are truly amazed and sometimes disappointed. The public must realize that humans have always survived successfully when surrounded with these “impure” substances and many of these substances that exist in very small amounts are critical to the survival of living things. Scientists are also discovering that minute amounts of substances, such as lead nitrate, can cause severe illnesses in children.

Gas chromatographs, thin layer chromatography, electron microscopes, and other pieces of equipment allow scientists to clearly identify what substances are in water, air, soil, etc. With the aid of these pieces of equipment, 1 part per billion and sometimes 1 part per trillion can be detected. It is important for students to conceptualize these small numbers so they can put numerical information they obtain into perspective.
PROCEDURE

1. Read an article to the students that mentions the quantities ppm and/or ppb. Ask them what they think those quantities mean. The article “Nitrate Debate” is included in the selected student readings section of this unit and uses these measures.

2. Complete the student activity ‘What is a ppm? ppb?’ and discuss the answers to the lab questions. Explain that scientists are able to detect such very small amounts because of advancements in technology. Some answers to key questions are provided below.

   - Concentrations:

     | Concentration | Value |
     |----------------|-------|
     | Cup #1         | pure  |
     | Cup #2 = 1/10  |       |
     | Cup #3 = 1/100 |       |
     | Cup #4 = 1/1000|       |
     | Cup #5 = 1/10,000|     |
     | Cup #6 = 1/100,000|    |
     | Cup #7 = 1/1,000,000|   |
     | Cup #8 = 1/10,000,000| |
     | Cup #9 = 1/100,000,000| |

     - Answer to question #5: The last cup is 1 part per billion. If there were 1 billion particles, there would be 1 food coloring particle and 999,999,999 water particles. This is true only if distilled water was used. Tap water has other dissolved particles that would affect the numbers and are not measurable in this experiment.

3. Discuss how scientists determine the quantity of allowable residues on food and that groundwater is analyzed for nitrates in ppm. Perhaps you can invite a toxicologist or food analyst to talk with your students about his/her occupation.

CONCLUSION

1 part per million is a very small amount of a substance: it cannot be seen by the unaided eye. 1 ppb is one thousand times smaller than one part per million. To be able to detect such small amounts is fascinating and makes science a very precise subject.

EXTENSION

1. Read the article, ‘Insects and Rodent Hairs are Probably in Your Daily Diet’ to your students (article included). Have your students research and find government standards on other food items. Discuss why ‘zero tolerance’ is not feasible for insect contamination of food, and that if all insect parts were removed, then pest control chemicals might be detectable.

(Adapted from materials from the Science Education for Public Understanding Program (SEPUP) at the Lawrence Hall of Science, University of California, Berkeley. Used with permission. Original material copyright, 1990 by the Regents of the University of California.)
WHAT IS A ppm? A ppb?

Introduction:

As you read the newspaper and listen to radio and television news, you often hear that “detectable amounts” of certain substances were found in groundwater, drinking water, in soil, or in human blood streams. Today, “detectable amounts” are much smaller than they once were. Not more than 200 years ago, “detectable amounts were amounts that could be seen with the unaided eye or tasted. Through advancements in technology, scientists now are able to detect very tiny amounts of substances. Most substances can be measured in parts per million (ppm) and parts per billion (ppb). Some substances can even be measured in parts per trillion (ppt).

The ability to measure substances in such minute amounts has allowed the Environmental Protection Agency (EPA) to set advisory levels for many substances. For example, it is advised that no more than 200 parts per million of calcium and magnesium salts should be in drinking water. These salts are what determines the “hardness” of water, affects taste but not health, and may require that more detergent be added to wash clothes and dishes. Calcium and magnesium salts may also leave scaly deposits on water tanks and pipes.

Other advisory levels, such as the one set for 40 ppm of NO₃ (nitrates) in drinking water, are set for safety reasons. Nitrates are natural substances that come from animal and human waste, natural soil deposits, and fertilizers. High concentrations of nitrates in drinking water can cause potentially fatal illnesses in human infants and young farm animals. Nitrates in groundwater recently have been in the spotlight. Lots of research is being done to reduce the amount of nitrates that leach into groundwater.

Pesticide residues in water are also measured for safety reasons. Parts per million quantities of a particular herbicide can kill fish: parts per billion quantities of a particular herbicide can be tasted by humans. The screening of pesticide residues and control standards on pesticide safety have been very successful. Generally, 99% of the food analyzed for various residues meets the required standards. This screening ensures that the food we eat is safe to eat.

What do parts per million and parts per billion actually mean? These are difficult numbers to comprehend. The following activity will help you gain a tangible feeling for the terms ppm and ppb.

Procedure

1. Place a piece of white paper under the tray.

2. Put one drop of food coloring into small cup 1 and cup 2.

3. To small cup 2, add 9 drops of water. Mix the solution by drawing it up into the medicine dropper and carefully putting it back into cup 2 by gently squeezing the bulb. Be sure to squeeze the bulb before putting the dropper tip into the solution.

4. Using the medicine dropper, transfer one drop of the solution in cup 2 to cup 3. Return any excess back to cup 2. Then add 9 drops of water to cup 3. Use the dropper to mix the solution in cup 3 and transfer one drop to cup 4. Return any excess to cup 3.

6. Continue the process through cup 9, taking a drop of the solution from the previous cup and adding 9 drops of water.

7. Record the color of the solution in each cup on the data table.

8. Determine the concentration of the solution for each cup and record it on the data table.
   
   ex: cup #1 - 1 drop out of ten drops was food coloring so the concentration of food coloring is 1/10 or .1 or 1 part per ten.

### DATA TABLE

<table>
<thead>
<tr>
<th>Cup</th>
<th>Color</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
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<td>9</td>
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<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Questions

1. What is the number of the cup in which the solution first appeared colorless? ____ ____

2. What is the concentration in parts of dye per parts of solution in this first colorless cup?
   ___________ _______________________________ _____ _____

3. Do you think there is any of the colored solution present in this cup of diluted solution even though it is colorless? Explain.
   ___________ _______________________________ ____ ______

   _______________________________ _________________________

   _______________________________ _________________________
4. Try to think of an experiment you can do with the solutions prepared in this experiment to see what would be left if the water were not present. Describe the experiment and predict what you would observe.

5. Do the experiment you described above. Do you think there are any food coloring particles left in this container? If the last cup contained 1,000,000,000 water particles, how many food coloring particles would this cup contain?

6. Look at the chart below:

<table>
<thead>
<tr>
<th>1 ppm is equivalent to:</th>
<th>1 ppm is equivalent to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 second in 11 days, 13 hours, and 46 minutes</td>
<td>1 second in 31 years, 41 weeks, and 3 days</td>
</tr>
<tr>
<td>1 inch in 15.78 miles</td>
<td>1 inch in 15,782 miles</td>
</tr>
<tr>
<td>1 hole in 55,555 rounds of golf</td>
<td>1 hole in 55,560,000 rounds of golf</td>
</tr>
<tr>
<td>5 people in the U.S.</td>
<td>5 people in the entire world</td>
</tr>
</tbody>
</table>

Which analogy above is the most meaningful to you? Why?

(Adapted from materials from the Science Education for Public Understanding Program (SEPUP) at the Lawrence Hall of Science, University of California, Berkeley. Used with permission. Original material copyright, 1990 by the Regents of the University of California.)
Insects and rodent hairs are probably in your daily diet

The Associated Press

WASHINGTON — Most Americans would not knowingly include insects, rodent hairs or maggots in their daily diet, but they may be surprised to learn that these vermin and their residues may be in the food they eat.

Take a seven-ounce glass of tomato juice, for example. It can contain up to 20 fly eggs under government standards, though the Food and Drug Administration says their consumption poses no health hazard.

A one-pound box of macaroni can have up to nine rodent hair fragments, a pound of frozen broccoli can have 216 aphids, 3.5 ounces of apple butter can have up to five whole insects and a pound of cocoa beans can have up to 10 milligrams of rodent feces.

While these may be "aesthetically unpleasant," they present no health hazard, the FDA says in its manual of "Food Defect Action Levels."

"The defect action levels are set because it is not possible, and never has been possible, to grow in open fields, harvest and process crops that are totally free of natural defects."

The alternative to setting such levels is using more chemicals to control insects, rodents and other natural contaminants, but that "is not satisfactory because of the very real danger of exposing consumers to potential hazards from residues of these chemicals," the agency says.

(Reprinted with permission from Mr. Allan Meath, Publisher, The Oakland Tribune, Oakland, California.)
HOW SOILS, WATER, AND FERTILIZERS AFFECT PLANT GROWTH

PURPOSE.

The purpose of these experiments is for students to use the scientific method to find out how water quality, soil quality, fertilizer content, and timing of fertilizer application affect plant growth. The students will relate their findings to California agriculture.

CONCEPTS

- Plants have basic requirements including the need for 16 elements, as well as environmental conditions such as appropriate temperature, humidity, light, and soil composition.
- There are many ways to maintain or improve the quality of soil so it can provide the nutrients and conditions needed for successful plant growth.
- Optimum water quality is critical to the survival of living things.
- Many factors are important in optimizing the production of food and fiber.

MATERIALS

For Entire Class:
- various books and/or articles related to how plants grow and are affected by various factors—general biology books, advanced biology books, encyclopedias, physiology books, gardening books such as Sunset’s *Western Garden Handbook* and the *Organic Gardening Handbook*, articles from newspapers and magazines.
- various empty fertilizer containers or labels
- video or slide show that talks about an overview of California agriculture—‘Fields of Gold’ and ‘California’s Amazing Agriculture’ are available from the California Foundation for Agriculture in the Classroom.

For Each Team of 3 or 4:

A basic supply of items students can choose for their experiments

- light source
- places of total darkness
- water
- watering devices
- graduated cylinders
- test tubes
- eye droppers
- planting pots—see ‘Growing Plants in the Classroom’ at the beginning of this unit
- bean seeds
- corn seeds
- radish seeds
- basic fertilizer
- potting soil
- well rinsed sand, gravel, or other planting medium such as perlite or vermiculite
- labels
The following readings (all are included in this unit):
- ‘What’s In A Plant?’
- ‘Why Must We Replace Nutrients Back Into The Soil?’
- ‘Crop Rotation, Green Manure and Nitrogen-fixing Plants’
- ‘Manure and Composting’
- ‘Fertilizers’
- A master copy of the appropriate ‘Team Experiment Check-Off Sheet’ that will be kept with the teacher

For Each Person:
- 1 copy of the appropriate ‘Team Experiment Check-off Sheet’
- Materials needed for oral presentations--student’s responsibility
- Markers
- 1 copy of ‘How to Write a Laboratory Report’

TIME: 4 fifty-minute sessions for introductions and set-up
- 4 weeks--growing and observation time
- 3 fifty-minute sessions--conclusions and presentations

BACKGROUND INFORMATION

Many factors affect plant growth. A slight change in conditions can truly affect a plant’s production. In agriculture, it is extremely important for the farmers to consider many factors as a field is plowed, planted, cultivated and harvested. Science must be used to optimize the production of food and fiber. The experiments your students design may be ones that scientists perform for the farmers or experiments that the farmers can do themselves. This lesson concentrates on how soils, waters and fertilizers affect plant growth. Other environmental factors--such as humidity, light, and temperature conditions--should also be considered when planting crops. Experimentation continues at universities and with agribusinesses in cooperation with farmers so food can be produced and the environment can be protected.

PROCEDURE

1. Show a video or slide show that provides students with an overview of California agriculture. The ‘Fields of Gold’ video and ‘California’s Amazing Agriculture’ slide show, both available from the California Foundation for Agriculture in the Classroom, do this. Pose different questions that have students discuss factors that might affect how much food and fiber is available to the consumers and what challenges California agriculture faces today.

2. Make a class list of possible factors that could affect plant growth. However, DO NOT DISCUSS ACTUAL DATA FROM ANY STUDIES OR EXPERIMENTS. Your students will perform experiments to determine the effects of the factors.

3. Group your students, appropriately, into teams of 3 or 4 students. Students will create and perform an experiment that tests one variable of plant growth. The teams will work together, on and off, for a period of one month. Explain to your students that each group will design and perform an experiment that illustrates how one particular variable affects plant growth.
4. Assign each group one of the listed topics or a topic you have created. You should have at least two groups for each topic so that generalizations can be made rather than global conclusions from one small experiment. Keep a “Team Experimentation” sheet for each group which you can use as a check-off sheet, and provide each person with the appropriate Team Experimentation Student Worksheet. Some other helpful hints are described below.

- Require students to complete introductory research before they design and perform their experiments.

- The instructions and suggestions for experimental designs are purposely very general. After researching their topic, it is your students’ responsibility to design an experiment that will test one specific variable related to their topic. Review the scientific method, if necessary.

- Show your students the supplies you have available BEFORE they design their experiments. This will guide them without your telling them exactly how to design their experiments.

- Develop a handout that clearly explains to your students what should be included in their lab write-up. One possible format is described in the “How to Write a Lab Report” handout in this unit.

5. After all the groups have designed and set-up their experiments, have each group describe its experiment to the class and discuss possible outcomes of the experiments.

6. After the students have completed their experiments, have them give oral presentations to the class. The best oral presentations occur when you provide guidelines; explain how you will grade the presentations, yet provide enough room for creativity.

7. As each student group presents its material, have the rest of the class take notes in their FACT/REACT Journals.

8. Discuss with the students the overall concepts they learned from all of the experiments.

CONCLUSION

Many factors affect plant growth. Farmers must update their knowledge on how to maintain and/or improve the production and quality of the food they grow while keeping in mind the quality of the ground and water that feeds us and other living things.

VARIATION

Design class experiments for each of the variables instead of having groups design the experiments. After the experiments are designed, assign student groups to set up and maintain the various experiments.

EXTENSION

For a science fair or FFA project, have individual students develop an experiment that tests how an environmental factor, such as humidity or temperature, affects plant growth.
Team Experimentation Student Instructions

WATER QUALITY

As you know, plants require water for **survival**. Distilled water is the only type of water that contains pure H₂O molecules. All other types of water including drinking water, ocean water, river water and groundwater contain other substances. Plants benefit from some of the substances and are harmed by other substances found in water. The ambient of a particular substrate in water is also a factor that affects plant growth. Your group task is to complete the Research, Design, Experiment and Report sections described below so that you can learn more about how the quality of water affects plant growth.

**Research**

1. How do plants, in general, obtain water?
2. What is the main function of root hairs?
3. All members must read “What’s In A Plant?” and write down 3 key points from the reading.
4. What are at least 3 substances that are normally found in drinking and/or farming irrigation water?
5. List at least 3 specific reasons plants need water for survival.
6. Each student in this group must read “Clear Facts About Clean Water.” Write down 5 key points about this reading.

**Design**

1. Think of 3 possible experiments your team could do to test the effects of water quality on plant growth. Jot down your ideas.
2. Decide on one experiment your team will perform.
3. Write a complete experimental ‘Purpose,’ ‘Procedure’ and ‘Materials’ list for your experiment.
4. Get your experimental design approved by your instructor.

**Experiment**

1. Obtain the supplies needed for your experiment.
2. Set up your experiment.
3. Write down your hypothesis for your experiment.
4. Each person must record appropriate experimental data.
5. At the conclusion of your experiment, each person must write a professional lab report as described by your instructor.

**Report**

1. Discuss with your team how your results could possibly help California farmers.
2. Prepare a 3-4 minute oral presentation, including visual aids, that explains what you learned from your research and your experiment and how your newly gained knowledge might help or affect California agriculture.
3. Present your report on ___________, (date)

*Extra Credit*--Discuss your experiment with a farmer. Have the farmer explain to you how your results could actually help agriculture, or discuss what is currently being done about current challenges related to your experiment.
Team Experimentation Student Instructions

SOIL TYPE AND SOIL QUALITY

As you know, there are many different types of soil on this planet. Some are better for growing plants than others. Farmers must analyze their soils and the plants they grow in them to determine what, if anything, must be put into the soil to maintain or improve crop production. Most soils are made of many types of substances including clay, silt and sand particles, and dead plants and animals (organic matter). Your group task is to complete the Research, Design, Experiment and Report sections described below so you can learn more about how soil type and/or soil quality affects plant growth.

Research

1. Read “What’s In A Plant?” and write down 3 key points from the reading. List the 2 basic reasons plants need soil.
2. What is hydroponics? Why is this not currently a feasible way of growing food for the entire human population?
3. Read the chapter entitled “Soil Types” from the Western Fertilizer Handbook. Write down 5 key points about the reading assignment.
4. Name at least 4 different types of soil and compare and contrast them.
5. Find out how nutrients are added to nutrient-poor soils.
6. What current strategies are being used to improve soil quality? Perhaps reading “Manures and Composts” and “Crop Rotation, Green Manures and Nitrogen-fixed Plants” may help you with this.

Design

1. Think of three possible experiments your team could do to test the effects of soil type on plant growth. Jot down your ideas.
2. Decide on one experiment your team will perform.
3. Write a complete experimental ‘Purpose,” “Procedure” and ‘Materials’ list for your experiment.
4. Get your experimental design approved by your instructor.

Experiment

1. Obtain the supplies needed for your experiment.
2. Set up your experiment.
3. Write down your hypothesis for your experiment.
4. Each person must record appropriate experimental data.
5. At the conclusion of your experiment, each person must write a professional lab report as described by your instructor.

Report

1. Discuss with your team how your results could possibly help California farmers.
2. Prepare a 3-4 minute oral presentation, including visual aids, which explains what you learned from your research and experiment and how your newly gained knowledge might help or affect California agriculture.
3. Present your report on __________, (date)
   • Extra Credit--Discuss your experiment with a farmer. Have the farmer explain to you how your results could actually help agriculture, or discuss what is currently being done about current challenges related to your experiment.
Team 'Experimentation Student Instructions

HOW DOES THE TIMING OF FERTILIZER APPLICATION AFFECT PLANT GROWTH?

Fertilizers are nutrients that are added to soil and water so that plants can obtain the nutrients they need for growth. Farmers have discovered that they get best use of their fertilizers when they apply them at specified times. Proper application of fertilizers is very important so plants have required nutrients available at times when they can use them. Thus, farmers do not spend extra money and time applying unnecessary fertilizers, and groundwater and soils do not contain excessive amounts of unused fertilizers. Your group task is to complete the Research, Design, Experiment and Report sections described below, making it possible for you to learn more about how the timing of fertilizer application affects plant growth.

Research

1. List at least 3 reasons why fertilizers are added to soils.
   - 2. Find out why plants might use fertilizers more efficiently at some times than at others.
   - 3. Define “organic” and “inorganic” fertilizers and list 3 examples of each type of fertilizer.
   - 4. Read “What's In a Plant?,” “Why Must We Replace Nutrients Back Into the Soil?,” “Crop Rotation, Green Manure, and Nitrogen-Fixing Plants,” “Fertilizers,” and “Manure, Green Manure and Compost.”

Write down 2 key points from each of the 5 readings listed above.

Design

1. Think of 3 possible experiments your team could do to show how fertilizer application time affects plant growth. Jot down your ideas.
   - 2. Decide on one experiment your team will perform.
   - 3. Write a complete experimental “Purpose,” ‘Procedure” and ‘Materials’ list for your experiment.
   - 4. Get your experimental design approved by your instructor.

Experiment

1. Obtain the supplies needed for your experiment.
   - 2. Set up your experiment.
   - 3. Write down your hypothesis for your experiment.

Each person must record appropriate experimental data.

- 5. At the conclusion of your experiment, each person must write a professional lab report as described by your instructor.

Report

1. Discuss with your team how your results could possibly help California farmers.
   - 2. Prepare a 3-4 minute oral presentation, including visual aids, which explains what you learned from your research and experiment and how your newly gained knowledge might help or affect California agriculture.
   - 3. Present your report on __________, (date)

Extra Credit--Discuss your experiment with a farmer. Have a farmer explain to you how your results could actually help agriculture or discuss what is currently being done about current challenges related to your experiment.
Team Experimentation Student Instructions

**HOW DOES THE AMOUNT OF A FERTILIZER APPLIED AFFECT PLANT GROWTH?**

It is known that if an applied fertilizer is not used by the plants, it can leach into groundwater, run off into streams and rivers and become a potential hazard to the environment. Crop quality or yield can also be affected by improper fertilizer dosage. Research is being done to determine how much of a certain type of fertilizer should be applied to a certain type of plant so that these problems will not occur. Your group task is to complete the Research, Design, Experiment and Report sections described below so that you can learn more about how the amount of fertilizer applied affects plant growth.

**Research**

1. Read “What’s In A Plant?,” “Why Must We Replace Nutrients Back Into the Soil?” and “Fertilizers.”
2. Write down 3 key points about each reading mentioned above.
3. Read a variety of “Directions For Use” sections on fertilizer labels. Are all fertilizers applied in the same amounts?
4. Describe different situations where plants may need fertilizer. Describe 1 situation where fertilizers may not be necessary.
5. Find out how composts, manures, and legumes may help provide nutrients to plants. Ask your instructor for some appropriate reading materials.

**Design**

1. Think of 3 possible experiments your team could do that would show how the amount of fertilizer applied affects plant growth. Jot down your ideas.
2. Decide on one experiment your team will perform.
3. Write a complete experimental “Purpose,” “Procedure” and “Materials” list for your experiment.
4. Get your experimental design approved by your instructor.

**Experiment**

1. Obtain the supplies needed for your experiment.
2. Set up your experiment.
3. Write down your hypothesis for your experiment.
4. Each person must record appropriate experimental data.
5. At the conclusion of your experiment, each person must write a professional lab report as described by your instructor.

**Report**

1. Discuss with your team how your results could possibly help California farmers.
2. Prepare a 3-4 minute oral presentation, including visual aids, which explains what you learned from your research and your experiment and how your newly gained knowledge might help or affect California agriculture.
3. Present your report on __________. (date)

Extra Credit--Discuss your experiment with a farmer. Have the farmer explain to you how your results could actually help agriculture or discuss what is currently being done about current challenges related to your experiment.
How To Write A Lab Report

Scientific laboratory write-ups generally have a standard format. They consist of seven or eight sections, are professional in appearance, and provide enough information so the experiment can be repeated, if necessary. The following lab report guidelines describe one way to write up a lab report.

Introduction

Provide background information that relates to the experiment about to be described. Describe current issues about the topic and possible advantages to performing the experiment.

Purpose

What do you expect to learn from this experiment?

Materials

A specific list of materials needed to perform the experiment.

Procedure

A detailed explanation of how to perform the experiment. Another person should be able to replicate the experiment by following the instructions you have here.

Data

Detailed information that you gather on a regular basis—plant measurements, amount of water applied, etc.

Results

A one or two paragraph summary of your data. This section may also include some graphs that show plant growth or another factor.

Conclusions

What did you find out from your experiment? Was your hypothesis correct? How might your experiments benefit others?
WHAT'S IN A PLANT?

Imagine that you are sitting in an inner tube in a mountain lake, breathing fresh air. You become larger... larger... and even larger. Every once in a while you stretch your toes and touch the dirt and sand. You wiggle your toes in the sand and squish them in the mud. You don’t know why, but touching the soil always makes you feel a little better and grow stronger. You decide to never get out of the water. In fact, you do not need to because you do not have to eat. You just bath in the sun and breath! It’s amazing how great life is as long as you have your water, air, sun, and soil.

Of course this is not possible, but could it be if you were a human plant?

Plants are unique living things. They have the ability to photosynthesize. “Photo” means light and “synthesize” means to “put together”; thus, plants are able to make food for themselves by using light energy. Plants take water, carbon dioxide, and nutrients and convert them into food for themselves. Without light, this could not happen.

All animals, including human beings, depend on plants for survival. Animals either eat plants or eat animals that consume plants for their nourishment. Animals are also dependent on plants for their ability to produce oxygen. For these reasons, if no others, people should learn about plants and agriculture.

Plants absorb air from pores, called stomates, in their leaves. Guard cells open and close to make the stomates as large as necessary. The air contains carbon dioxide, which plants use for photosynthesis. Sometimes stomates absorb other things, too, like water molecules and nutrients. Most of the time, however, water and nutrients are absorbed through the root hairs of plants.

Plants are like humans. They need certain minerals and nutrients to stay healthy. Let’s learn more about the special nutrients plants need.

NITROGEN

The element nitrogen (N) is required by all living things, including humans and plants. Nitrogen is needed to make the trunks, stalks, vines, flowers...every part of a plant. This is because nitrogen is part of all proteins. Proteins make up the “brains” of cells too. DNA and RNA
are nitrogen-containing substances that make the plants look the way they do. DNA and RNA are called genetic materials. Without DNA and RNA, plants would not be able to grow or reproduce.

Chlorophyll is a chemical that enables plants to photosynthesize. One chemical formula for chlorophyll is \( \text{C}_{55}\text{H}_{70}\text{O}_{6}\text{N}_{4}\text{Mg} \). The N stands for nitrogen. If plants did not have nitrogen as a nutrient, chlorophyll molecules could not be formed, the plants could not capture energy to make food for themselves and the plants would die. As you can see, nitrogen is essential for plant survival.

```
Nitrogen --> Proteins
          DNA, RNA --> a healthy plant!
          chlorophyll
          lots of other things
```

**POTASSIUM**

Potassium (K) is another nutrient that plants must have—without potassium, a plant would not survive. Potassium helps plants in many ways. It helps plants open and close the guard cells that surround the stomates. This allows the plants to take in carbon dioxide from the air but not let other things out. Potassium helps all kinds of chemical reactions occur, such as the formation of starches and proteins. It helps transport the sugar and starches made in the leaves to other parts of the plant. Without the proper amount of potassium, plants become weak and cannot resist pests or withstand periods of little water. Plants would die if they did not have potassium.

**PHOSPHORUS**

Plants need the element phosphorus (P). Phosphorus is also part of the genetic material of cells—DNA and RNA. It helps roots grow and helps plants produce seeds. Phosphorus is especially needed when the weather is cold or when seedlings are beginning to grow. Without phosphorus plants would die.

It is believed that there are 16 nutrients that plants must have in order to survive. They are: hydrogen, boron, carbon, nitrogen, oxygen, magnesium, phosphorus, sulfur, chlorine, potassium, calcium, manganese, iron, copper, zinc, and molybdenum. Water gives plants hydrogen and oxygen. Air (carbon dioxide) gives plants carbon and oxygen. The other 13 nutrients are most often absorbed from soil or groundwater. Plants also need to have other things, such as proper temperature condition and soil types. In the following readings, you will learn how farmers and gardeners make sure their plants get enough "food" so that we can have enough food.
WHY MUST WE REPLACE NUTRIENTS BACK INTO THE SOIL?

Farmers must take good care of their land. Without it, they would not be able to make a living producing food and fiber for the rest of the people. Farmers understand this fact and constantly try to keep their soil in top-producing condition. They know if they abuse the land, they will not be able to grow healthy plants.

Long ago, when people began to settle in one place, they realized that particular lands were good for growing food while other land was better off kept in its natural form or used as pasture land for their animals. There was enough land available to those who wanted to grow their own food, and people would locate in those prime areas (places like river fronts and valleys). Once an area became overcrowded, people would migrate to other desirable places. People also noticed that the manure from their animals made the soil better, and that if they rotated their crops, their soil would not become "tired." Most of what they learned was the result of trial and error.

In agriculture, people have learned a lot from their ancestors but also realize that prime agricultural land is not easy to find anymore. The human population is growing and people need places to live. New towns are covering a lot of the land that once was used for agriculture.

Most farmers must grow their commodities (crops, cattle, etc.) on the land they already own or lease, and that land has been farmed for generations.

For these reasons, farmers must be creative on how they keep their soil fertile so it can produce enough food for all the people in the world. Farmers and scientists know that plants, in order to grow, need more than sunlight, water, and carbon dioxide. They must have 13 other nutrients and proper thematic conditions. Most of the needed nutrients are in the soil and groundwater, but when a crop is harvested, the nutrients are removed from the ground. The nutrients must be replaced if another crop is to grow there.

Let's look at this scenario from the past:

A small amount of wheat is grown in a field. The wheat kernels are harvested and made into flour for the people of the small community of Wheatland. Cattle roam in the harvested wheat field and eat what they choose. The people who eat the wheat go to the bathroom in an outhouse on the edge of the wheat field. When the outhouse hole is full, the human manure is plowed into the field along with the cattle manure and wheat stubble (plant that remains after harvest). This land is let alone for at least one year before another crop is planted. Perhaps the next time this field is planted it will grow beans or corn. A new wheat field is planted on the other side of town next year.
Can you see how almost everything that was taken out of the soil was returned back to the soil?

Is this town similar to the situations we have in our country today? Of course not. The farm equipment used today enables farmers to plant and harvest larger wheat fields. When harvested, the wheat is taken elsewhere--the wheat kernels go to a mill and then to a bakery and the straw is given to cattle, or plowed back into the field. Human waste products go through sewers to sewage treatment plants and then out into rivers and eventually to oceans. Sometimes treated sewage water is used to irrigate crops. For today’s agriculture to remain sustainable, nutrients and plant matter that are removed from the soil and shipped to distant locations must be returned to the soil in one form or another.

The other reading assignments in this unit focus on how nutrients removed from soils are replaced.
As you will find out, there are many ways to replace nutrients which are lost from soil. As the population of California and the rest of the world increases, farmers must produce more food while maintaining or improving the quality of the earth. Decreasing water quality, lack of water and the demand for healthy and plentiful food at low costs are current issues that farmers are dealing with. In an attempt to maintain or improve water quality, some farming methods that were once used in soil maintenance are once again becoming popular. You will read about three ways of enhancing soil quality—crop rotation, using green manure and nitrogen-fixing plants.

**CROP ROTATION**

Many plants, such as corn, cotton and tomatoes, remove large amounts of nutrients from the topsoil if planted on the same land several years in a row. These crops especially deplete the amount of nitrogen in the soil.

Farmers and scientists have learned that other crops, such as legumes (peas, peanuts and beans), do not remove an excessive amount of nutrients from the soil; they, in fact, replace some of the nutrients that other plants take away. Farmers rotate the nutrient-removing crops with these crops so that the soil can get replenished with organic matter and nitrogen. Here are some possible examples:

- One year farmers might plant corn on a field. After the corn is harvested, a crop of beans is planted instead of another crop of corn. The beans help replenish the soil with nitrogen.
- One farmer might plant beans in-between his prune trees. These beans put nitrogen back into the soil and improve the quality of the soil. Sometimes these beans and bean plants are plowed into the soil (this is called green manure), but many times the beans are harvested before tilling. This not only helps maintain the quality of the soil, but farmers say it can help reduce the number of pests in a field.

**GREEN MANURE**

Green manure is fresh or growing green vegetation that is plowed into the soil to increase the amount of organic matter that is in the soil. Green manure is full of nutrients and replenishes the worked soil with some minerals it is lacking.

Sometimes crops such as alfalfa, soybeans, or other legumes are purposely planted in fields and then plowed into the ground without harvesting any of the crop. In other places, such as pasture land for animals, the grasses and clover are tilled into the soil each summer or fall.
Mustard plants, which are planted in-between grapevines and other crops, have deep taproots and are able to obtain nutrients that other plants cannot reach. The mustard is then plowed into the field and provides the soil surface with nutrients obtained from deep within the soil.

NITROGEN-FIXING PLANTS

Legumes are very special plants. A legume is a plant that has a pod--such as peanuts, peas, alfalfa, clover, and beans. Legumes are special because they have a unique ‘mutualistic” relationship with a certain type of bacterium called rhizobium. (This means they help each other to survive.) Rhizobia are bacteria that live in little nodules in the roots of plants. They are able to take nitrogen from the air and convert it into nitrogen plants can use. The plants benefit because they get the nitrogen they need and the bacteria benefit because they have a habitat that provides them with food (the food the plant makes for itself). When a farmer plants a field of legumes, he “inoculates” the soil with rhizobium bacteria to make sure that there are enough beneficial bacteria in the soil to produce the needed nitrogen. Sometimes the seeds are coated with the bacteria before they are planted. Often, after replanting the same type of legume, the soil does not have to have rhizobia added to it because a population of bacteria is already established in the field. Next time you go to a nursery, ask to see the packets of rhizobia they have for sale.

SUMMARY

Crop rotation and the use of green manure and nitrogen fixing plants are important ways to maintain and enhance soil quality. However, if these methods were “the answers” to the soil quality problems, then every farmer would be using them. Crop rotation and the planting of legumes introduce a new set of challenges. Cover crops help increase the amount of nitrogen available to new plants, but plants also need to have potassium and phosphorus. There are other challenges associated with legumes. Many legumes require more water than other crops, planting and harvesting dates of rotated crops often conflict with one another, there is not always a demand for the crops that are rotated in, and there is a new set of pest interactions that exists. Each of these challenges requires continuing research and analysis. Farmers must consider the new strategies and techniques that become available, but they must also consider how they can continue to make a living for themselves.

As you drive by fields and orchards, look to see if you can find two crops growing at the same time in one field. This technique is becoming more and more popular.
There are many ways to keep soils healthy. It is important to enrich soils, especially ones that are used over and over again for growing crops, so that the plants grown in them are strong and healthy. You will read about some natural ways of adding nutrients back into the soil.

**MANURE**

Centuries ago, farmers would cart animal waste from their barns and pastures out to their fields to get rid of it. They did not know why, but they knew that the animal waste, called manure, made the soil better for growing crops. This process of using manure to enhance soil quality is still used today. Farmers use both the solid waste, called dung, and the liquid waste, called urine.

Animal manure adds many things to soil. It provides organic matter which makes the soil lighter so that sprouting seeds, roots, and water can move through it easily. It also replaces nutrients, especially nitrogen, that are removed from the soil when plants are harvested.

Cattle manure is the most common type of manure found in gardening stores and nurseries, but any kind of manure can be used--horse, sheep, chicken, goat, rabbit, etc.. Each type of animal has a different quantity of nitrogen, phosphorus, and potassium in its solid waste. Many studies have been done to determine the actual nutrient quantities of different manures.

You can go to any garden center and buy manure. It is relatively inexpensive and is readily available in most areas. There are some drawbacks with manure, however. Transporting manure from large feedlots to farmer’s fields can become expensive. Also, it can be very concentrated; it sometimes burns the leaves and roots of plants, especially on young seedlings, if it is not mulched (mixed) into the soil or allowed to age. Farmers believe that manure is best used when applied in small amounts on a regular basis and when it is used on land that will not be planted for a while. Many farmers are considering reintroducing animals to their farms so they have their own sources of manure.

**COMPOST**

Compost is a rich, natural fertilizer and soil conditioner. It adds both fiber and nutrients to soils just like manure does. However, it does it in a milder way so that plants do not get ‘burned.’

Compost is made by mixing plant material--such as lawn and tree clippings, straw, and kitchen waste--with manure and topsoil. This pile is allowed to sit and decompose. The pile’s temperature increases and kills seeds and a variety of harmful plant diseases. Topsoil, added to the
bin, provides the micro-organisms (bacteria and fungi) needed to decompose the waste into humus--nutrient rich soil. Earthworms also eat the dead plants and convert them into organic matter that can be used to enrich soil.

The science of composting has really become popular. Many studies have been done to see how plant and animal waste can be quickly converted to organic matter. Compost not only enriches soils but also reduces the amount of waste put in landfills. A lot of things people used to throw away are now becoming part of household compost piles. Farmers are also beginning to use composting as a part of their crop growing procedure. There are many ways to make a home compost bin. One example is shown below.

Here are some important things to remember about making compost.

- **Allow air to get into the pile so the micro-organisms can breathe.** Mix the compost pile about once a week.
- Layer the pile with a variety of things so that the compost will contain a variety of nutrients. A pile of lawn clippings will not become organic matter very quickly unless other things are added to it.
- Do not add a lot of kitchen waste or lawn clippings at one time. Do not add meat scraps to your pile. The pile will tend to get smelly. You might add a layer of cat litter or alfalfa meal to the pile every once in a while to reduce the odor. Compost bins really should not smell if piled appropriately.
- Keep a well-like depression on top of the pile so that rainwater can collect. If you do not get rain frequently, water your compost periodically.
- Experiment with composting to see how you can make the best for your garden or field.

**SUMMARY**

The two nutrient supplements mentioned above--manure and compost--are called organic fertilizers. They are fertilizers that originate from living things. These methods are not problem-free. Manures sometimes infest fields with weeds and various diseases. Even though it takes longer to use these methods and they tie up soil that can be used for growing crops, it is becoming more popular to try to use more of these methods so that the nutrient cycle is well balanced and croplands can continue to produce food for people. Research continues to discover ways to make organic fertilizers a more feasible source of nutrients for crop production.
The word “fertilizer” means a substance that adds nutrients to soils so the soil can help produce high quality crops, trees, or other vegetation. There are two classes of fertilizers—organic and inorganic. Fertilizers, organic or inorganic, are applied to replace nutrients removed by crops or to add nutrients that may be low in the soil naturally.

ORGANIC FERTILIZERS

Organic fertilizers are fertilizers that originate from living organisms. Two organic fertilizers commonly used are fish and seaweed emulsions. These are liquids made from seaweed or fish and are easy to apply. These fertilizers are popular because they are easy to use. Most of the time when fish or seaweed emulsions are used, there are few problems with “burning” young plants with the chemicals. Some disadvantages of using these emulsions are that they often have a disagreeable smell, can be very expensive, and large quantities are needed when growing crops in large fields. The other readings in this unit will talk about other organic fertilizers.

COMMERCIAL INORGANIC FERTILIZERS

Commercial inorganic fertilizers are fertilizers that are prepared in factories and then mixed into the soil to restore nutrients so crops can continue to be produced on a particular plot of land. Most inorganic fertilizers contain nitrogen, phosphorus, potassium, and a few trace minerals.

Nitrogen is the most abundant element in the earth’s atmosphere, but plants cannot absorb pure nitrogen into their cells. It must be in a special form for it to be absorbed. Commercial inorganic nitrogen is made by combining hydrogen and nitrogen from the air. In order to combine the two elements together, natural gas (a fossil fuel) is required.

Commercial inorganic phosphorus is made by mixing phosphate rock, which is mined from the earth, with sulfuric acid and water.

Potassium fertilizer is commonly called potash (pronounced ‘pot ash’). This name comes from the fact that the ashes left over from a campfire contain potassium and were, throughout history, put into fields. Commercial inorganic potassium is usually obtained by mining it from deep within the earth. Potash is currently mined in New Mexico, Utah, and Canadian Saskatchewan. Potassium can also be obtained from brine (salt) deposits on the earth’s crust. Brine deposits are places where large bodies of salt water used to exist. One brine salt deposit you might be familiar with is the salt flats near the Great Salt Lake in Utah.
Commercial inorganic fertilizers are popular for a variety of reasons. They are readily available, and are easy to transport, store, and apply. They also exist in a variety of formulas. Some commercial fertilizers are high in nitrogen while others are high in phosphorus or potassium. People can pick the “perfect” fertilizer that meets their needs. Organic fertilizers typically have a limited variety of formulas and usually release nutrients more slowly than commercial nutrients.

There can be problems with commercial inorganic fertilizers, however. The most obvious problem is that they do not add organic matter back into the soil like manures, composts, and green manures. Without organic matter, soil cannot hold water effectively or provide air to plant roots. Also, if not used in appropriate amounts or applied at appropriate times, a lot of the fertilizer cannot be used by the plant, and gets into the groundwater or is run-off into streams.

Today, the trend is to use all the knowledge and technology available to keep the soil of the earth healthy and productive. Farmers, just as home gardeners should, try to use fertilizers appropriately. Courses are available to interested people for becoming better informed on how to apply fertilizers. Studies have shown that fertilizers are misused most often by home gardeners rather than farmers. Is your family doing its part to properly store and use fertilizers?
GROUNDWATER

PURPOSE

The purpose of these activities is to show students the mechanics of water flow and the mechanics of pollution in groundwater.

CONCEPTS

- Optimum water quality is critical to the survival of living things.
- Many factors are important in optimizing the production of food and fiber.
- Much of the United States depends on groundwater as its source for humans and agriculture.

MATERIALS

For the Class:
- 1 knife or razor blade that can cut through a 2-liter soda bottle

For Each Team of 3-4 Students:
- 3 baby food jars
- water
- pebbles (enough to fill baby food jar)
- clay (enough to fill baby food jar)
- sand (enough to fill baby food jar)
- red food coloring
- 2-liter bottle (cut 1/3 from the top)
- old nylon stocking
- rubber band
- dirty water (water that contains mud, plant fragments, micro-organisms, etc. Pond water is fine, or you can make up your own version of “dirty water”)
- knife (if bottles are not already prepared)

TIME: 2-fifty minute sessions

BACKGROUND INFORMATION

The water cycle is crucial to the existence of life on earth. Among other things, it replenishes the amount of fresh water available to plants and animals. The majority of the United States depends on groundwater as its water source for humans and agriculture. Groundwater is renewed at a slower rate than other fresh water sources, but is often more dependable in years of low rainfall.

Under normal conditions, groundwater is formed by the percolation of water through soil and rocks. It collects in pores, channels, or cracks underneath the ground. This activity illustrates the percolation of groundwater and how substances can contaminate groundwater.
PROCEDURE

1. Have your students read a current newspaper article on groundwater. If you wish to have your students read more about groundwater, ‘Ground water,’ ‘How Does Groundwater Travel,’ and ‘What’s In Groundwater?’ are included in this packet. Have your students complete a Fact/React section in their journal.

2. Divide your class into groups of four.

3. Have each group complete the ‘What’s In Groundwater?’ experiment. 2-liter soda bottles can be cut relatively easily with a razor blade or scissors. Begin cutting the bottle with the lid on it.

CONCLUSION

Students will see that what is done to the surface of the planet or what they bury inside the earth or remove from inside of the earth affects, among other things, groundwater quality. They will also see how soils work as filters and realize it is not easy to remove all substances from ground water.

EXTENSION

1. Have a contest where students create a filter, using materials and a design of their own, that will produce the clearest water.

2. Have students design a filter that will remove salt and chlorine. This requires a basic knowledge of chemistry. Have students contact your local water officials to determine how this is done.

(Adapted from NVATA Groundwater Project. Permission granted from Linda Howe, UVM; Extension Systems, RR-4 Box 2298, Mount Pelier, Vermont 05602-8927.)
WHAT'S IN GROUNDWATER?

Introduction

The term “groundwater” is used frequently. After reading the various summaries on groundwater, you should now have a clear understanding of what groundwater is and what substances it might contain. The following experiment will demonstrate how soil acts as a water filter.

Questions

A. Out of the choices pebbles, sand, and clay, which type of substance do you think could hold the most water? Why?

B. Suppose a toxic substance was spilled on the top of each of the three soil types mentioned above. Draw a sketch of what you think the soil and groundwater underneath it would look like. Use a red marker or crayon to represent the contaminant.

Procedure

1. Fill 3 baby food jars with different types of soil components--pebbles, sand, and clay.

2. Add enough water to each soil component so that it is completely moist but not soaking wet. Dump out any extra water that might be present. Which type of substance holds the most water? Which holds the least?

3. Add one drop of food coloring to the top of each soil. Add 2 tsp. of water to the top of each in a rain-like fashion.

4. Observe how the food coloring moves through the soil. Describe what you see.
5. Now you will construct a soil water filter that is made of a combination of pebbles, sand, and clay. Stretch an old stocking over the neck opening of the 2-liter bottle. Secure it with a rubber band.

6. First place a layer of small pebbles, then a layer of coarse sand, and finally a layer of fine sand in the neck of the bottle.

7. Pour some tap water through the filter to remove any dust.

8. Pour some "dirty water," obtained from your instructor, into the filter and collect the water that comes out of the bottom in a clean container. Describe what the water looks and smells like. DO NOT TASTE IT! Compare its new appearance to its original appearance.

9. Repeat the same experiment, but this time use "dirty water + food coloring." Describe what you observe. Do you think some of the red food coloring particles are trapped in the soil filter? If the soil filter were twice as large, do you think less food coloring would be in the filtered water?

10. Write a paragraph that summarizes what you learned from these experiments about soil and groundwater.
Groundwater

When some people think of groundwater, they imagine large underground lakes or intricate systems of subsurface rivers, but this is not the case. In fact, groundwater is simply water that fills pores, channels, or cracks in permeable rocks beneath the surface of the earth.

Groundwater comes from precipitation. When rain falls or snow melts, some of the water evaporates, some of it is taken up by plants, and some of it runs off into gutters, ponds, or streams. The rest seeps down into the earth to become groundwater. The amount of precipitation that ends up as groundwater varies, depending on the climate and soil conditions.

Groundwater is constantly moving toward a point of discharge, usually a stream, lake, or well. Some groundwater may travel only a few feet until it emerges at a point of discharge a few hours later. Some groundwater may percolate down to depths of 6,000 feet or more, travel hundreds of miles underground to a point of discharge, and emerge hundreds or thousands of years later.

The permeable rock materials that groundwater travel through are called aquifers. The word aquifer comes from two Latin words: aqua, or “water,” and ferre, “to carry.” Thus, an aquifer is any material that carries water underground. It may be a layer of sand and gravel, or a deposit of sandstone or limestone.

An aquifer may be only a few feet thick or hundreds of feet thick. It may be just below the surface or thousands of feet below. It may underlie a few acres or thousands of square miles. Aquifers may occur one on top of the other, separated by layers of less permeable rocks. Shallow aquifers (those fairly close to the surface) are replenished-called recharging—by local rainfall. Deep aquifers may be recharged by local rainfall or from distant rains, perhaps occurring many years in the past.

Groundwater aquifers are not normally replenished by surface streams. Groundwater discharge constitutes the base flow (the flow not coming directly from rain and runoff) of many streams that would otherwise be dry in non-rainy periods. Thus the quality and purity of our streams are greatly affected by the quality of groundwater.

The speed at which groundwater travels also varies significantly. In a very permeable sand and gravel aquifer, the rate of movement is as high as 1,800 feet in five months, or 12 feet per day. In a silty clay formation, groundwater travels less than 200 feet in 20 years, or ten feet per year. The generally slow movement of groundwater is a significant factor in making groundwater contamination so great a problem.

Source: Illinois Department of Energy and Natural Resources.

NVATA Groundwater Project.
How Does Groundwater Travel?

We can, to some degree, control how quickly water is pumped out of the ground, but the factors that control how quickly groundwater moves into an area are another matter.

It’s not just a matter of how much recharge (rainfall, snowmelt, etc.) that an area receives, although that’s important. It’s also a question of how quickly recharge water can move into and through the ground. The movement of this recharge water depends on the types of soils and rocks through which it is moving. Soil samples that are dug up from different places such as a creek bank, a garden plot, the beach or the woods, are quite different in appearance and in other qualities as well. For example, if water is poured through different soil types such as sand, clay, gravel and garden soil, we would find that it moves at different rates. It moves quickly through the gravel and sand, more slowly through the garden soil and the slowest of all through the clay.

Water also moves through rock material in much the same way. The gravel could be viewed as a close-up of a single rock and the spaces between the chunks of gravel are like a rock’s pores. The pores are the spaces that water occupies when the rock (or a soil) is part of the saturated zone.

Rocks with large pore spaces are called porous; that means that they can hold a great deal of water. How easily the water can travel through a rock depends on whether the pores are connected to each other or not.

A rock that water cannot move through is called impermeable. (The “im-” means “not.”) Spaces in a rock can be compared to bubbles. If the bubbles were connected, water could flow from one bubble to another, in one side of the rock and out the other. Water could move through the rock just as it can through a sponge. This second kind of rock, the one that water can move through, is called a permeable rock. The water is able to permeate (move through) it.

Water can move freely between the grains of sand in sandstone. Sandstone is called sedimentary rock because it’s made of compressed sediment (sand). Because water can move through it and because, if it is below the water table, it can hold a lot of water, sedimentary rock tends to be a good place to find groundwater. Sedimentary rocks usually have “grainy” textures. Limestone is also sedimentary rock. Limestone is less porous than sandstone, but it is permeable, water moves easily through solution channels in the limestone’s weak spots.

Other rocks, such as granite, were partially melted by heat sources deep in the earth. When they cooled and hardened, they had hard, crystalline textures.
CRYSTALLINE rocks are made of tightly intergrown crystals. They don’t have pore spaces, therefore they are not porous. Crystalline rocks can’t absorb liquids because they don’t have pore spaces. But they can hold and transport water if there are FRACTURES (cracks) in the rock. And water can move from one fracture to another if the cracks meet. The more fractures, the more water the rock can contain.

One special kind of rock fracture is called a FAULT. Suppose a very large rock formation gets fractured by an earthquake. If the fracture splits the rock so that part of the rock moves upward while the other part moves downward, the gap where the rock broke apart is called a fault. What has that got to do with groundwater? Groundwater can travel very, very easily through a fault. Instead of moving slowly through the pores or small cracks of a rock, now the water can just flow right between the pieces.

One last kind of earth material important to know about in connection with groundwater is called UNCONSOLIDATED. Sand and gravel deposits are unconsolidated (“not solid”) and water can flow right through them. They’re called unconsolidated because the pieces are loose. Clay is also unconsolidated, but its pores are so tiny that water cannot pass through easily. Some clays are nearly impermeable.

Groundwater in PERMEABLE soils and rock layers will be moved by the force of gravity from high areas to low areas. But what happens when water reaches an IMPERMEABLE layer (a layer that the water can’t move through, like some types of clay)?

If the groundwater can’t move through an impermeable layer, it may just collect on top of that layer. If the groundwater collects on top of an impermeable layer ABOVE the water table, it’s called a PERCHED WATER TABLE. Usually perched water tables don’t hold much water and they often dry up during dry seasons, so they aren’t good places to put wells.

Let’s assume, however, that the groundwater makes it down to the water table. Whatever layer it collects in (and moves through) is called an AQUIFER. Aquifers can be found in sedimentary or crystallinerocks or unconsolidated deposits. Groundwater can be sandwiched between two layers of impermeable rocks. This groundwater sandwich is called a CONFINED AQUIFER. The confined aquifer is like water running through a garden hose. If you punctured the hose, a jet of water would shoot straight up in the air.

ARTESIAN WELLS are wells that have been drilled into a confined aquifer. An artisan aquifer is confined from above and below by materials such as clay or a type of rock that has a low permeability. Thus, artesian aquifers are similar to
pipelines. When a well is drilled, the water level in artesian wells rises above the level of the confined aquifer. This rise in water level is due to the difference in elevation from the point of recharge to the point of discharge (the well). Sometimes there is enough pressure in an artesian well to push the water above the surface of the ground. Then it's called a FLOWING ARTESIAN WELL.

Source: University of Vermont Extension Service
What’s In Groundwater?

Some of the groundwater’s traveling companions (such as bacteria and viruses) can make people sick. Some (such as minerals) may make the water taste bad. And some (like industrial pollutants and other hazardous wastes) may become long-term health hazards.

These things, which pollute our groundwater, come from many sources. Some occur naturally, but many are caused by people. Some people-caused sources of pollution include: faulty septic or sewer systems, overly enthusiastic use of fertilizers and pesticides, animal manures, chemicals dumped by industries, leaking oil and gasoline tanks, improperly constructed landfills and garbage dumps, improper disposal of household hazardous materials, etc. Water naturally dissolves some elements out of the rocks through which it flows. These elements include calcium, iron, sodium, fluoride, manganese, magnesium and sulfur.

Some minerals dissolve out of rock formations and make water “hard.” Hard water keeps soap from getting very sudsy, and causes thick, hard, white deposits to accumulate on pots and pans and water heaters. This hard water, however, tastes a lot better than groundwater that has dissolved iron in it, a problem that often occurs because so many rocks contain iron.

The kinds of minerals found in groundwater will depend on the kinds of rocks found in an area. The amount of mineral found in the groundwater depends mostly on how long the water was in contact with the rock. The longer the contact, the greater the chance the groundwater has to dissolve the mineral.

People are the biggest cause of groundwater pollution that is hazardous to our health. One very common cause of groundwater pollution comes from untreated sewage leaking into the ground. It comes from damaged sewer lines or from septic systems that aren’t working properly. People who live in towns or cities usually depend on municipal water and sewer systems. Many rural families, however, have their own water supplies (wells and springs) and septic systems. In a home septic system, household wastes are piped to an underground septic tank, where bacteria decompose some of the solid wastes. Wastewater then flows out of the tank into an underground drainfield.

Given enough time, soil has the ability to cleanse wastewater of its bacteria and viruses. If wastewater filters through enough soil, eventually it will become clean and safe enough to drink. That’s important, because eventually, after it’s made its way into the saturated zone, it may again end up in someone’s water supply.
Things don’t always work the way that they are supposed too, however. If some of the septic system’s pipes clog, wastewater will be forced through the unclogged pipes, causing only a small area of the drainfield to accept the load of water intended for the entire field. When that happens, contaminated water may ooze up to the surface where it can be a health hazard to people and animals.

Another problem is that the drainfield might be in a location that doesn’t give the wastewater a chance to filter through enough soil to get clean. If the wastewater flows into fractured crystalline rocks, for example, it may move too quickly through the rocks to be cleansed. This contaminated water may end up back in the family well or in nearby streams, or it might carry its contaminants great distances to other unsuspecting users.

Many people don’t realize that they may be polluting groundwater when they pour TOXIC MATERIALS, such as paint thinner or insecticides, down the drain. “Toxic” means that a substance can be dangerous enough to make people or animals very sick or even kill them. Many toxic substances don’t break down in the soil. They can travel with the water right into the saturated zone and thus into the aquifer, just as toxic as they were when they were poured down the drain.

Even when toxic household chemicals are not poured down the drain, some of them end up in our groundwater. For example, when old bug spray containers or varnish cans, or other toxic materials are thrown in the trash can, they usually get hauled off with the rest of the garbage to the local LANDFILL, a piece of land the town or county has set aside for that purpose. Most landfills are now called SANITARY LANDFILLS because the garbage is compacted (squashed), then covered with dirt or clay, to cut down on health and safety risks to the public. Before a landfill can be opened today, it must meet very strict regulations governing its construction and location.

Many old landfills, however, were built before anyone had any idea that they might cause trouble for groundwater. All sorts of trash—including poisonous household chemicals—were dumped into them. The problem was that nothing kept rainwater from percolating (filtering) down through the landfill. Suppose a landfill was located where water travelled easily through the soil and rock layers. Now suppose some of the trash in the landfill includes water-soluble toxic chemicals. Rainwater dripping down through the landfill could dissolve out some of those chemicals and carry them into the groundwater. It’s like brewing a pot of coffee. Water dripping through the coffee grounds picks up the soluble parts—the flavor and color—of the ground-up coffee beans.
The rainwater filtering through a landfill performs in a similar fashion, resulting in a liquid called LEACHATE. Leachate is the groundwater equivalent of a cup of coffee—except that no one would want to drink it, and it may continue on to pollute an aquifer which may be someone's water supply.

Newer landfills are designed with a clay barrier and lined with a plastic material. These materials act as an impermeable barrier through which water cannot filter. A small amount of leachate may eventually leak (very, very slowly) through clay, but the clay itself will filter many of the contaminants out of the leachate. Even if we could fix all our old landfills so that they wouldn't leak leachate into aquifers, there are still many private dumps and trash heaps with all kinds of contaminants leaking out of them. These private dumps may be smaller but they pose the same kind of threat to groundwater as do the landfills.

Source: University of Vermont Extension Service
PLEASANTVILLE AND CLEAR RIVER

PURPOSE

The purpose of this activity is for students to appreciate the complexity of human interactions with the environment and to realize that there are many legitimate sides to an issue. They should conclude that knowledge is needed before adequate decisions can be made that benefit all living and nonliving things involved.

CONCEPTS

- Optimum water quality is critical to the survival of living things on earth.
- Many factors are important in optimizing the production of food and fiber.
- Average citizens and political activists have an impact on what legislation and policies are adopted by the government.  
- Humans use air, fresh water, soil, minerals, fossil fuels and other sources of energy from the earth.
- There is a finite amount of fresh water on the earth.

MATERIALS

For the Entire Class:

- a variety of reference books on water use and water quality (see the Background References section of this booklet)
- props for a public hearing--gavel, podium, room arranged in appropriate fashion
- a box to store 9 manila file folders

For Each Role-Play Team:

- 1 ‘Pleasantville Scenario” handout
- 1 “Public Hearing on Water Quality and Quantity Proposals for Pleasantville’ handout
- 1 ‘Report Format” sheet
- 1 overhead marker
- 1 overhead transparency of Pleasantville Map
- markers
- materials group needs for their presentation (chosen and obtained by the students)
- 1 group copy of role-play card
- 1 manila file folder

For Each Person:

- 1 role-play card that describes his/her particular role

TIME: 3 fifty-minute sessions--research and preparation
       2 fifty-minute sessions--Public Hearing
BACKGROUND INFORMATION

"Much of the United States depends on groundwater as its water source for humans and agriculture. There is a finite amount of fresh water on the earth... and it is the responsibility of living things to use it and share it wisely. Along with groundwater sources, California has a series of surface rivers and lakes. Water usage is controlled by federal and state agencies which also monitor water quality. As the human population continues to grow and farmers must use desirable land for agriculture, water quantity and water quality are concerns for everyone.

Whatever the outcomes of the Public Hearing, your students are sure to learn about local politics and how water quantity and quality affect local communities and the world.

PROCEDURE

The students will participate in a class role-play that resembles a public hearing coordinated by the Water Commission of Pleasantville. Some students will be water commission members while other students will represent special interest groups that may be affected by decisions made at the meeting.

1. Read the “Pleasantville Scenario” to the class. (Also, have a written copy of the scenario available to each group of students after roles are assigned.)

2. Explain to the students that this scenario is hypothetical. However, it represents many current issues affecting towns throughout the United States, especially in California.

3. Distribute role-play cards to students. This should be done randomly. This forces the students to see a particular side of an issue without letting personal biases interfere. Make sure that all students are assigned a role. You should end up with a water commission and 8 other special interest groups. There should be at least 3 people in each group so that group discussions can occur.

4. Have the students read their role-play cards. After they are clear with what their roles are, read “DECISIONS, DECISIONS!” to the entire class.

5. Distribute one manila file folder to each group. Have the students write their names on the folder. Explain to the students that this is where group information should be stored and that the folder is not to leave the classroom. This will allow each group to have a safe place to keep their work.

6. Instruct each group to discuss the following and record the key points of the discussion for later reference.

SPECIAL INTEREST GROUPS

a. What are the 3 most major problems facing Pleasantville?

b. What problems are facing your own interest group?

c. How is your special interest group willing to assist in solving the problems of Pleasantville water?

d. If applicable, how much water should your group be able to remove from the river? How much should your group have to return to the river?

e. How does your group propose the water problem be resolved? (Who should reduce their water usage? By how much? Who should clean up the water? How?)

f. If appropriate, write a new specific proposal the water commission should consider.
g. Prepare a 24 minute statement your special interest group will present to the city council at the Water Commission Public Hearing. This statement should discuss your group’s views on the current water problems facing Pleasantville. Make sure your statement is convincing and clearly states your group’s decisions on letters c, d and e above, as well as how your group thinks the water commission should vote on the specific ballot measures proposed. Justification of why your group needs the water should also be included.

WATER COMMISSION MEMBERS
a. What are the 3 most major problems facing Pleasantville?
b. Looking at the numbers, what are some possible ways of reducing water usage from the river? Increasing water return to the river?
c. Using specific numbers, what are some reasonable scenarios of reducing Pleasantville’s water usage? (For example, Cattle Ranchers will have to reduce their water usage to 175,000 gallons per day and reduce their nitrate flow into the river by 15% within the next 4 months.)
d. Discuss the ballot that you will vote on at the meeting. Are there any other items that should be added to the ballot?
e. Develop a report that commends or warns groups about what they are currently doing and make suggestions to them about what they should do in the near and long term future.
f. Elect a chairperson who will lead the meeting. Practice the meeting agenda.

EACH GROUP SHOULD WORK INDEPENDENTLY OF THE OTHERS. NO CONSULTATIONS BETWEEN GROUPS SHOULD BE ALLOWED. THIS WILL MAKE THE PUBLIC HEARING MORE EXCITING.

7. The day before the Public Hearing, discuss with each group their role in the meeting and review their speeches with them. While you are meeting with individual groups, each group should make signs, flyers, or other props to create a setting for the town meeting.

8. The next day, have the Public Hearing. Stick to the agenda and sequence of speakers. At the meeting recess, allow teams to form a closing statement that justifies their water usage and suggestions for change.

9. At the conclusion of the meeting, have the water commission vote on the issues and present a final map with all appropriate figures.

10. As a class, discuss how the outcome of the vote will affect the people of Pleasantville. How would the people be affected differently if an alternative decision would have been made?

CONCLUSION

The students will conclude that decisions made in the local community are affected by interested community members from various backgrounds. The more informed and active citizens are in their community, the more influence they will have in community decisions. The students will also realize how interconnected people are with the environment and that their decisions directly affect the quality of the water, soil, air, and other living organisms that surround them.

EXTENSION

1. Video tape the public hearing. Discuss how different statements made by certain individuals could have changed the outcome of the hearing.

2. Invite other classes to observe the hearing. Have ballots prepared and let them vote.
PLEASANTVILLE SCENARIO

The town of Pleasantville is 100 square miles (approximately 10 miles wide and 10 miles long). The rapidly growing agricultural community spans both sides of Clear River. It currently has a population of 10,000, but is continuing to grow as developers build more and more homes. Most of the townspeople work locally. The major occupation is farming and ranching, but many people are employed by the Port of Pleasantville, Pleasantville Canning Company, small local businesses (grocery stores, banks, the River Raft and River Fishing Company, etc.), and the City of Pleasantville.

Pleasantville, along with the rest of the state, has been severely affected by a 6-year water shortage. The snow pack in the mountains this year is no better than it has been the past six years, and there is no sign of quick relief. The salinity (salt content) of the minimal amount of water running down Clear River has increased tremendously due to the influx of sea water that is not diluted by fresh water. The fish population is diminishing and water fowl are dying. The Clear Water reservoir is almost empty, and the two major groundwater wells are now dry.

Currently, Pleasantville removes 3,500,000 gallons of water per day from the river for irrigation and town use. Only 2,500,000 gallons of that water is returned to the river. The rest is lost, mostly through evaporation.

The state has mandated that Pleasantville return 500,000 gallons per day back into the river. If the town does not return that amount to the river, heavy fines will be charged to the city. Another problem also exists: The salt content of the water that is returned to the river is very high. This is due to cattle, farming, and city sewer inefficiencies. The state has mandated that the salt content be only 5% higher than the water that is removed. A special water commission has been formed to complete the water reform required by the law. The Water Commission consists of city council members, engineers, water experts from the community, and other interested individuals.

The Water Commission is planning a public hearing to discuss and vote on issues related to the major Pleasantville water problem. This class will role-play the Water Commission meeting. Each of you will be a member of the community and participate in the meeting.
ROLE-PLAY CARDS

CATTLE RANCHERS OF PLEASANTVILLE

Your family has lived in Pleasantville for 4 generations. Your ancestors have raised cattle here for over 100 years. You have watched the city change from a tiny rural town to a mid-sized city. You and your sisters and brother run the cattle operation now and have college degrees in a variety of animal and plant sciences. You understand that there is a problem with the lack of water and groundwater contamination. You are willing to work with a university research team to explore ways to decrease the amount of nitrates your cattle put into groundwater and run-off that goes into Clear River, and you are considering water conserving irrigation techniques. You know that under normal conditions, nitrates from cattle urine and manure percolate through the soil and cause little water contamination. But the number of cattle you raise is increasing, and you are unable to purchase more land for your cattle since surrounding land is owned by developers. An increase in nitrates in water is now a concern of yours. You feel strongly that the city must learn to co-exist with the agriculture that created the town. You refuse to reduce the head of cattle on your ranch voluntarily unless you are compensated in some other way. You are willing to reduce your water consumption and have an idea. Perhaps the water from the sewage treatment plant can be used to irrigate your pasture land. This will allow the water to be used more than once before putting it back into the river. Before doing this, however, you must be convinced that this water will not harm your cattle. You are worried that your family’s longtime ties to the land may be broken. Your family will not be able to survive monetarily if you must reduce your head of cattle or pay large fees to the city.

Water taken from the river=800,000 gallons per day
Water returned=600,000 gallons per day
Water used=200,000 gallons per day

SEWAGE TREATMENT PLANT MANAGEMENT TEAM

You have worked at the Pleasantville Sewage Treatment Plant for 17 years. You have seen the city grow and have worked through two expansions of the sewage treatment facility due to population increases in the community. You feel that the townspeople use water frivolously and do not realize how much water they use each day. You have a personal commitment to educate people about the fact that all water that goes down drains in homes and in streets must go through the sewage treatment plant before entering Clear River. You also want to educate them on how sewage water is cleaned before it is put back into the river. You feel that if people knew this information, they might think twice about wasting water. You also feel, however, that the townspeople will not reduce their water usage considerably unless there is a price to pay—higher water and sewer bills. You would like to experiment with producing cleaner water before it is output into the river, but you are not sure how to go about getting the local farmers and ranchers to believe that treated sewage water is acceptable for some types of irrigation. You also want to explore ways treated sewage water can be used to irrigate city lawns and gardens. You strongly support the increase in property tax for your facility or a surcharge that would be billed to water users greater than 150 gallons per capita. You want to keep your job and not receive a cut in your salary; therefore, you want to make sure that the sewage treatment plant management team works hard to solve this water problem.

Water taken from the river=0 gallons per day
Water returned to the river=1,000,000 gallons per day
Water used=0 gallons per day
Pleasantville Farmers

You represent the local farmers of Pleasantville. Most of you have family farms that have been in the area for three or four generations. You are determined to keep your land in productive agriculture, and are extremely tired of newcomers and environmentalists telling you that you waste water. You feel strongly if people knew how their food was grown, perhaps spend even a couple of hours working on a local farm, they would better appreciate the people who grew it for them. You feel that you are environmentalists yourselves because you realize that if you do not take care of the soil you till, you will not have a job in the future.

You agree that there is room for water use reduction. You are willing to use drip irrigation where appropriate, and use the more drought-resistant varieties of corn and wheat, even though the seeds are slightly more expensive. You are willing to try to reduce the amount of salts and other chemicals that exist in water run-off by carefully timing fertilizer and pesticide application. You want to remind the public that plants help cleanse the air and soils, and evapotranspiration (plants losing water vapor through their leaves) is one of the main reasons for water loss.

You feel strongly that you should have a break on how much you pay for water since you are providing an invaluable service to mankind. Without your hard work, people would have to fend for themselves. There would be more people in the world dying from starvation. You support the property tax increase for sewage treatment plant reworkings.

Water taken from the river=1,100,000 gallons per day
Water returned to the river=620,000 gallons per day (but higher in salt content)
Water used=480,000 gallons per day.

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Land Developer

Six years ago, you purchased, a plot of land from a farmer who could not make ends meet. This farmer received more money from the sale of his land than he could earn from farming the land. You are frustrated with the city council because they have turned down your requests, 12 times, for developing the land. You have proposed many options, but the one most agreeable to you is the production of 50 new homes on the southwest end of town. You think it is unfair that your property is zoned for single family homes, and that all you are allowed to do presently is lease the land to farmers. You agree to install water saving devices in all new homes built, and there will be a limit to yard space each home can make into lawns. You will install drip irrigation lines in the front landscaping you provide to the homeowners. Your feeling is that agriculture is using more water on the land you own than would be used by new homeowners. You feel that progress is when new buildings are built so people can live in desirable places with new homes. You do not support the increase in property tax since this will discourage some potential homeowners from purchasing. You will donate some money to the city for sewage treatment expansion and will donate some land so that a new school can be built. You truly do not understand why the town will not let you build the new homes and, at times, you become a bit irate about it.

Water taken from the river=100,000 gallons per day
Water returned to the river=80,000 gallons per day
Water used=20,000 gallons per day

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RIVER RAFT AND RIVER FISHING COMPANY

Every summer, thousands of tourists spend some time on the river rafting and fishing. Your company has been in existence for 20 years and you have never seen the river so low. You have also noticed that fewer people are coming to the area for fishing because the prime fishing spots have disappeared due to the lack of water. You had to resort to other sources of income—you have built a miniature golf course and also rent bicycles.

You understand that Mother Nature controls the natural water cycle, but you feel strongly that the townspeople and farmers and ranchers of Pleasantville can assist in improving the quality of the river. You do not feel that enough is being done to improve the river quality. You agree with the state that the water level must increase so that river wildlife can survive the difficult times. You support all tax increases, but believe that education programs should be provided to all people so that their consciences will make them feel guilty when they waste water.

Water taken from the river=0
Water returned to the river=0
Water lost=0

PORT OF PLEASANTVILLE

You truly understand how low the river is. You are having trouble keeping a safe depth in your deep water channel. During low tidal action, loaded ships are hitting bottom. You have to dredge the deep water channel more frequently and this is getting very expensive. If much more dredging is required, the port will have to shut down until water levels rise. You will not be the only ones out of a job—the port provides jobs to over 500 people.

You promote anything that will increase the water flow in the river. However, your port ships grains such as wheat, corn and rice that are locally grown to various parts of the world. You do not want the farmers to reduce their production of these grains because the port will not have enough grain to ship. You support increases in taxes and do not mind the water fees proposed to industries. Your major concern is that the port remains open, and that it can operate at a profit.

Water taken from the river=80,000 gallons per day
Water returned to the river=80,000 gallons per day
Water used=0 gallons per day
CITIZENS OF PLEASANTVILLE

You are extremely concerned about the severe water situation. You want quality drinking water from your tap at a reasonable price. You do not feel that the average community member wastes a considerable amount of water. After all, you already take showers from showerheads that trickle, you flush your toilet only when necessary, drive dirty cars since fines are imposed if you are caught washing your car, and water your plants with recycled bath water. What next? You'll have to wear the same clothes at least three times before washing them or stop brushing your teeth?

You understand that there is a water shortage, but do not understand why the townspeople must reduce water usage when farmers and ranchers are still using enormous quantities of water. You do not promote many tax increases and fines, but are willing to look at the proposals to see if they will affect the few water wasters there are. You have some questions you want answered: How does the sewage treatment plant operate? Why do farmers and ranchers use so much water? You are anxious to hear the comments of the other groups and will make a strong closing statement so that the average citizen will not be forgotten.

City removes 1,500,000 gallons per day from river
City returns 300,000 gallons per day through storm sewers
City sends 900,000 gallons per day to sewage treatment plant
City loses 300,000 gallons per day

SAVE THE WATER–ENVIRONMENTALIST GROUP

SAVE THE WATER is a national environmental organization that promotes the proper handling and usage of the planet's water. The group's major interest is to maintain and, in most cases, improve the natural waters and land that surround them. You know that the wetlands (marsh-like areas) are diminishing due to development and decreasing water quality. The wetlands are a cleansing mechanism for the water. Over the years, your group has sent spokespeople to federal and local meetings that are addressing local water issues. You are the spokespeople for this meeting and want to make darn sure that the community understands what they face if they do not resolve the water issue at hand--fines paid to the state will not save the planet that is being destroyed. You have a portfolio of beautiful pictures of water fowl, fish, water plants, etc. and many photos of desolate rivers and dead water fowl. You're going to try to have people act with emotion and sympathetic hearts so Clear River can be saved. You strongly support any type of water rate increase and think that the increase should go to improving water quality, water education for young people, and the formation of a natural waterway restoration project.

Water taken from the river=0 gallons per day
Water returned to the river=0 gallons per day
Water used=0 gallons per day

WATER COMMISSION

Your commission has been formed to deal with the severe water problem in Pleasantville. The state has provided a minimal amount of money so members of this commission can obtain the necessary information needed to make the best policies for the city. You are extremely concerned about how the final numbers will look. You know that 500,000 gallons more must be returned to the river than is currently being done. Your job is to create different possible solutions to the problem and pick the one that will best meet the needs of everyone involved. You are open to suggestions made by special interest groups and the public. You are looking forward to the time when it begins to rain, but also the time when the 500,000 gallons are returned to the river with acceptable chemical qualities.
DECISION, DECISIONS

As you know, the city of Pleasantville must make drastic cuts on water usage as well as improve the quality of water returned to the river. In the past, water has been relatively inexpensive and readily available. Times have changed. The state has required the city of Pleasantville to return an extra 500,000 gallons per day to the river so that the river will not get any lower than it is right now. This is required to control the salinity of the water and to provide optimum water quality.

Take a look at the map of Pleasantville. Notice how much water is removed from and returned to the river in different areas of the city. The water commission must take action this week and report to the state on how the town will reduce its water usage.

The Water Commission has been meeting regularly. The Pleasantville Gazette published 4 possible options the commission has preliminarily considered. Here are the statements that were published:

- Property taxes will increase $80 annually for two years ($40 every six months). Approximately $1,600,000 will be available to enlarge and improve the Pleasantville Sewage Treatment Plant. More water of a better quality will be returned to the river.

- Each family member will be allotted 120 gallons of water per day. This is a 20% cutback from the normal usage of 150 gallons per person per day. A 5 cents per gallon charge will be made to households which use more than their allotted amount of water. The money collected from this fee will be used to educate students about water conservation.

- The City Council and Water Commission approve of the construction of 50 more homes (approximately 200 people) on the southwest side of Clear River. This would be a “state of the art” water conserving community.

- All non-residential businesses will be billed according to how much water they do not return to the river and by how much water they return in below-standard quality. Industries will pay a $200 annual fee for water-monitoring devices. They will also pay 3 cents per gallon for water used above their allotted amount, which is not returned to the river or is of unacceptable quality.
Pleasantville Map

Town of Pleasantville
Removes 1,500,000 gal/day
Returns 300,000 gal/day
Sends 900,000 gal/day to sewage treatment plant
Uses 300,000 gal/day

Land Developer Owned but currently farmed
Removes 100,000 gal/day
Returns 80,000 gal/day
Uses 20,000 gal/day

Sewage Treatment Plant
Removes 0 gal/day
Returns 1,000,000 gal/day
Uses 0 gal/day

Farms
Remove 1,100,000 gal/day
Return 620,000 gal/day
Use 480,000 gal/day

River Raft and Fishing Company
Removes 0 gal/day
Returns 0 gal/day
Uses 0 gal/day

Port of Pleasantville
Removes 80,000 gal/day
Returns 80,000 gal/day
Uses 0 gal/day

Cattle Ranch
Removes 800,000 gal/day
Returns 600,000 gal/day
Uses 200,000 gal/day
PUBLIC HEARING ON
WATER QUALITY AND QUANTITY PROPOSALS FOR PLEASANTVILLE

1. Opening Statement - City manager (Teacher)

2. Commission Proposals
   a. Proposals published by commission in Pleasantville Gazette
   b. New Commission Proposals (authored by Water Commission members or special interest groups)

3. Citizen Testimony

4. Business/Industry Testimony

5. Other Testimony

6. Closing Statements (1 minute per group)

7. Questions by Commission

8. Conclusion and Vote - Commission Members
Public concern over nitrates in groundwater has the Salinas Valley considering solutions.

by Caroline Mufford

Nitrogen, as every farmer knows, is essential to food and fiber production (to say nothing of profits), yet it is also a potential source of environmental stress. In some cases this stress can increase under drought conditions. Minimizing its leakage from the crop root system by avoiding overloading the soil with nitrogen is the key to reducing the amounts of the substance moving to ground and surface waters. While nitrates in groundwater can hardly be described as a statewide problem, a California Department of Food and Agriculture (CDFA) Nitrate Working Group report warns, "Several regions of California have significantly higher levels of nitrate in groundwater." The report calls for the establishment of local management programs in areas with high levels of nitrate sensitivity.

"Whether it's food safety, or environmental hazards, farmers and ranchers in this state have a different burden than in other states—that of being a good neighbor," says Merlin Fagan, natural resources director for the California Farm Bureau. "If they don't move swiftly to solve it, others will."

While the Environmental Protection Agency (EPA) estimates that only a small percentage of wells tested have nitrate contamination above the federal health advisory level of 10 parts per million, more farmers are seeking reassurance that responsible production agriculture will not contaminate water. As a result, ConAgra Technologies, along with Neogen Corporation, has introduced Agri-Screen Nitrate test to allow individuals to determine the nitrate levels in their water. A simple kit is used to test drinking, well and surface water as well as water from field runoff or tile drainage. (For information on the test call 1-800-634-7571.)

Monterey County, the "salad bowl" of the nation, is one of several areas that illustrates the complexities of concerns and problems associated with nitrate pollution. The fields of celery, lettuce and other shallow-rooted vegetables dominate the landscape. High levels of nitrogen in the shallow-rooted vegetables increases the landscape nitrogen. Agriculture's visibility, growers and other community leaders say, makes it an easy target. Some public concerns are real and some overblown, but growers are realizing they must face them and find educational, political and agricultural solutions.

 Monterey County has the most nitrate-contaminated drinking water in California. Of monitored wells, 48 percent show unacceptable levels of nitrate contamination, according to Monterey County Water Resources Agency (MCWRA) figures.

Matt Zidar, senior county hydrologist, says, "We have the largest number of small water systems in the state." The agency projected in its June 1988 report, "Nitrate in Groundwater," that "Based on the trend of the last 10 years, the projected mean nitrate concentrations will exceed the drinking water standard of 10 mg/L in the year 2000 by 3 to 4 times in all unconfined aquifers." This projection is based on 90 comparison wells. The drought,

now in its fifth year, worsens contamination because of lack of "recharge" to aquifers, says Russ Jeffries, the mayor of Salinas. "It had not been for not having any rain for the last five years, personally I don't think we'd even be talking about nitrate contamination," says grower Sid Christiensen of Major Farms.

Controversy over nitrates in Monterey revolves around money, but the underlying issues involve much more, including public health, real estate development, cleanup of drinking water, assignment of liability and responsibility for costs and the well-being of local agriculture. For example, one local paper linked Monterey's high rate of birth-defect deaths (highest among California's 30 large counties) to nitrate pollution in groundwater.

On the Monterey Peninsula, a recent moratorium halted the drilling of new wells. The health department cites nitrate pollution as the reason, but growers consider it a no-growth ordinance in disguise. "If you know you have nitrate contamination on your property, there may be disclosure requirements before a property transfer," which could make properties unattractive to potential buyers. Zidar explains.

A major concern revolves around the imminent threat to the aquifer providing drinking water for Salinas, Monterey's largest city, with 106,000 residents. Jeffries says an aquifer on the valley's east side that is highly contaminated with nitrate is now migrating toward an aquifer feeding the city. "Most reports point fingers at growers, but there are several other points of nitrate contamination," Jeffries says.

Zidar adds that nitrates in groundwater are almost impossible to trace. If scientists find this kind of contamination underneath a 30-year-old feedlot, for instance, they can make "an educated guess" that the nitrates come from feedlot animal waste, but the complexities of soil and water moves—
Jacques Franco, CDFA nitrate management coordinator, says statewide oversight of this contamination is easier than it is for local agencies. However, he says, nitrate contamination exists as a localized problem, varying widely among areas within counties. "It's a touchy subject because you are dealing with liability, particularly at the local level," Franco says. "In Monterey I've seen all sorts of funky manipulations to sanitize reports. Everyday there is under tough pressure to come up with the kinds of answers the constituency is willing to accept." For instance, he says, Monterey County is caught in a squeeze between state and local pressures. "The state board has power to adjudicate a basin. They have threatened the board of supervisors to do that if they don't clean up the groundwater. Some people say 'let them do it.'"

The fertilizer industry has been pursuing nitrate management, according to Steve Beckley, executive vice-president of California Fertilizer Association. CFA helped set up a fertilizer sales tax to fund Franco's program through CDFA. "We want to make sure we (the fertilizer industry) are (not part of the problem)," Beckley says. Many factors contribute to nitrate contamination, and the complexities of Salinas Valley provide a good example. Backflow often gets lingered, but Jefferson, who serves on the nitrate committee, feels the issue is overblown. "Nitrate from wells is over-calculated as a problem in this county," he says. "No one injects more fertilizer than absolutely necessary." Christianson, who also is a member of the committee, agrees. "We're not going to put on any more fertilizer than we have to...Nobody in their right mind is going to run fertilizer down a well," UC Extension soils specialist Stuart Pettegrouse says geologic source leaching from irrigation water has been incorrectly ruled out in Salinas.

Photographic evidence from the Monterey area shows, in fact, that active greenhouse operations may be among the highest sources of nitrate contamination, according to Gerald Snow, water quality analyst with MCWRA. Greenhouses historically use three to four times the nitrate as comparable root crops—Snow says they flush excess nitrogen.

For example, the nitrate level in Quail Creek, along which a greenhouse is located, often runs up to 1,000-2,000 ppm.

Evidence also shows that long-running cattle feedlots may contribute high levels of nitrate. However, Snow contends, feedlots have improved their practices in recent years.

According to Snow, other nitrate "hot spots" in Monterey County include an agrichemical dealer with poor handling practices (the dealer has since improved), a barn where nitrates fertilizers were siphoned down a well, numerous former dairies in the county, and even septic tanks. Sandy soils, irrigation and organic matter in the soil also affect nitrogen movement levels.

Growers outside of Monterey County will not escape the issue, either. Although groundwater-nitrate problems, hence political pressures, vary tremendously among counties. In Fresno County, groundwater nitrate values have tested above the maximum contaminant level (MCL) for years. Last summer, Fresno Extension advisors Dan Munk and Pedro Illic found 10 (X) ppm of nitrates in a well supplying household drinking water on a small farm. However, Munk says, another farm two miles away, well water measured only 20-15 ppm. Small-farm and vegetable advisor Illic says farmers he works with tend to overfertilize. "The Valley has a serious problem with nitrate contamination," Illic says. Noting 60 years of continuous farming as a factor, "We all need to assume we contribute to the problem," he warns.
The "Nitrate Debate"--continued

Sources for rising nitrate levels in California aquifers include greater numbers of people generating more sewage, the mining of fossil fuels, greater industrial utilizes and greater amounts of nitrogen fertilizer and livestock. CDFA's Nitrate Working Group says in its February 1989 report, "Nitrate and Agriculture in California.

Nationwide concern over nitrates intersects other growing public concerns. Consumers want clean drinking water, local and federal governments seek to stop groundwater pollution, and everywhere than interests seem to be rubbing against use of agriculture.

"Historically," says Franco, "EPA has directed state water quality agencies toward point-source problems. Most of the forts have been put into these programs in the past 20 years. Nonpoint water sources are much more complicated, clinically and politically."

"Nitrate is ubiquitous in the environment," says Pettygrove, of UC Davis. "You can't trace it to a bag of fertilizer." According to the CDFA report, "Fertilizer applications, when associated with porous soils and excessive application of irrigation water or in areas with shallow water tables, have contributed to the increase in groundwater nitrate. Additionally, areas within the state which are vulnerable are those where multiple plants of high-nitrogen requiring, low-efficiency vegetable and truck crops are grown. The high nitrogen requirement and addition of up to three crops a year make the total nitrogen applied several times the normal application rate for most other systems."

Last year, Franco says, California initiated a "nonpoint source" nitrate unit in Sacramento, managed by Stan Martinson. "I think the pressure on nitrates is going to come," Franco says. On a federal level, the EPA released in November 1990 a five-year, $12 million study of drinking-water wells in the United States. EPA thus started an undoubtedly busy year of debate, as the 10-year-old Clean Water Act comes up for reauthorization this year. EPA found more than half the wells it tested were tainted with nitrate. But it found more nitrate above the MCL in fewer than 3 percent of wells. The American Farm Bureau states: "Farmers and Farm Bureau may be forced to defend themselves against headlines that talk about nitrate detections even though levels of 0-3 ppm nitrate-nitrogen are considered natural background levels. EPA did not say how many detections were in this natural range."

The Salinas Valley experience suggests growers can prepare for increasing pressure over nitrates by educating themselves as well as the public; by political organizing, particularly at local or county levels; and by a score of agricultural approaches. For education, the says Extension offices can guide growers to material, adding that new publications on nitrate are plentiful. For organizing, counties with high groundwater nitrate issues can consider the Salinas Valley report recommendations: "A cooperative effort among numerous agencies and groups will be required. These may include the District, the County Agricultural Commissioner's Office, agency interests, UC Extension Service, the Soil Conservation Service, Monterey County Environmental Health Department, the Central Coast Regional Water Quality Control Board, the State Water Resources Control Board, and the CDFA."

Such a group could institute programs to locate abandoned wells and ensure containment of polluted water, for example. It also could set up a program to educate farm workers on fertilizer handling practices.

The CDFA report from the Nitrate Working Group also suggests establishment of local management programs in areas with high levels of nitrate sensitivity. It calls for immediate reduction of significantly high levels in several regions of California, and recommends CDFA facilitate these five actions: Identify nitrate-sensible areas; list priority areas for nitrate control; set up nitrate management programs in these areas with local government and agriculture; develop best-management practices to incorporate in these local programs; and establish a research and demonstration project on nitrate control through irrigation, fertilizer, and manure management.

For agricultural approaches, "It's a different prescription for each soil and crop condition," Pettygrove says. Munk says one eggplant and tomato grower with high nitrate groundwater levels plans to forgo additional nitrate applications this year. Grower Jefferson says, "One of the most important things you can do is make sure your injection point for fertilizer is on the downstream side of your check valve." Monterey invites growers to begin with evaluation of their irrigation systems, since water use is integral to nitrate movement. The county has available a new mobile lab to offer free, no-obligation evaluations.

To growers who feel beleaguered over nitrates, Franco reminds them the same programs can be seen as environmentally motivated, "bottom-line enhancement. Energy savings, water savings and water quality--all these goals are aligned when you reduce water contamination from nitrate."
They’re worming their way into your yard

Worms are the wonder-workers of winter. They’re not merely the garden’s and the fisherman’s slippery squigglers. While we see a few after it rains or when we dig for bait, they’re generally out of sight.

These critters are composting kings! Give them some plant clippings, shredded newspaper and a bit of soil, and presto! Richer-than-rich soil. And they can do this in a corner of your kitchen or closet, neatly in their own box and without smell or noise, all winter long (they prefer temperatures between the mid 30s and mid 80s). Nothing simpler!

First, make a box: 3 feet by 1 foot by 2 feet deep is a good start for a family of four. For a larger box, move out longer and wider but not deeper. Deeper compostable bulk will heat up too much for the comfort of the worms. Make it of wood or other material that won’t let in light — worms like to work their magic in the dark.

For the worm bedding and mix, provide moistened material such as shredded newspaper, cardboard, pages of phone books, manure, leaf mold, peat, garden soil or compost (just a couple of handfuls), and kitchen scraps (no fats, oils or meat).

Mix it all up, and sprinkle so the paper collapses, but not till it’s soggy.

For the workers in this farm, choose redworms, red wiggler worms, red hybrid worms, California red worms, or regular old manure worms. These worms are specialized to do composting work. A 10-foot-square box should start with about 10,000 worms (to start working at top speed). Or, you can start with less (and wait a while for them to get to high-level production), since they multiply rapidly — doubling their numbers in a month or so.

Add more kitchen clippings (not fat or animal matter) as they’re available, chopped or ground in a blender so the pieces are small. Toss gently into the mix as you would a fragile-leaf salad — you don’t want to bang up the workers after all. Check ever day to make sure the mix is moist and cool to the touch. Happy workers are productive and procreative workers!

Within a few months, the bedding will have darkened and become five times richer than the most fertile soil. This mix, with its worm “castings” that look like dark coffee grounds, can be used to fertilize and condition garden soils and indoor potting mix. Casting tea can also be brewed into a tea and used as a liquid fertilizer. Not bad for some throwaways and garden freebies!

(YVONNE SAVIO is a UC master gardener, WOODY WATSON is a certified nurseryman and executive director of HUGS, an organization devoted to organic pest control and maintenance.)
What is Sustainable Agriculture?

University of California
Sustainable Agriculture Research and Education Program

Agriculture has changed dramatically, especially since the end of World War II. Food and fiber productivity soared due to new technologies, mechanization, increased chemical use, specialization and government policies that favored maximizing production. These changes allowed fewer farmers with reduced labor demands to produce the majority of the food and fiber in the U.S.

Although these changes have had many positive effects and reduced many risks in farming, there have also been significant costs. Prominent among these are topsoil depletion, groundwater contamination, the decline of family farms, continued neglect of the living and working conditions for farm laborers, increasing costs of production, and the disintegration of economic and social conditions in rural communities.

A growing movement has emerged during the past two decades to question the role of the agricultural establishment in promoting practices that contribute to these social problems. Today this movement for sustainable agriculture is garnering increasing support and acceptance within mainstream agriculture. Not only does sustainable agriculture address many environmental and social concerns, but it offers innovative and economically viable opportunities for growers, laborers, consumers, policymakers and many others in the entire food system.

This paper is an effort to identify the ideas, practices and policies that constitute our concept of sustainable agriculture. We do so for two reasons: 1) to clarify the research agenda and priorities of our program, and 2) to suggest to others practical steps that may be appropriate for them in moving toward sustainable agriculture. Because the concept of sustainable agriculture is still evolving, we intend the paper not as a definitive or final statement, but as an invitation to continue the dialogue.

Concept Themes

Sustainable agriculture integrates three main goals - environmental health, economic profitability, and social and economic equity. A variety of philosophies, policies and practices have contributed to these goals. People in many different capacities, from farmers to consumers, have shared this vision and contributed to it.

Despite the diversity of people and perspectives, the following themes commonly weave through definitions of sustainable agriculture.

Sustainability rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own needs. Therefore, stewardship of both natural and human resources is of prime importance. Stewardship of human resources includes consideration of social responsibilities such as working and living conditions of laborers, the needs of rural communities, and consumer health and safety both in the present and the future. Stewardship of land and natural resources involves maintaining or enhancing this vital resource base for the long term.

A systems perspective is essential to understanding sustainability. The system is envisioned in its broadest sense, from the individual farm, to the local ecosystem, and to communities affected by this farming system both locally and globally. An emphasis on the system allows a larger and more thorough view of the consequences of farming practices on both human communities and the environment. A systems approach gives us the tools to explore the interconnections between farming and other aspects of our environment.

A systems approach also implies interdisciplinary efforts in research and education. This requires not only the input of researchers from various disciplines, but also farmers, farmworkers, consumers, policymakers and others.

Making the transition to sustainable agriculture is a process. For farmers, the transition to sustainable agriculture normally requires a series of small, realistic steps. Family economics and personal goals influence how fast or how far participants can go in the transition. It is important to realize that each small decision can make a difference and contribute to advancing the entire system further on the "sustainable agriculture continuum." The key to moving forward is the will to take the next step.

Finally, it is important to point out that reacching toward the goal of sustainable agriculture is the responsibility of all participants in the system, including farmers, laborers, policymakers, researchers, retailers, and consumers. Each group has its own part to play, its own unique contribution to make toward the sustainable agriculture community.
The remainder of this document considers specific strategies for realizing these broad themes or goals. The strategies are grouped according to three separate though related areas of concern: Farming and Natural Resources, Plant and Animal Production Practices, and the Economic, Social and Political Context. They represent a range of potential ideas for individuals committed to interpreting the vision of sustainable agriculture within their own circumstances.

Farming and Natural Resources

Water. When the production of food and fiber degrades the natural resource base, the ability of future generations to produce and flourish decreases. The decline of ancient civilizations in Mesopotamia, the Mediterranean region, Pre-Columbian southwest U.S. and Central America is believed to have been strongly influenced by natural resource degradation from non-sustainable farming and forestry practices. Water is the principal resource that has helped agriculture and society to prosper, and it has been a major limiting factor when mismanaged.

Water supply and use. In California an extensive water storage and transfer system has been established which has allowed crop production to expand to very arid regions. In drought years, limited surface water supplies have prompted overdraft of groundwater and consequent intrusion of salt water, or permanent collapse of aquifers. Periodic droughts, some lasting up to 50 years, have occurred in California. Several steps should be taken to develop drought-resistant farming systems even in "normal" years, including both policy and management actions: 1) improving water conservation and storage measures, 2) providing incentives for selection of drought-tolerant crop species, 3) using reduced-volume irrigation systems, 4) managing crops to reduce water loss, or 5) not planting at all.

Water quality. The most important issues related to water quality involve salinization and contamination of ground and surface waters by pesticides, nitrates and selenium. Salinity has become a problem where water of even relatively low salt content is used on shallow soils in arid regions and/or where the water table is near the root zone of crops. Tile drainage can remove the water and salts, but the disposal of the salts and other contaminants may negatively affect the environment. Temporary solutions include the use of salt-tolerant crops, low-volume irrigation, and various management techniques to minimize the effects of salts on crops. In the long-term, some farmland may need to be removed from production or converted to other uses. Other uses include conversion of row crop land to production of drought-tolerant forages, the restoration of wildlife habitat or the use of agroforestry to minimize the impacts of salinity and high water tables. Pesticide and nitrate contamination of water can be reduced using many of the practices discussed later in the Plant & Animal Production Practices section.

Wildlife. Another way in which agriculture affects water resources is through the destruction of riparian habitats within watersheds. The conversion of wild habitat to agricultural land reduces fish and wildlife through erosion and sedimentation, the effects of pesticides, removal of riparian plants, and the diversion of water. The plant diversity in and around both riparian and agricultural areas should be maintained in order to support a diversity of plant and wildlife. This diversity will enhance natural ecosystems and could aid in agricultural pest management.

Energy. Modern agriculture is heavily dependent on non-renewable energy sources, especially petroleum. The continued use of these energy sources cannot be sustained indefinitely, yet to abruptly abandon our reliance on them would be economically catastrophic. However, a sudden cutoff in energy supply would be equally disruptive. In sustainable agricultural systems, there is reduced reliance on non-renewable energy sources and a substitution of renewable sources or labor to the extent that is economically feasible.

Air. Many agricultural activities affect air quality. These include smoke from agricultural burning; dust from tillage, traffic and harvest; pesticide drift from spraying; and nitrous oxide emissions from the use of nitrogen fertilizer. Options to improve air quality include incorporating crop residue into the soil, using appropriate levels of tillage, and planting wind breaks, cover crops or strips of native perennial grasses to reduce dust.

Soil. Soil erosion continues to be a serious threat to our continued ability to produce adequate food. Numerous practices have been developed to keep soil in place, which include reducing or eliminating tillage, managing irrigation to reduce runoff, and keeping the soil covered with plants or mulch. Enhancement of soil quality is discussed in the next section.

Plant Production Practices

Sustainable production practices involve a variety of approaches. Specific strategies must take into account topography, soil characteristics, climate, pests, local availability of inputs and the individual grower's goals. Despite the site-specific and individual nature of sustainable agriculture, several general principles can be applied to help growers select appropriate management practices:

- Selection of species and varieties that are well suited to the site and to conditions on the farm;
- Diversification of crops (including livestock) and cultural practices to enhance the biological and economic stability of the farm;
- Management of the soil to enhance and protect soil quality;
- Efficient and humane use of inputs; and
- Consideration of farmers' goals and lifestyle choices.
Selection of site, species and variety. Preventive strategies, adopted early, can reduce inputs and help establish a sustainable production system. When possible, pest-resistant crops should be selected which are tolerant of existing soil or site conditions. When site selection is an option, factors such as soil type and depth, previous crop history, and location (e.g. climate, topography) should be taken into account before planting.

Diversity. Diversified farms are usually more economically and ecologically resilient. While monoculture farming has advantages in terms of efficiency and ease of management, the loss of the crop in any one year could put a farm out of business and/or seriously disrupt the stability of a community dependent on that crop. By growing a variety of crops, farmers spread economic risk and are less susceptible to the radical price fluctuations associated with changes in supply and demand.

Properly managed, diversity can also buffer a farm in a biological sense. For example, in annual cropping systems, crop rotation can be used to suppress weeds, pathogens and insect pests. Also, cover crops can have stabilizing effects on the agroecosystem by holding soil and nutrients in place, conserving soil moisture with mowed or standing dead mulches, and by increasing the water infiltration rate and soil water holding capacity. Cover crops in orchards and vineyards can buffer the system against pest infestations by increasing beneficial arthropod populations and can therefore reduce the need for chemical inputs. Using a variety of cover crop is also important in order to protect against the failure of a particular species to grow and attract and sustain a wide range of beneficial arthropods.

Optimum diversity may be obtained by integrating both crops and livestock in the same farming operation. This was the common practice for centuries until the mid-1900s when technology, government policy and economics compelled farms to become more specialized. Mixed crop and livestock operations have several advantages. First, growing row crops only on more level land and pasture or forages on steeper slopes will reduce soil erosion. Second, pasture and forage crops in rotation enhance soil quality and reduce erosion; livestock manure in turn contributes to soil fertility. Third, livestock can buffer the negative impacts of low rainfall periods by consuming crop residue that in-plant only systems would have been considered crop failures. Finally, feeding and marketing are flexible in animal production systems. This can help cushion farmers against trade and price fluctuations and, in conjunction with cropping operations, make more efficient use of farm labor.

Soil management. A common philosophy among sustainable agriculture practitioners is that a "healthy" soil is a key component of sustainability; that is, a healthy soil will produce healthy crop plants that have optimum vigor and are less susceptible to pests. While many crops have key pests that attack even the healthiest of plants, proper soil, water and nutrient management can help prevent some pest problems brought on by crop stress or nutrient imbalance. Furthermore, crop management systems that impair soil quality often result in greater inputs of water, nutrients, pesticides, and/or energy for tillage to maintain yields.

In sustainable systems, the soil is viewed as a fragile and living medium that must be protected and nurtured to ensure its long-term productivity and stability. Methods to protect and enhance the productivity of the soil include using cover crops, compost and/or manures, reducing tillage, avoiding traffic on wet soils, and maintaining soil cover with plants and/or mulches. Conditions in most California soils (warm, irrigated, and tilled) do not favor the buildup of organic matter. Regular additions of organic matter or the use of cover crops can increase soil aggregate stability, soil tilth, and diversity of soil microbial life.

Efficiency of inputs. Many inputs and practices used by conventional farmers are also used in sustainable agriculture. Sustainable farmers, however, maximize reliance on natural, renewable, and on-farm inputs. Equally important are the environmental, social, and economic impacts of a particular strategy. Converting to sustainable practices does not mean simple input substitution. Frequently, it substitutes enhanced management and scientific knowledge for conventional inputs, especially chemical inputs that harm the environment on farms and in rural communities. The goal is to develop efficient, biological systems which do not need high levels of material inputs.

Growers frequently ask if synthetic chemicals are appropriate in a sustainable farming system. Sustainable approaches are those that are the least toxic and least energy intensive. and yet maintain productivity and profitability. Preventive strategies and other alternatives should be employed before using chemical inputs from any source. However, there may be situations where the use of synthetic chemicals would be more "sustainable" than a strictly nonchemical approach or an approach using toxic "organic" chemicals. For example, one grape grower switched from tillage to a few applications of a broad spectrum contact herbicide in the vine row. This approach may use less energy and may compact the soil less than numerous passes with a cultivator or mower.

Consideration of farmer goals and lifestyle choices. Management decisions should reflect not only environmental and broad social considerations, but also individual goals and lifestyle choices. For example, adoption of some technologies or practices that promise profitability may also require such intensive management that one's lifestyle actually deteriorates. Management decisions that promote sustainability, nourish the environment, the community and the individual.

Animal Production Practices

In the early part of this century, most farms integrated both crop and livestock operations. Indeed, the two were highly complementary both biologically and economically. The current picture has changed quite drastically since then. Crop and animal producers now
are still dependent on one another to some degree, but the integration now most commonly takes place at a higher level—between farmers, through intermediaries, rather than within the farm itself. This is the result of a trend toward separation and specialization of crop and animal production systems. Despite this trend, there are still many farmers, particularly in the Midwest and Northeastern U.S. that integrate crop and animal systems—either on dairy farms, or with range cattle, sheep or hog operations.

Even with the growing specialization of livestock and crop producers, many of the principles outlined in the crop production section apply to both groups. The actual management practices will, of course, be quite different. Some of the specific points that livestock producers need to address are listed below.

Management Planning. Including livestock in the farming system increases the complexity of biological and economic relationships. The mobility of the stock—daily feeding, health concerns, breeding operations, seasonal feed and forage sources, and complex marketing—are sources of this complexity. Therefore, a successful ranch plan should include enterprise calendars of operations, stock flows, forage flows, labor needs, herd production records and land use plans to give the manager control and a means of monitoring progress toward goals.

Animal Selection. The animal enterprise must be appropriate for the farm or ranch resources. Farming capabilities, and constraints such as feed and forage sources, landscape, climate and skill of the manager must be considered in selecting which animals to produce. For example, ruminant animals can be raised on a variety of feed sources including range and pasture, cultivated forage, cover crops, shrubs, weeds, and crop residues. There is a wide range of breeds available in each of the major ruminant species, i.e., cattle, sheep, and goats. Hardier breeds, that, in general, have lower growth and milk production potential, are better adapted to less favorable environments with sparse or highly seasonal forage growth.

Animal nutrition. Feed costs are the largest single variable cost in any livestock operation. While most of the feed may come from other enterprises on the ranch, some purchased feed is usually imported from off the farm. Feed costs can be kept to a minimum by monitoring animal condition and performance and understanding seasonal variations in feed and forage quality on the farm. Determining the optimal use of farm-generated by-products is an important challenge of diversified farming.

Reproduction. Use of quality germplasm to improve herd performance is another key to sustainability. In combination with good genetic stock, adapting the reproduction season to fit the climate and sources of feed and forage reduce health problems and feed costs.

Herd Health. Animal health greatly influences reproductive success and weight gains, two key aspects of successful livestock production. Unhealthy stock waste feed and require additional labor. A herd health program is critical to sustainable livestock production.

Grazing Management. Most adverse environmental impacts associated with grazing can be prevented or mitigated with proper grazing management. First, the number of stock per unit area (stocking rate) must be correct for the landscape and the forage sources. There will need to be compromises between the convenience of tilling large, un fenced fields and the fencing needs of livestock operations. Use of modern, temporary fencing may provide one practical solution to this dilemma. Second, the long term carrying capacity and the stocking rate must take into account short and long-term droughts. Especially in Mediterranean climates such as in California, properly managed grazing significantly reduces fire hazards by reducing fuel build-up in grasslands and brushlands. Finally, the manager must achieve sufficient control to reduce overuse in some areas while other areas go unused. Prolonged concentration of stock that results in permanent loss of vegetative cover on uplands or in riparian zones should be avoided. However, small scale loss of vegetative cover around water or feed troughs may be tolerated if surrounding vegetative cover is adequate.

Confined Livestock Production. Animal health and waste management are key issues in confined livestock operations. The moral and ethical debate taking place today regarding animal welfare is particularly intense for confined livestock production systems. The issues raised in this debate need to be addressed.

Confined Livestock production is increasingly a source of surface and ground water pollutants, particularly where there are large numbers of animals per unit area. Expensive waste management facilities are now a necessary cost of confined production systems. Waste is a problem of almost all operations and must be managed with respect to both the environment and the quality of life in nearby communities. Livestock production systems that disperse stock in pastures so the wastes are not concentrated and do not overwhelm natural nutrient cycling processes have become a subject of renewed interest.

The Economic, Social & Political Context

In addition to strategies for preserving natural resources and changing production practices, sustainable agriculture requires a commitment to changing public policies, economic institutions, and social values. Strategies for change must take into account the complex reciprocal and ever-changing relationship between agricultural production and the broader society.

The “food system” extends far beyond the farm and involves the interaction of individuals and institutions with contrasting and often competing goals including farmers, researchers, input suppliers, farmworkers, unions, farm advisors, processors, retailers, consumers, and policymakers. Relationship among these actors shift over time as new technologies spawn economic, social and political changes.
A wide diversity of strategies and approaches are necessary to create a more sustainable food system. These will range from specific and concentrated efforts to alter specific policies or practices, to the longer-term tasks of reforming key institutions, rethinking economic priorities, and challenging widely-held social values. Areas of concern where change is most needed include the following:

Food and agricultural policy. Existing federal, state and local government policies often impede the goals of sustainable agriculture. New policies are needed to simultaneously promote environmental health, economic profitability, and social and economic equity. For example, commodity and price support programs could be restructured to allow farmers to realize the full benefits of the productivity gains made possible through alternative practices. Tax and credit policies could be modified to encourage a diverse and decentralized system of family farms rather than corporate concentration and absentee ownership. Government and land grant university research policies could be modified to emphasize the development of sustainable alternatives. Marketing orders and cosmetic standards could be amended to encourage reduced pesticide use. Coalitions must be created to address these policy concerns at the local, regional, and national level.

Land use. Conversion of agricultural land to urban uses is a particular concern in California. As rapid growth and escalating land values threaten farming on prime soils. Existing farmland conversion patterns often discourage farmers from adopting sustainable practices and a long-term perspective on the value of land. At the same time, the close proximity of newly developed residential areas to farms is increasing the public demand for environmentally safe farming practices. Comprehensive new policies to protect prime soils and regulate development are needed, particularly in California's Central Valley. By helping farmers to adopt practices that reduce chemical use and conserve scarce resources, sustainable agriculture research and education can play a key role in building public support for agricultural land preservation. Educating land use planners and decision-makers about sustainable agriculture is an important priority.

Labor. In California, the conditions of agricultural labor are generally far below accepted social standards and legal protections in other forms of employment. Policies and programs are needed to address this problem, working toward socially just and safe employment that provides adequate wages, working conditions, health benefits, and chances for economic stability. The needs of migrant labor for year-around employment and adequate housing are a particularly crucial problem needing immediate attention. To be more sustainable over the long-term, labor must be acknowledged and supported by government policies, recognized as important constituents of land grant universities, and carefully considered when assessing the impacts of new technologies and practices.

Rural Community Development. Rural communities in California are currently characterized by economic and environmental deterioration. Many are among the poorest locations in the nation. The reasons for the decline are complex, but changes in farm structure have played a significant role. Sustainable agriculture presents an opportunity to rethink the importance of family farms and rural communities. Economic development policies are needed that encourage more diversified agricultural production on family farms as a foundation for healthy economies in rural communities. In combination with other strategies, sustainable agriculture practices and policies can help foster community institutions that meet employment, educational, health, cultural and spiritual needs.

Consumers and the Food System. Consumers can play a critical role in creating a sustainable food system. Through their purchases, they send strong messages to producers, retailers and others in the system about what they think is important. Food coat and nutritional quality have always influenced consumer choices. The challenge now is to find strategies that broaden consumer perspectives, so that environmental quality, resource use, and social equity issues are also considered in shopping decisions. At the same time, new policies and institutions must be created to enable producers using sustainable practices to market their goods to a wider public. Coalitions organized around improving the food system are one specific method of creating a dialogue among consumers, retailers, producers and others. These coalitions or other public forums can be important vehicles for clarifying issues, suggesting new policies, increasing mutual trust, and encouraging a long-term view of food production, distribution and consumption.

FOR MORE INFORMATION: contact the UCSustainable Agriculture Research and Education Program, University of California, Davis, CA 95616, (916) 752-7556.

Written by Gail Fecnsrra, Writer; Chuck Ingels, Perennial Cropping Systems Analyst; and David Campbell, Economic and Public Policy Analyst with contributions from David Chaney, Melvin R. George, Eric Bradford, the staff and advisory committees of the UC Sustainable Agriculture Research and Education Program.

December 17, 1991
EXTENSION ACTIVITY

WINOGRADSKY COLUMN

PURPOSE

The purpose of this activity is for students to observe changes that occur in a unique self-contained ecosystem.

MATERIALS

For the Class:
- Mud from marine or fresh water
- Clear plastic tube 2 inches in diameter x 30 inches tall (or a glass 1000 ml graduated cylinder)
- Shredded paper = cellulose, a carbohydrate source
- One teaspoon of plant fertilizer, a nitrogen and phosphorous source
- Iron nail or screw
- Fresh or marine water
- Plastic wrap
- Rubber band

PROCEDURE

1. Stuff one handful of shredded paper to bottom of the column.
2. Mix mud with an equal part of water.
3. Pour mud water mixture into column.
4. Add fertilizer and iron source into column.
5. Cover the column with the plastic wrap and secure with a rubber band.
6. Set the Winogradsky column in a spot where it will get some sunlight.
7. Observe the changes that occur over the next 6 months.

CONCLUSION

Ecosystems are ever-changing. They continue to function as long as the required nutrients are available in the proper forms.

VARIATION

1. Make 3 or 4 columns at the same time, but leave out a different component such as fertilizer or paper from the set up. Compare the standard set up to those with other variations.

(Reprinted with permission from Nancy Stevens, San Rafael High School, San Rafael, CA)
EXTENSION ACTIVITY

THINK ABOUT IT -- SOIL

Soil is more than just dirt. Pick up a handful of soil and imagine it is the earth’s surface. Right away, remove three-fourths of the handful and drop it back on the ground—that’s how much of the earth is covered by oceans, rivers, and lakes. What’s left represents the land. Now, drop one-half of the soil in your hand to account for the desert regions, glacial poles, and mountain peaks where many things won’t grow. Then drop one-tenth to account for the places where people live—where the land is used for big cities, towns, houses, schools, roads, and parking lots.

Now look. What’s left in your hand represents all the soil we have to support life on earth. This soil is trickling through our fingers at an alarming rate due to unchecked erosion. In fact, recent statistics indicate the U.S. is losing 6.4 billion tons of soil each year due to erosion. This amount of soil would fill 320 million dump trucks, which if parked end-to-end would extend to the moon and three-quarters of the way back. The eroding soil is washed into lakes and rivers and is blown into our air where it pollutes our environment. If we all knew a little bit more about soil, we could each do our part to help conserve this precious resource. Read on for some fascinating facts and conservation tips about soil.

- Soil makes up the outermost layer of our planet.
- Topsoil is the most productive soil layer. It has varying amounts of organic matter (living and dead organisms), minerals, and nutrients.
- Five tons of top soil spread over an acre is as thick as a dime.
- Natural processes can take 500 years to form one inch of top soil.
- Soil scientists have identified over 70,000 kinds of soil in the United States.
- Soil is formed from rocks and decaying plants and animals.
- An average soil sample is 45% minerals, 25% water, 25% air, and 5% organic matte-
- Different sized mineral particles, such as sand, silt, and clay, give soil texture.
- Lichens help break apart rocks to form soil.
- Fungi and bacteria help break down organic matter in the soil.
- Plant roots break up rocks, which become part of the new soil.
- Roots loosen the soil and allow oxygen to penetrate. This is beneficial to the animals living in the soil.
- Roots hold soil together and help prevent erosion.
- Five to ten tons of animal life can live in an acre of soil.
- Earthworms digest organic matter, recycle nutrients, and make the surface soil richer.
- One earthworm can digest 36 tons of soil in one year.
- Mice take seeds and other plant materials into their underground burrows, where this material eventually decays and becomes part of the soil.
- Mice, moles, and shrews dig burrows to help aerate the soil.

(Reprinted with permission from the National Wildlife Federation
8925 Leesburg, Pike Vienna, VA 22184; 1-(800) 432-6564)
EXTENSION ACTIVITY

COMPOSTING WITH A WIGGLE

What do earthworms eat? Why are they slimy? What good are they, anyway?

BACKGROUND

Worms play a crucial role in the breakdown of many organic wastes making them grand and vital participants in the natural decomposition and recycling processes. As their name suggests, earthworms live in soil. Some species live in the leaf litter on the soil surface, while others dwell several meters below. The term *vermicomposting* comes from the Latin *vermis* meaning worm; literally, vermicomposting means 'worm composting.'

PROCEDURE

Building the Bottle

1. Remove label from bottle using hot water or hair dryer. Peanut butter works well for removing stubborn glue remnants; use 1-2 teaspoons of peanut butter on a warm bottle and rub. (Some folks prefer chunky peanut butter for this task, believing that the chunks add to the success of the rub.)

2. Cut off the bottle top about 1 cm above the shoulder.

3. If your bottle has an attached base, cut down about three inches into the base - keeping it glued to the bottle - and continue cutting around its circumference until you remove the three inch portion. This cut makes more of the column visible. Be sure not to cut into the base bottom - if you do this, the column will have stability problems.

4. Melt four 0.5 cm holes with a large, hot nail in a ring around the base for drainage. These holes should be placed low enough on the bottle so excess liquid can drain out of the column.

5. Melt one or two rows of six to ten 3.0 mm holes (using a smaller hot nail) around the bottle to provide necessary aeration.

6. Use the second bottle base as a lid for the column.
Constructing a screen

Worms are creatures of the dark and will avoid light. Keep them happy and in the dark by constructing a paper screen:

1. Cut a piece of dark paper about 4 cm taller than the finished bottle and wide enough to encircle the entire column.

2. Tape the paper around the column, keeping it loose so you can remove the screen easily.

Preparing the bedding

Many types of bedding can be used: shredded leaves, peat moss, or straw. We use newsprint—it is clean and readily available—but don’t let this keep you from experimenting with your own bedding mixture:

1. Cut 8-10 pages of newsprint into 0.25-0.75 cm strips using shears or a guillotine straight blade paper cutter. Cut these strips in half.

2. Toss the bedding like a fresh green salad. This is important because if the strips are not separated they will clump together when you moisten them.

3. Worms breathe through their skin and to do this they need to be wet. Keep their bedding moist to accommodate this transfer of oxygen through their skin. This explains why earthworms are slimy! Moisten the bedding in a bowl or bucket using 2-3 cups of water, adding more water if necessary. Knead the water into the paper until it is saturated. Then drain the bedding well by gently squeezing out excess water. Re-toss the bedding vigorously.

4. Mix a few tablespoons of soil into the bedding. This inoculates the bedding with natural soil microorganisms which hasten breakdown and improve the quality of bedding.

5. Fill bottle 2/3 with the moist (but fluffy!) bedding.

6. Worms prefer a near neutral or slightly basic pH: 6.5-8.5. Mix some powdered lawn lime or finely crushed eggshells into the bedding if a litmus paper test indicates that your column is too acidic.

7. Although worms are physically tough, the temperature of your column should stay within 20-25 degrees Celsius. If the temperature rises above 35 degrees Celsius, your worms will cook!

Note: Although worms survive well in bottles, five gallon buckets (and other large containers) often work better. In a bucket, you can maintain a larger worm colony for a longer period of time. Simply follow the bottle, bedding and feeding procedures, adjusting quantities accordingly. Institutional food buckets are perfect for this construction: check your school cafeteria. A couple bucket pointers:

- Use a hand-drill for the drainage and aeration holes: make these holes about 1 cm in diameter.
- Fill the bucket only a little over half full with bedding.
- Make sure to keep the lid on the bucket at all times.
Feeding your worms

Worms cannot live on newsprint alone, though this might make an interesting experiment!

Add organic food every 3 to 4 days for as long as you have the worms; any sort of plant material works, from kitchen wastes to leaves. Worms feed by sucking or pumping material into their bodies with a muscular pharynx, so the food should be moist and in small (1-2 cm) pieces.

Feel free to add other foods besides plant matter: worms will eat pasta, pizza crusts, paper, coffee grounds, etc. Meat, however, is a problem since it will spoil. Also, according to some worm vermicomposting experts, lawn clippings can create a strong odor. Used sparingly, your worms should have no problems with an occasional snack of grass!

A rule of thumb: worms need 2 or 3 times their mass of food every few days. Place food directly on the bedding and then cover with about 1-2 cm of moist bedding.

Maintaining the experiment

Simply follow the above guidelines to keep the worms alive. Then, just let them do their thing! Keep them dark. Keep them cool. Keep them moist, but be careful about how much water you add—not too much, not too little. Follow your nose. If things smell too nasty, something may be wrong. All of these procedures can be tested and revised: use your own judgement and creativity!

(Reprinted with permission from the Bottle Biology Project: Madison, Wisconsin)
EXTENSION ACTIVITY

OUTDOOR COMPOST BIN

PROCEDURE

There are many ways to make compost. You can purchase a ready-made compost bin or make one of your own. You can use any type of fencing materials that can be wrapped to form a cylinder that is 3-4 feet in diameter and about 3-4 feet high.

A more complex compost bin is illustrated below.

Here are some important things to remember about making compost.

- Begin your compost pile with layers of twigs or brush for aeration.
- After adding about 1 foot of organic matter, add 1-2 inches of soil and 1 cup of 10-10 or 8-8-8 fertilizer.
- Allow air to get into the pile so the micro-organisms can breath. Mix the compost pile about once a week.
- Layer the pile with a variety of things so that the compost will contain a variety of nutrients. A pile of lawn clippings will not become organic matter very quickly unless other things are added to it.
- Do not add meat scraps to the bin except in very small quantities.
- Do not add much kitchen waste, meat scraps or lawn clippings at one time. The pile will tend to get smelly. You might add a layer of cat litter or alfalfa meal to the pile every once in a while to reduce the odor. Compost bins really should not smell if piled appropriately.
- Keep a well-like depression on top of the pile so that rainwater can collect. If you do not get rain frequently, water your compost periodically.
- Experiment with composting to see how you can make the best for your garden or field.
Composting is based on the biological process of decomposition. What turns plants and animals into compost? Microscopic bacteria and fungi, which feed on dead tissue, are the chief agents.

What affects the composting process? The amount of moisture and air, temperature, light, sources of bacteria and fungi, and the nature of the decomposing material are all critical. The presence or absence of air (oxygen) is one of the most important factors in composting. The practice of composting allows air and moisture to speed the natural process of biodegradation. Making a compost column lets you see and experiment with this process and witness nature’s world of recycling.

Materials Needed

- Three 2-liter plastic beverage bottles
- Hot tap water, knife or razor blade, scissors, marking pen, sharp needles for poking holes, clear tape, netting or mesh fabric, rubber bands.
- Organic materials for composting, such as kitchen scraps, leaves, newspapers, animal manure, and grass clippings.

Procedure

Remove the bases from two bottles, and the labels from all three by pouring about two cups of hot tap water into the bottles. (Columns can also be made from bottles that don’t have removable bases.) Replace the cap, tilt the bottle so the water softens the heat-sensitive glue, peel off the label and twist off the base. Pour out the water, draw cutting lines around the bottle, make incisions with the knife and cut with scissors and assemble as illustrated.

Most columns will require air holes for ventilation; these can be poked into the plastic with a sharp cold needle or with a needle or paper clip heated in a candle flame. Alternatively, larger holes can be cut into the sides with the knife and covered with the fine mesh fabric held in place with tape. A piece of mesh fabric over the lower end allows for drainage. Refer to the illustrations. Add ingredients for composting through the top of the column.
Explorations:

The possibilities for compost column explorations and discoveries are endless: There is no limit to what can be put inside, or the conditions under which the column can be kept. In addition to simply observing changes, you can design experiments which explore the effects of variables on your column.

Compost Column Construction

TWO POSSIBLE EXPLORATIONS

- **Leaf Digester**
  Make two columns, and use a balance or postal scale to weigh out two equal quantities of leaves. Loosely pack one column with leaves only. Mix about a half cup of garden soil to the other batch of leaves and loosely pack the second column. Pour equal amounts of pond or rainwater into each column, and wait several hours for it to percolate through. If none comes out the bottom, add more in equal amounts until about a half cup drips into the reservoir. Schedule a rainstorm to occur in the column every few days, pouring the drippings back through the column. Which column decomposes faster and why?

- **Compost Tea**
  Compost columns can be used to generate a liquid fertilizer called “compost tea.” Try making several columns using different ingredients, whose drippings will differ in color and chemistry. Use this liquid to water and fertilize identical sets of seedlings to see how different brands of “tea” affect plant growth. Some drippings, such as those from a column filled with leaves from a black walnut tree, may even inhibit growth.

(Reprinted with permission from Bottle Biology Project; Madison Wisconsin)
ANSWERS TO COMMONLY ASKED QUESTIONS

*What is botany?*
Botany is the study of plants. There are many different careers available to people who enjoy working with plants. Plant lovers can enjoy careers as nursery workers, gardeners, farmers or landscape designers. Specialized studies are also available in areas such as plant anatomy, plant history, fertilizer manufacturing, pest management, genetic engineering, natural plant preservation, etc.

*Why has composting become so popular?*
Composting is a mixture of decayed organic matter. With an increase in public concern over environmental issues such as overflowing landfills, increasing human population, decreasing soil and water quality and the reduction of fossil fuels, humans have looked for ways to reduce the amount of natural resources used and to reuse and recycle the materials that are available. Composting allows farmers and the public to take the organic wastes such as kitchen scraps and lawn clippings and turn them into organic matter that can be used to fertilize plants. Composting not only provides plants with nutrients but also improves soil quality. Adding organic matter to the soil increases the amount of air available to plant roots and improves the soil’s ability to absorb water. Composting also kills weed seeds that are not destroyed by the tilling of the soil or animal digestion.

*Why do plants die if they get too much water?*
Plants require energy to grow. Using light, plants are able to take water and carbon dioxide, a gas from the atmosphere, and make food for themselves. After the food is produced, plants must convert that food into energy for growth-this process is called respiration and requires oxygen. Respiration only occurs in the dark and must occur constantly. Normally, respiration occurs in the roots of plants since plant roots are in dark soil. Under normal conditions, air including oxygen is available to plant roots so respiration can occur. If the soil is too wet there is not enough oxygen available to the plants. Therefore, the plants cannot respire and will die. This is similar to why animals die from a lack oxygen.

*Why do plants need fertilizer?*
Just like humans, plants require certain nutrients for survival. These nutrients are used to build different plant components. For example, carbon, hydrogen and oxygen are used to build plant foods of sugars and starches; nitrogen is needed to make chlorophyll and plant proteins. It is believed that plants require 16 chemical elements. If the necessary elements are available to the plants, fertilizers do not need to be added to soils. It is when nutrients are thought to be lacking that fertilizers are added. Fertilizers can be natural such as manures and composts or processed such as store-bought concentrated fertilizers.

*What do the three numbers mean on a fertilizer label?*
The three numbers on a fertilizer label stand for the percentages of nitrogen, phosphorus and potassium in that particular fertilizer. These three elements are the major nutrients required by plants for growth and reproduction. For standardization, nitrogen is always listed first, followed by phosphorus and then potassium. When buying a fertilizer, one should consider the nutrients their plants need and buy a fertilizer high in the required nutrients.

*Why do some fertilizers require people to wear protective clothing such as masks or gloves?*
Most commercial fertilizers are more concentrated than natural manures and composts. They are also applied in salt form. Large quantities of salt draw water out from cells and cause them to dehydrate. This can cause irritation to skin cells, eyes and lungs. For most household fertilizers, rinsing exposed areas with generous amounts of water will prevent damage. However, it is always better to be cautious when applying chemicals of any type.
**Why do plants die if they get too much fertilizer?**
Most fertilizers are applied as salts. Any type of salt is water-loving—it attracts water. Fertilizers draw water from plant cells. If too much fertilizer is applied to a plant, the plant cells dehydrate and become brittle and sometimes discolored. This is called burning plants. The plants are not actually on fire, they just do not contain any water.

**Why do plants grow towards the light?**
Plants are phototropic. They are attracted to light because they need it for energy. The process that causes plants to grow towards the light is very interesting. All plants have a growth hormone, auxin, that only functions in the dark. Imagine a plant in a window—the stem has a sunny side (the side facing the window) and a shady side (the side not facing the sun). Since the hormone only functions in the shade, the shady side of the plant cells elongate. The shady side of the plant grows faster than the sunny side of the plant; thus causing the plant to lean over and face the sun.

**In what ways do manures benefit plant growth?**
Manures are animal excrements. Manures contain nutrients that can be used by plants as well as organic matter that improves soil texture. Plants must not only have nutrients but must also grow in soil that has good aeration and can hold water. Animal manures vary in nutrient composition depending on the type of animal and the diet of the animal.

**How are fertilizers made?**
Fertilizers can be “natural” or ‘man-made.’ Natural fertilizers are substances such as manures and composts. Nitrogen can be made available to plants by the natural process of nitrification, where bacteria convert atmospheric nitrogen to nitrogen that can be used by plants. Many fertilizers are manufactured in factories using materials from the earth and atmosphere. Atmospheric nitrogen, nitrogen from the air, can be converted to ammonia or nitrates through a complex factory process. Phosphorus is usually made into fertilizer by mining phosphate rock and combining it with sulfuric acid (which comes from fossil fuels). Potassium often is obtained from salt deposits throughout the world like those of the Great Salt Lake in Utah.

**What is hydroponics?**
Hydroponics is a process in which plants, normally grown in soil, are grown in water. This is possible when the required nutrients are available in the water and the plants have some sort of support system to hold them up. The science of hydroponics is growing, but is not seen as an immediate solution in solving the world hunger problem.

**Why does manure smell?**
Bacteria and other organisms decompose manure converting it to organic matter. During this process the bacteria release different gases as their waste products. Some of these gases smell. Ammonia substances are commonly given off as bacterial decomposition by-products. Another interesting fact about smell, is that the more smell that is given off, the less efficient the bacteria are in decomposing matter—the ammonia is released into the atmosphere rather than converted into the organic matter that can be used by plants.

**Why do plants yellow if they do not have enough nutrients?**
Yellowing is a sign of an unhealthy plant. There are many causes of yellowing but, generally, it means that the process of chlorophyll formation is interrupted. Chlorophyll is the green substance in plants that is able to absorb energy from the sun and is used to convert carbon dioxide and water into sugars and starches. The main chemical formula for chlorophyll is C_{55}H_{70}O_{6}N_{4}Mg. As the chemical formula illustrates, certain elements are needed to build the molecule. Other elements such as iron, are needed as catalysts to help form chlorophyll molecules. If the required nutrients are not available, chlorophyll cannot be produced and the plant turns yellow and eventually dies.
EDUCATIONAL RESOURCES

AIMS activity books, AIMS Education Foundation; P.O. Box 7766, Fresno, CA 93747.

These books contain hands-on activities that integrate math and science and contain wonderful graphics and ideas for grades K-8. Request a current catalogue.

"Biotechnology-- On the Cutting Edge," Hawkhill Associates, Inc.; 125 East Gilman St., P.O. Box 1029, Madison, WI 53701-1029.

A video interview with Richard Burgess, a biotechnology expert. Many current issues about the use of biotechnology are discussed.


This easy to read book for all ages provides interesting facts about plants as well as many hands-on ideas that teach general botany concepts.

“Bottle Biology,” Bottle Biology Program; University of Wisconsin-Madison, Department of Plant Pathology, 1630 Linden Drive, Madison, WI 53706; (608) 2635645.

Bottle Biology is an inexpensive, motivating way to teach hands-on biology using one and two liter plastic bottles. Sign up to be put on their mailing list for newsletters.

California Fertilizer Association’s Lending Library of Motion Pictures, 1700 I Street, Suite 130, Sacramento, CA 95814. (916) 441-1584.

A variety of videos and slides discussing fertilizer use and water quality are available.

Chemical Education for Public Understanding Program, Lawrence Hall of Science, University of California, Berkeley (510) 642-8718

This program has a variety of hands-on lessons that relate chemistry to the real world.

Conservina Soil, National Association of Conservation Districts Service Department; P.O. Box 855, Dept. SCS, League City, Texas 77573: (916) 324-0864.

24 activity masters, four color transparencies, and teacher guide about soil history and uses. (Middle-Secondary) approximately $8.50.

“Fast Plants,” University of Wisconsin-Madison; Department of Plant Pathology-Fast Plants, 1630 Linden Drive, Madison, Wisconsin 53706; (608) 263-2634.

Rapid growing plants with many activities are available through this university. Ask to be put on their mailing list. “Fast Plants” can be ordered through Carolina Biological Supply at (800)- 334-5551.
“Field’s Of Gold” Video, California Foundation for Agriculture in the Classroom; 1601 Exposition Boulevard, Sacramento, CA 95815; (916) 924-4380.

This 28 minute historical video shows the relationships of agriculture with California history. $15.

The Growina Classroom, Roberta Jaffe and Gary Appel; Addison-Wesley Publishing Company, Jacob Way, Reading, MA 01867; (800) 447-2226.

This activity-packed teacher sourcebook makes elementary science and nutrition education an unforgettable experience for students as they experiment with indoor and outdoor gardens. (K-6) $27.00.

Growing Seeds, Growing Minds, Kathryn B. Donald; California Association of Nurserymen, 4620 Northgate Boulevard, Suite 155, Sacramento, CA 95834. (916) 567-0200.

Hands-on horticultural activities and experiments that assist K-6 students in learning scientific process skills.


112 easy to use and interesting activities. Includes simple lessons on solid-waste management, fat content in foods, earthworm farms, etc.

Living Lightly On The Planet, Maura O’Connor: Schlitz Audobon Center, 111 East Brown Deer Road, Milwaukee, WI 53217.

Two series of hands-n lessons are available to educators who want to incorporate environmental education into their science classrooms. Adaptable to many grade levels.

The No Waste Anthology, California Department of Health Services Toxic Substances Control Program; P.O. Box 942732, Sacramento, CA 94234-7320. (916) 322-0476.

A compilation of environmental education activities for grades K-12 to assist educators in implementing the Environmental Education Framework.

Project Wild, Western. Regional Environmental Education Council and Western Association of Fish and Wildlife Agencies: Salina Star Route, Boulder, Colorado 80302. (303) 444-2390.

This is an interdisciplinary, supplementary environmental and conservation K-12 education program emphasizing wildlife.
BACKGROUND REFERENCES

“Ag Alert-A Weekly Newspaper on California Agriculture,” California Farm Bureau Federation.

Available to Farm Bureau members, this weekly newspaper provides readers with articles on current issues in agriculture. Contact your local county Farm Bureau to order this publication.

Agriculture and Fertilizers, Oluf Chr. Bockman; Norsk Hydro, 1990.

This book provides readers with different perspectives about fertilizers and fertilizer use as well as detailed fertilizer science facts. Contact the California Foundation for Agriculture in the Classroom, (916) 924-4380, for information on how to order this book.


This yearbook examines environmental concerns facing agriculture, and indicates what the United States Department of Agriculture (USDA) is doing to address these concerns. This publication is made available by your local congressmen or can be ordered from the U.S. Government Printing Office.


This high school agriscience textbook presents general information taught in introductory high school agricultural science classes. It is a great reference to have for student research and teacher background information.


This report examines, in detail, the science and economic viability of alternative agricultural systems such as crop rotation and biological pest control so that many challenges facing agriculture today can be overcome. To order this book, call 1-800-624-6242.

California Farmer, Farm Progress Companies, Inc.

This colorful monthly magazine contains articles on current agricultural issues as well as editorials, classified ads, weather information and more. Write to P.O. Box 11375, Des Moines, IA 50340-1375 for subscription information.


This pamphlet provides detailed information about water contamination, especially groundwater, drinking water and nitrate contamination. To request a class set of these pamphlets, contact Amy Jo Matthews at The Fertilizer Institute, 501 Second Street NE, Washington D.C. 20002.

This pamphlet provides factual information on fertilizers and specifically addresses many of the perceptions associated with fertilizer use. For ordering information, write to The Fertilizer Institute, 501 Second Street NE, Washington D.C. 20002.

A Glossary of Farm Terms, United States Department of Agriculture; 1983.

This booklet provides definitions to hundreds of agricultural terms. This is a great reference to have available to students during reading or writing assignments. Order from Ag in the Classroom, USDA, Rm 318-A, Administration Building, Washington, D.C. 20250.

"Improving Plant Production for Human Health and Environmental Quality" Handbooks, Potash and Phosphate Institute.

Five different comic book-type, easy to understand pamphlets provide the reader with information on various plant nutrients such as nitrogen, potassium and phosphorus. To order these booklets, write to PPI, Suite 410, 2801 Buford Hwy, NE, Atlanta, Georgia 30329.


This college environmental science textbook contains thorough, yet easy to understand, information about various factors that affect the environment. It also contains many short articles written by key authors that encourage the students to think of all sides of issues before making decisions.


This booklet describes soil organic matter and discusses a variety of organic soil amendments such as manures, composts, sewage sludge, and marine products. Call (510) 642-2431 for ordering information.


This document provides suggested guidelines for science education throughout California. All science educators should have a copy of the framework available to them. Themes and concepts are outlined, as well as guidelines on classroom management and teaching skills. Write to the Bureau of Publications, Sales Unit, California Department of Education, P.O. Box 271, Sacramento, CA 95802-0271 for order information.


This easy-to-use gardening book, written for gardeners of the western United States, provides general information on soils, pest control, planting techniques, and fertilizing and problem solving tips and plant selection guides. Available at most bookstores; this is a must for your student and teacher reference library.

This beautifully illustrated book provides an overview of American agriculture in commemoration of Columbus' voyage to the New World.


This manual, written for farm advisors, provides basic agronomy concepts in an easy to understand manner. Soil components, fertilizers, and plant nutrient requirements are some of the key points discussed in this booklet.


This college-level soil science book provides detailed information on introductory soil science.

**Western Fertilizer Handbook,** Soil Improvement Committee and the California Fertilizer Association; The Interstate Printers and Publishers, Inc., 1990.

This well-organized book provides information on the nutrient requirements of plants and nutrient management strategies. Contact the California Fertilizer Association at (916) 441-1584 for ordering information. This should definitely be part of your reference library for use by teachers and students.
USEFUL ORGANIZATIONS AND COMPANIES

Ag Access
603 4th Street
Davis, CA 95616
(916) 756-7177

This bookstore specializes in agricultural information. Knowledgeable personnel can help you find the resource books you need. Write or call for a free catalog.

California Association of Resource Conservation Districts
3830 "U" Street
Sacramento, CA 95817
(916) 639-6251

This organization has many soil science activities for all grade levels, including a popular comic book titled “Amazing Soil Stories.”

California Fertilizer Association
1700 1 Street, Suite 130
Sacramento, CA 95814
(916) 441-1584

This association has various videos and pamphlets on general and technical information of fertilizer manufacturing, application, safety, and more!

California Foundation for Agriculture In the Classroom
1601 Exposition Blvd. FB 16
Sacramento, CA 95815
(916) 924-4380

The Foundation has a wealth of materials for educators, including a teacher resource guide that provides information on how to order free or low cost materials for the classroom that promote agricultural information. Educator workshops and conferences on integrating agriculture into the classroom occur several times a year. Be sure to get on the mailing list!

Delmar Publishers, Inc.
2 Computer Drive West, Box 15-015
Albany, New York 12212-5105

This company publishes a variety of agriculturally-related science books.

The Fertilizer Institute
501 Second Street, NE
Washington D.C. 20002

This association has various videos and pamphlets on general and technical information of fertilizer manufacturing, application, safety, and more!
Lab-Aids
17 Colt court
Ronkonkoma, New York 11779
(516) 737-1 133

This company has for purchase, a variety of science kits for student use, as well as inexpensive "chemtrays."

NASCO West
1524 Princeton Avenue
Modesto, CA 95352-3837
(800) 558-9595

This company has classroom science and agricultural science educational supplies available for purchase. Request their science and/or agricultural sciences catalogs.

Potash and Phosphate Institute
Suite 401
Atlanta, GA 30329

This organization has colorful, easy to read booklets on potassium, phosphorus, nitrogen and other plant nutrients. Write for a list of other materials they have available.

University of California, Cooperative Extension

Cooperative extensions provide the public with general and technical information on various topics, including agricultural information. The Master Gardeners, Future Farmers of America (FFA) and 4-H programs are usually obtainable through this office. A pamphlet on current publications available from the U.C. Cooperative Extension is also available. Check your local phone book for your county’s U.C. Cooperative Extension phone number and address.

University of California Sustainable Agricultural Research and Education Program
University of California
Davis, CA 95616
(916) 752-7556

This department can answer specific questions you have about sustainable agriculture and current farming and gardening practices that are designed to enhance the environment.
GLOSSARY

Amendment--any material added to soil to make it more productive; usually used for materials added other than fertilizers such as lime or gypsum but a fertilizer is an amendment.

Boron--an essential plant nutrient that aids in cell division, protein synthesis, and cell differentiation at growing points as well as regulates carbohydrate metabolism.

Calcium--an essential plant nutrient; it stimulates root growth, strengthens cell walls, assists in the absorption of potassium and other ions, and is essential in the formation of new cells.

Carbon Dioxide (CO₂)--a gas in the air used by plants to make their own food.

Cell--the basic unit of life; usually contain nuclei, mitochondria, ribosomes, cytoplasm, endoplasmic reticulum, etc.

Chlorophyll--the green-colored substance in plants that absorbs energy from sunlight.

Component--a part of something; soil components make up soil.

Compost--a mixture made of decaying organic material; it is used to fertilize plants and amend soils.

Copper--an essential plant nutrient; aids in plant respiration, helps plants resist certain diseases, activates certain enzymes and helps produce vitamin A.

Cotyledon--the part of the seed that stores food for the young plant.

Crop rotation--the successive planting of different crops in the same field over a period of years to maintain or improve soil quality.

Decomposition--to break down into organic matter; this process performed by bacteria, fungi, nematodes, earthworms, etc.

Deficiency--a substance that is lacking.

Embryo--the tiny plant within the seed.

Emulsion--a solution where one substance is mixed in with another.

Fertilizer--any substance added to soil or water to increase the nutrients available to plants.

Fibrous root--a root consisting of a mass of roots rather than one main root.

Flower--the part of a plant that contains reproductive parts and attracts pollinators.

Fruit--the part of the plant that holds seeds.

Germination--the swelling and first growth of seeds.

Green manure--vegetation that is plowed into the field to improve soil composition and quality; normally a legume such as beans or alfalfa.

Inoculate--to introduce bacteria or other substances to a particular location on purpose.
Iron--an essential plant nutrient required for the formation of chlorophyll, protein synthesis and respiration

Leaf--the flat part of the plant where photosynthesis occurs

Legume--normally a plant that has pods whose seeds split into two; often helps with nitrogen fixation; examples include beans and alfalfa

Magnesium--an essential plant nutrient required to make chlorophyll and also activates enzymes required for growth

Manganese--an essential plant nutrient required for chlorophyll formation: accelerates growth and improves plant quality

Manure--solid animal waste products; can contain some straw or other animal bedding material

Molecule--any two or more atoms attached together

Mutualism--a symbiotic relationship where both living organisms benefit

Nitrogen--an element that naturally exists in air and is needed by plants to produce, among other things, proteins, chlorophyll, DNA, and RNA

Nitrogen-fixation--the transformation of atmospheric nitrogen (N2) into forms available for plant growth (N02, NO3 and NH3); often performed by a bacterium, Rhizobium

Nodule--a little knot or bump found in roots of plants; normally filled with a bacterium, Rhizobium, that performs nitrogen-fixation

Nutrient, plant--any element taken in by a plant which is essential to its growth

Organic Matter--material in soil made from the decomposition of plants or animals; it increases the soil's ability to hold water and air

Oxygen (02)--a gas in the air used by humans in respiration; it is also used by plants to convert sugars and starches to usable energy

Phosphorus--an element required by all plants that promotes root growth

Photosynthesis--the process in which sugars and starches are made from carbon dioxide, water and the use of sunlight

Plumule--the baby leaves of a seed that will grow into true leaves

Potassium--an element required by all plants for carbohydrate production and the hardening of tissues such as tree trunks; it also regulates the opening and closing of stomates and improves fruiting

Respiration--the process where sugars, starches, and other substances are converted into usable energy for growth and reproduction; all living cells respire

Root Hairs--tiny hair-like structures that are on the ends of roots and aide in nutrient and water absorption; they increase the surface area of root systems
Rudimentary Root--the young root of a plant embryo

Saline--another word for salt

Salt-a product of an acid reacting with a base; table salt, sodium chloride, is only one type of salt

Seed--the small object that will develop into another plant; usually surrounded by a fruit

Soil--the top portion of the earth’s surface that is used to grow plants; consists of organic and inorganic substances

Solution--one or more substances dissolved in one another; generally made of substances too small to be seen by the unaided eye

Stem--the part of the plant that supports the upper part of the plants and transports nutrients and water through xylem and phloem tubules

Stomate--an opening, normally on the underside of leaves, that allows gases such as carbon dioxide to enter or leave the cell

Sulfur--an essential plant nutrient required to make certain amino acids that build proteins: promotes growth of beneficial bacteria

Supplement--to add to something

Tap root--a root with one main root that extends deep into the soil

Urea [(NH2)2CO]--a widely used nitrogen fertilizer that is also a supplement in rudimentary animal feed; generally formed by the combination of ammonia and carbon dioxide

Weathering--the breaking down of rock into smaller particles: can occur by wind, water, plant roots, or chemical processes

Zinc--an essential plant nutrient required for plant hormone production: it activates certain enzymes
FOOTNOTES

The chapters and page numbers refer to the 1990 Science Framework for California Public Schools.

1  (Chapter 4 B-4, p. 97)
2  (Chapter 5 C-4, p. 142)
3  (Chapter 4 B-4, p. 98)
4  (Chapter 4 B-4, pp. 97-98)
5  (Chapter 4 B-4, p. 97; Chapter 5 A-4, p. 125)
6  (Chapter 4 C-1, pp. 99-100)
7  (Chapter 5 A-1, A-2, pp. 116-121)
8  (Chapter 4 C-1, p. 99)
9  (Chapter 4 C-1, p. 99)
10 (Chapter 4 B-4, p. 98)
11 (Chapter 5 C-4, p. 142)
12 (Chapter 4 B-4, pp. 97-98)
13 (Chapter 4 B-4, p. 98)