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ABSTRACT

Designed for science students in fourth, fifth, and sixth grades, the activities in this unit illustrate principles and problems related to biomass as a form of energy. (The word biomass is used to describe all solid material of animal or vegetable origin from which energy may be extracted.) Twelve student activities using art, economics, arithmetic, and other skills and disciplines help teachers directly involve students in exploring scientific questions and making discoveries of their own. Most activities in the unit can be conducted in the classroom, using materials readily available in any home or school. Experiments answer questions about plant growth, soil types, biomass production, and heat energy. Each activity is outlined on an illustrated single sheet which can be photocopied for distribution. The accompanying teacher's guide provides time guidelines, learner objectives, main concepts, process skills, materials and procedure clues, background information, precautions, strategies, and results for each activity. (LH)

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BIOMASS I.

SCIENCE ACTIVITIES IN ENERGY [and] TEACHER'S GUIDE

Oak Ridge Associated Universities
Tennessee

January 1981

SE 044 758

Science Activities in Energy

Science Activities in Energy, a series of simple, concrete, revealing experiments, was developed by Oak Ridge Associated Universities for students in the fourth through tenth grades. Biomass I is designed for students in the fourth, fifth, and sixth grades. However, the activities can be just as useful for older students or in community programs.

The purpose of the series is to illustrate principles and problems related to various forms of energy and their development, use, and conservation.

Other units in *Science Activities in Energy* include Chemical Energy, Conservation I, Electrical Energy, Solar Energy I, Solar Energy II, and Wind Energy. Units in Biomass II, Conservation II, and Energy Storage are under development.

Biomass

The word *biomass* describes all solid material of animal or vegetable origin from which energy may be extracted. Plant products (such as corn husks, branches, or peanut shells), waste paper, and cow dung are examples of biomass fuels. Biomass can be heated, burned, fermented, or treated chemically to release energy.

In some countries, such as China and India, biogas, consisting mostly of methane generated by fermenting cattle and human feces, is already a major alternative source of fuel. In India, animal dung has been used as a source of heat for many years. In Brazil, it is estimated that by 1981 one-sixth of the cars built in the country will be running on pure ethyl alcohol produced from sugar cane.

In some areas of the United States, wood is rapidly approaching oil as a prime source of home-heating fuel. In Vermont, for example, many residents have installed wood-burning stoves to supplement or replace fossil fuel furnaces for space heating. In Burlington, Vermont, two fossil-fuel-burning electrical generating plants recently have been converted to wood-burning plants for generating large quantities of electricity for commercial use.

Many U.S. service stations now offer gasohol, a mixture of 90 percent gasoline and 10 percent ethyl alcohol (ethanol). Ethanol is derived from corn, sugar beets, and other food grains. Wood alcohol (methanol) is also an important fuel of the future. Methanol can be produced from readily available sources, including garbage and agricultural waste.

But, there are problems with significantly increasing the amount of energy derived from biomass. Some experts maintain that producing energy from grains and other foods will inevitably lead to a choice between using food for fuel or for consumption. Others maintain that making ethanol requires more energy than it produces.

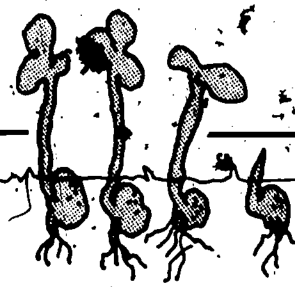
Extensive capital investments will be required for large-scale production of transport fuels from biomass. If methanol is to become a basic transport fuel, automobile manufacturers will have to develop materials which are not susceptible to methanol corrosion. New emission control systems and starting systems will have to be developed. Present automobiles will need to be retrofitted with methanol-resistant filters, seals, and gas tanks.

Since all biomass is produced by photosynthesis, basic research in photosynthesis may provide systems that directly convert sunlight into fuels. Although biomass already has many uses—from direct burning of wood and wood residues to converting animal wastes to gas—it will play a greater role in the future as research continues and the cost of oil continues to rise.

Published: January 1981

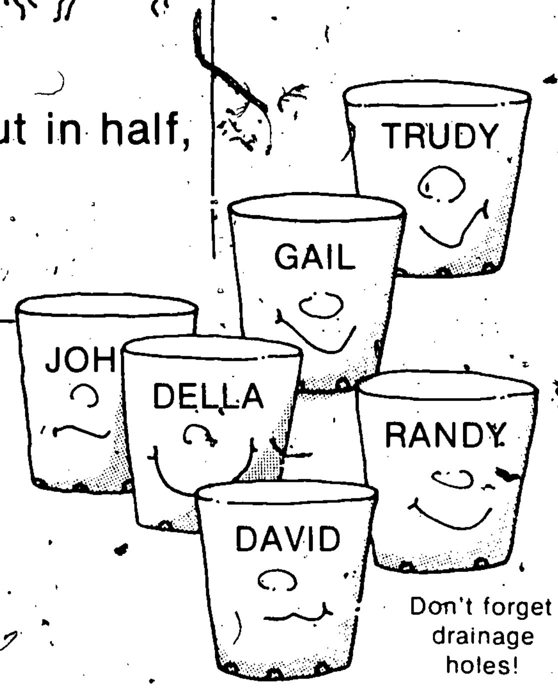
DO BEAN PLANTS GROW MORE IN THE DARK OR IN THE LIGHT?

1



MATERIALS:

Bean seeds; potting soil
Metric ruler; balance scale
Plastic cups or milk cartons, cut in half, for each student
Cardboard box or dark closet (must be light-tight)



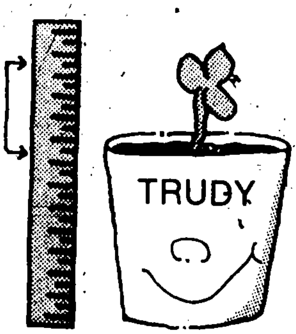
Don't forget drainage holes!

Plant three seeds in each cup.

Place half the cups in the sun and half in the dark. Keep moist.

DAY		1	2	3	4	5	6	7	8	9	10	11	12	13	14
TRUDY	Height of plant														
RANDY															
JOHN															
GAIL															
DAVID															
DELLA															

measure height



Record each bean plant's height for 14 days. You may have to support the plants as they get taller.

After 14 days remove the plants from the soil, wash, and dry with a paper towel. Weigh the plants and reco[illegible]

Dry the plants in the sun until they are crisp and weigh again.

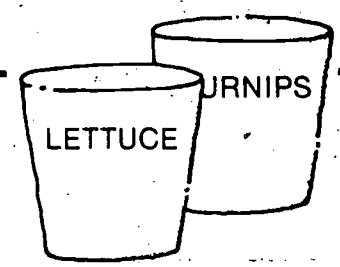
	Weigh all the plants together!	
	fresh weight	dry weight
		
		

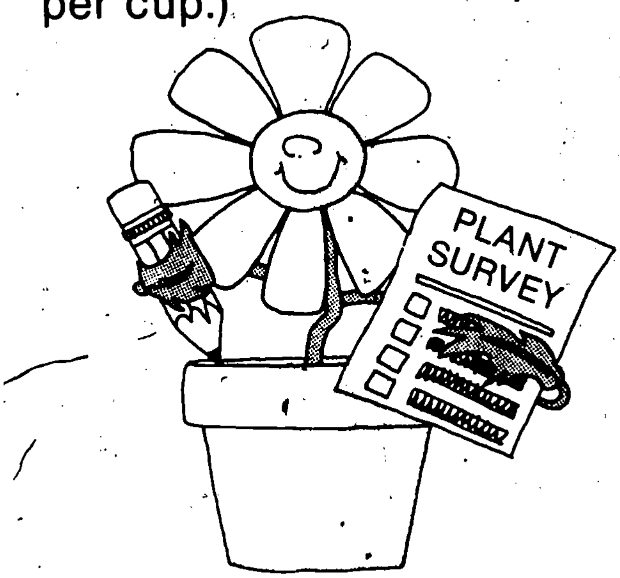
Summary questions:

Which plants grew the tallest? Which plants produced the most biomass?

OTHER IDEAS TO EXPLORE:

Try the same experiment using plants with smaller seeds, like radishes, lettuce, turnips, etc. (Use 8–10 seeds per cup.)





What happens if the bean plants' growing conditions are reversed after two weeks?

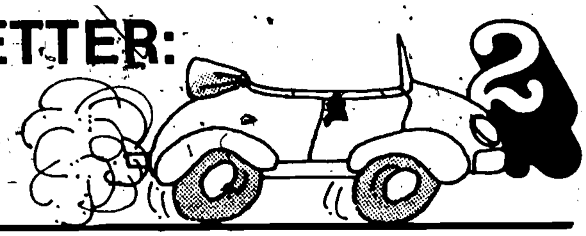
(Place the dark plants in the light and the light plants in the dark.)

Where did the bean plants in the dark get their energy to grow? Which set of plants would continue to grow for the longest time?

How can you tell if plants are getting enough light?

What's the most essential thing needed to produce biomass for energy production?

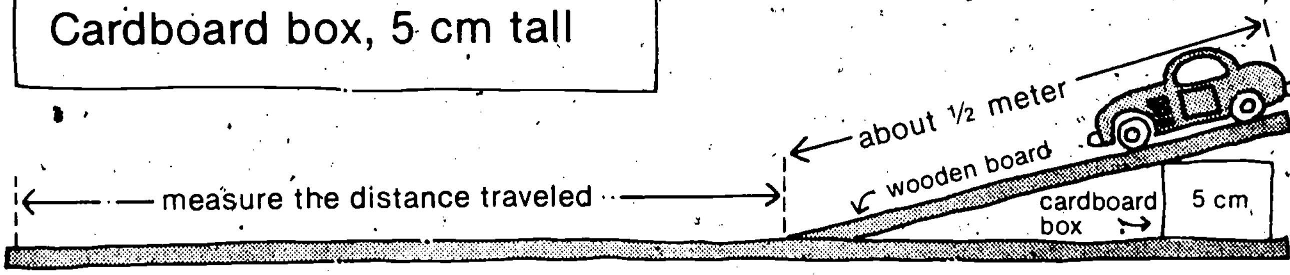
WHICH LUBRICATES BETTER: COOKING OIL OR AUTOMOBILE OIL?



MATERIALS:

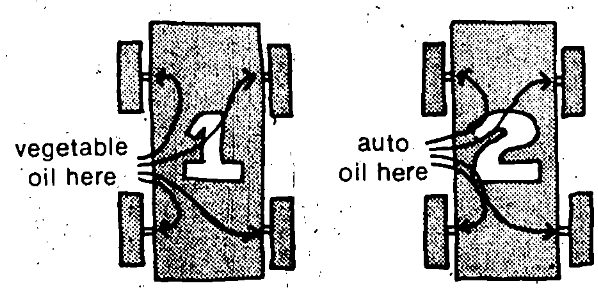
- Vegetable oil (safflower, corn, peanut, etc.)
- #20 or #30 Automobile oil
- 2 Small toy cars
- Meter stick
- Wooden board, about 12 cm wide
- Cardboard box, 5 cm tall

Set up the inclined plane like the diagram below. Measure the distance traveled without oil.



Add oil to the wheels of each car—vegetable oil to one car, automobile oil to the other car.

	distance traveled	
	1	2
no oil		
	vegetable	auto oil
fresh oil		
1 week old		
2 weeks old		
3 weeks old		

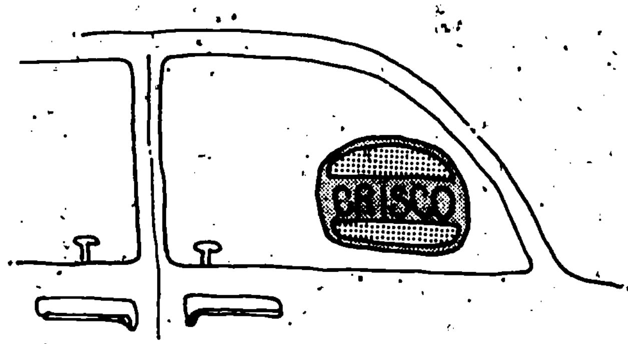


Test again and record the distance traveled. Store the cars in a clean place.

Test the cars each week for several weeks. Record the distance traveled without adding any extra oil.

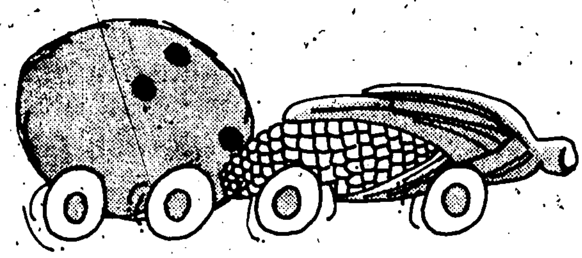
Summary questions:

If you were a racecar driver, what type of oil would you use? Why?



OTHER IDEAS TO EXPLORE:

Try using other cooking oils on one car and compare the results. Would a saturated oil like coconut oil be better than a polyunsaturated oil like corn oil? Would coconut oil be a good substitute for automobile oil?



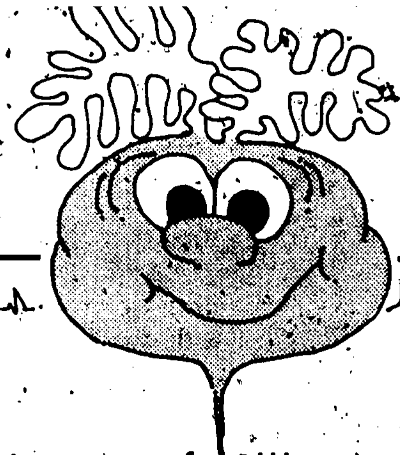
Oil protects iron from rusting. Would cooking oil do the same? What happens? Why?

Could machine oil be used in making paint?

Where did the energy originally come from that produced both cooking oil and automobile oil?

THE GREAT RADISH CONTEST!

3

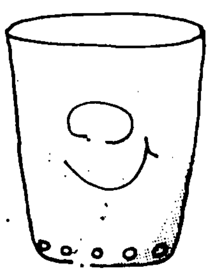


MATERIALS:

Radish seeds
Secret soil mix (soil, sand, peat moss, fertilizer)
2 Tongue depressors; balance scale; meter stick
Styrofoam cup or tin can for each student
Grow-type fluorescent lamp

The class may wish to set regulations for the race.

Prepare your own secret soil mix and plant six radish seeds in your cup. Be sure to punch drainage holes in the bottom of your cup.



OFFICIAL REGULATIONS

What methods can be used to grow radishes?

How will the largest radish be decided?

How long will the contest last?

Must everyone use the same brand of radish seed? The same soil mix?

HOW I GREW MY RADISH

secret soil formula ____________

____

planting depth ____________

____

watering record

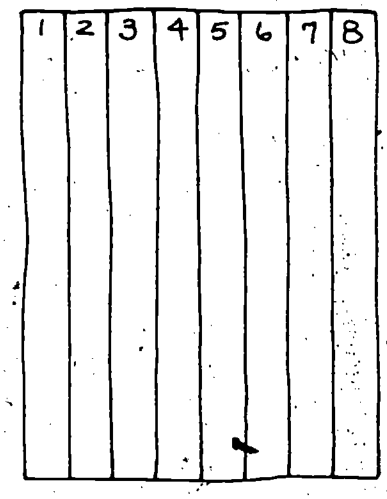
date							
amount							

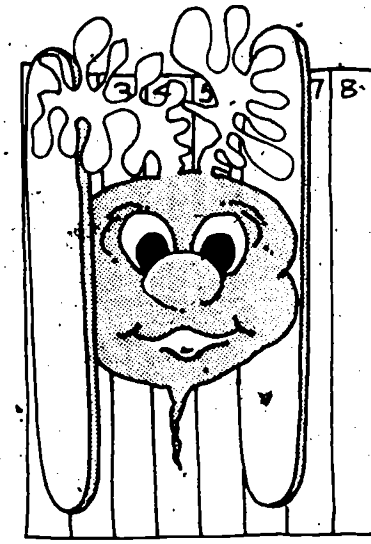
weight ____ length ____ width ____

The fluorescent light should be 7.5–10 cm above the top of the plants.

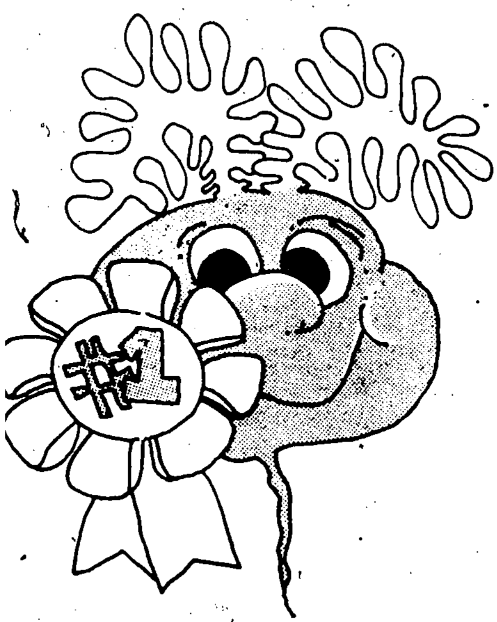
Keep accurate records during your experiment.

Place your radish between two tongue depressors and measure on this scale:





Award a badge to the winning radish!



Summary question:

**Compare the growing notes for each radish.
What secret soil mix grew the best radish?**

OTHER IDEAS TO EXPLORE:

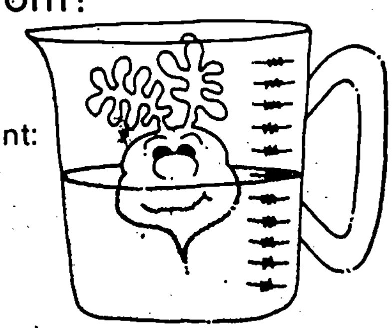
Try the best growing medium on a turnip or other root-crop plants. Try it on lettuce or legumes, too.

Did the largest top leaves always produce the largest radish?

Where did the energy in each plant come from?

How else might you measure the size of your radishes?

Hint:



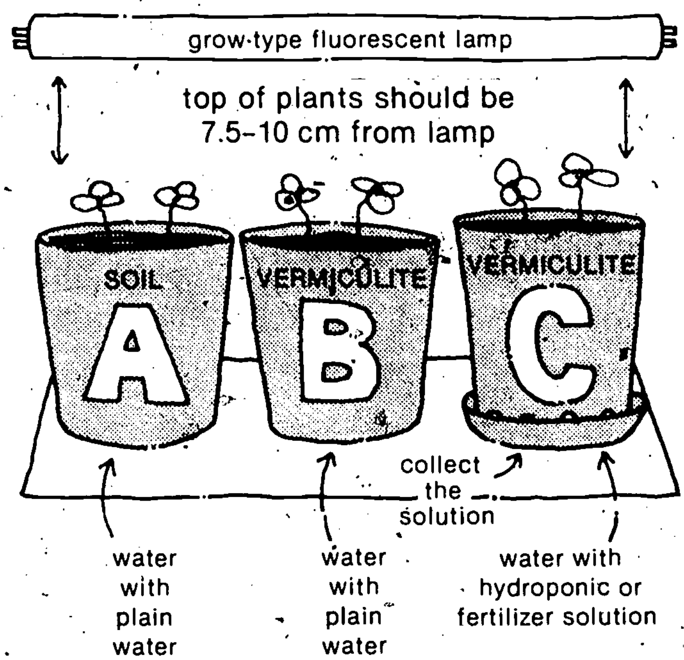
WHICH GROWING MEDIUM PRODUCES MORE BIOMASS: PLAIN SOIL OR HYDROPONIC SOLUTION? 4

MATERIALS:

Potting soil; radish seeds
Vermiculite or coarse sand
Grow-type fluorescent lamp
Styrofoam cups or tin cans
Balance scale
Hydroponic chemicals
or concentrated complete plant fertilizer (garden center or hardware store)

Plant 6-8 radish seeds in each cup. Keep the soil moist. Select the two best seedlings and pull the others out.

Mix the hydroponic or fertilizer solution according to the package directions.



Keep cups A and B moist with plain water. Water cup C with your solution twice daily, collecting and reusing it for 1 week. Mix a fresh solution each week.

After 4 weeks remove the plants from the growing media, wash, and dry with a paper towel.

Weigh them and record.

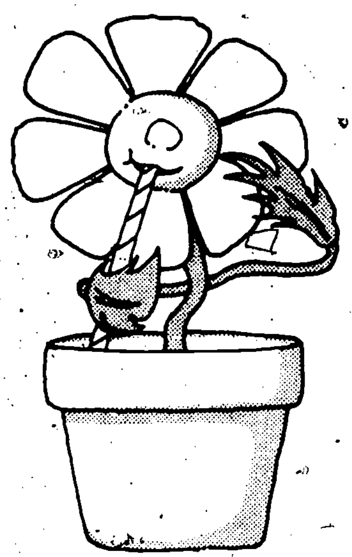
Dry the plants in the sun until they are crisp and weigh them.

growing media	compare the radish growth: fresh weight	dry weight
soil + water		
vermiculite + water		
vermiculite + hydroponics		

Summary questions:

How much better is one media than the other in producing biomass? Did you get any radishes?

OTHER IDEAS TO EXPLORE:



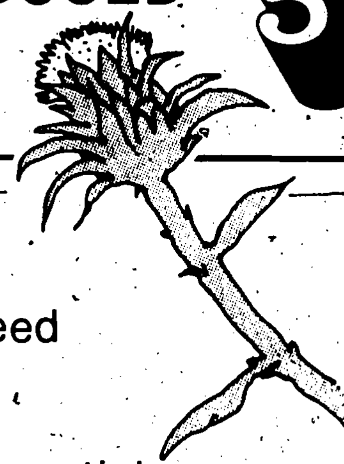
Try raising some other vegetable or flower the same way. Compare the results.

Find a hydroponic formula, and try making your own watering solution. Try raising a small garden outside or in a greenhouse.

What other materials could be substituted for vermiculite? Could hydroponics be an advantage in producing biomass?

HOW MUCH BIOMASS IS PRODUCED BY 1 SQUARE METER OF A LOCAL WEED?

5



MATERIALS:

An area with a lush growth of a local weed (kudzu, Johnson grass, honeysuckle, thistle, hyacinth, etc.)

Hoes; shovels; bags; balance scale; meter stick

Collect weeds (tops and roots) from one square meter of lush growth of a local weed.

	biomass of wild plant crop	
	fresh weight	dry weight
plant used		

Wash off the soil, dry them with a paper towel, and weigh.

Dry the plants until they are crisp, then weigh again.

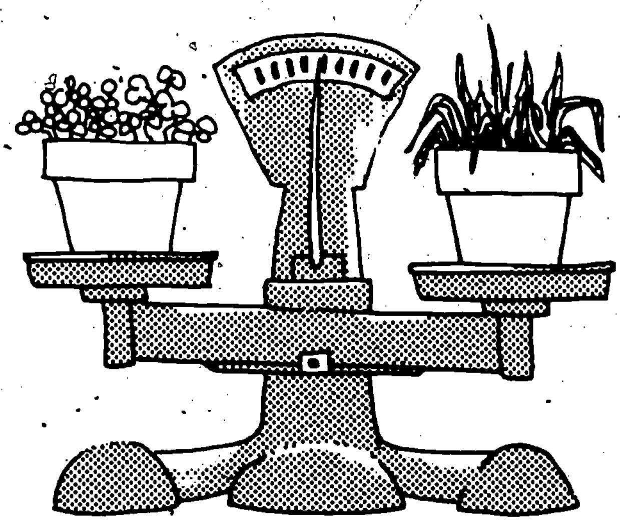
Summary questions:

Would the amount of weeds in your area be useful in solving the energy crisis?

What normally is done with the weeds in your area? What are new uses of weeds grown in your area?

OTHER IDEAS TO EXPLORE:

Try this experiment using one square meter of cultivated growth like clover, barley, or grass.



How do the weed and cultivated growth compare?

How much biomass could be produced in an acre of weeds? In an acre of cultivated crops?

Try cultivating the weed. Does it grow better with additional fertilizer and water?

Try growing the weed with a hydroponic solution. (See Activity 4.)

What is the difference between a weed and a cultivated crop?

Which plants, wild or cultivated, do you think might survive best under unfavorable conditions like lack of rain, poor soil, or disease?

HOW LONG WILL GAS BURN THAT IS PRODUCED BY HEATING 10 GRAMS OF WOOD IN THE ABSENCE OF AIR?

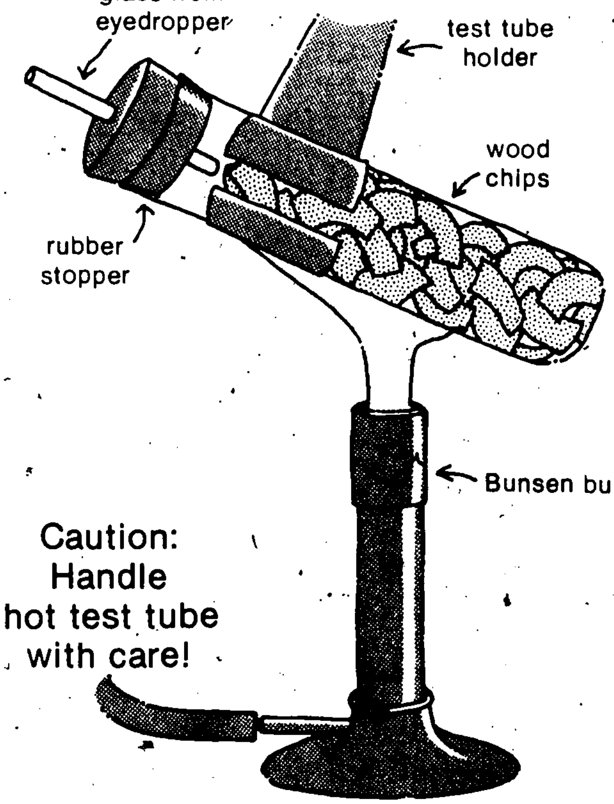
6

MATERIALS:

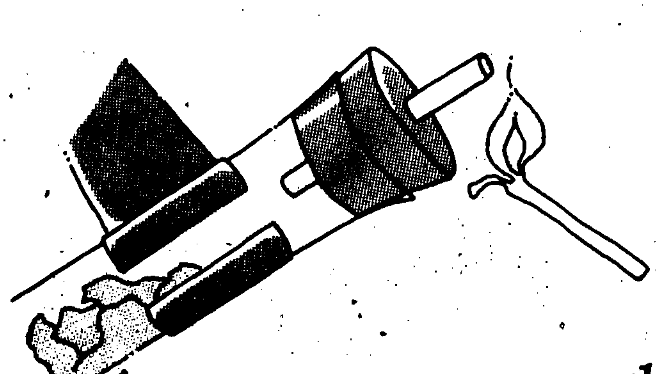
Wood splints or pencil shavings
Large pyrex test tube with 1-hole rubber stopper
Glass eyedropper; balance scale; tape
Teacher's Discretion ➤ Matches; Bunsen burner
Clock; test tube holder

Weigh 10 grams of wood splints and place in the test tube. Add the rubber stopper and the glass from the eyedropper.

Move the test tube through the flame. Heat the wood until you see gas escaping from the test tube.

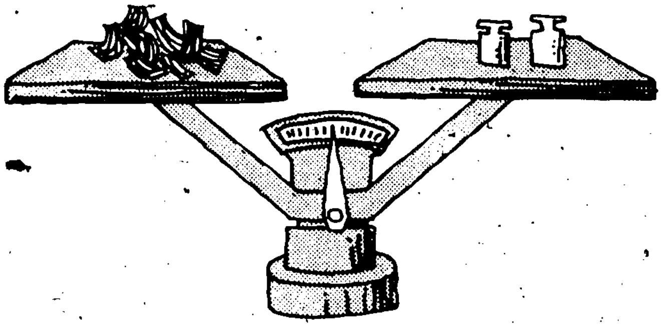


Caution: Handle hot test tube with care!



Summary question:

Light the gas while you continue to heat the wood. How long does it burn?

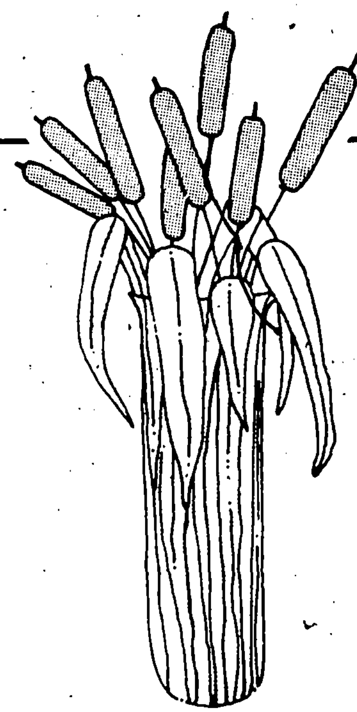


Weigh what remains in the test tube.

Has all the fuel value of the wood been used up in this process?

How can you find out?

OTHER IDEAS TO EXPLORE:

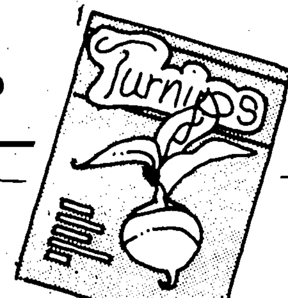


What other substances could be used to make burnable gas? Which would produce the most gas?

Do you think this is a good way to produce fuel? Why?

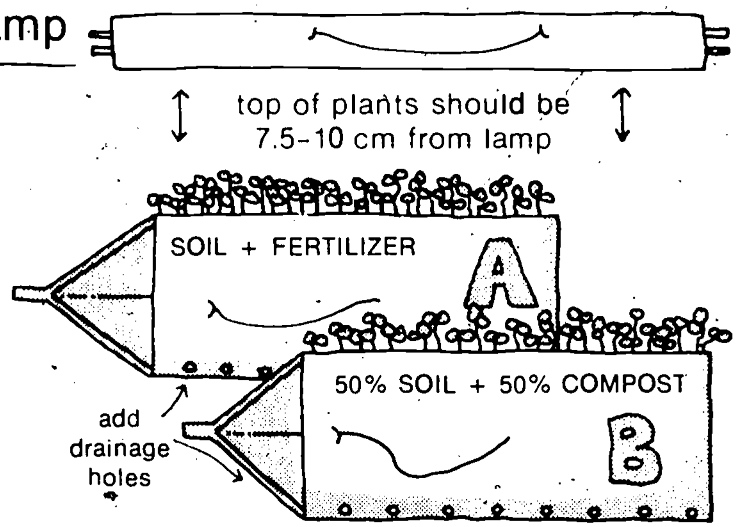
WHICH GROWS TURNIPS BETTER: COMPOST AND SOIL OR FERTILIZER AND SOIL?

7



MATERIALS:

2 Half-gallon milk cartons
Meter stick; balance scale
Chemical fertilizer, 10-10-10 (or equivalent)
Compost (garden centers or make your own!)
Turnip seeds
Grow-type fluorescent lamp



Plant 40 seeds in each container. Keep moist.

Select the 10 best seedlings in each container and pull the others out.

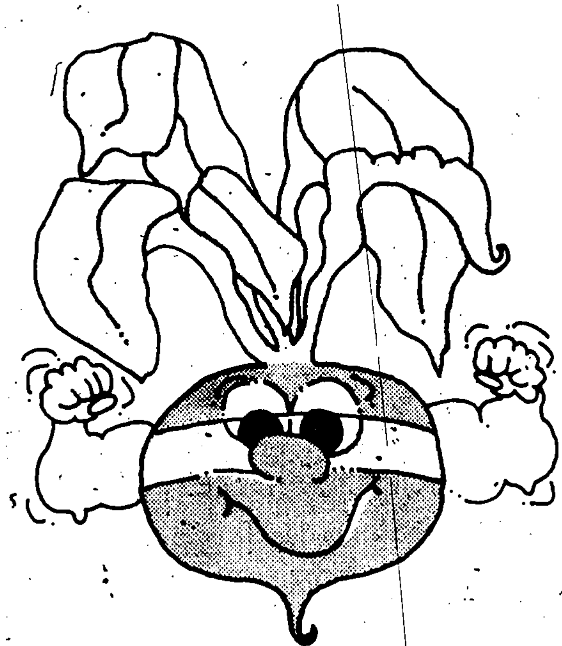
		A			B		
		Height	No. of leaves	Leaf size	Height	No. of leaves	Leaf size
week	1st						
	2nd						
	3rd						
	4th						
composite weight	fresh weight						
	dry weight						

Measure the growth of the turnips weekly after the seedlings appear. Count the number of leaves and measure the size of the largest leaf.

After 4 weeks pull the turnip plants. Wash off any dirt and dry with a paper towel.

Measure and record their weight.

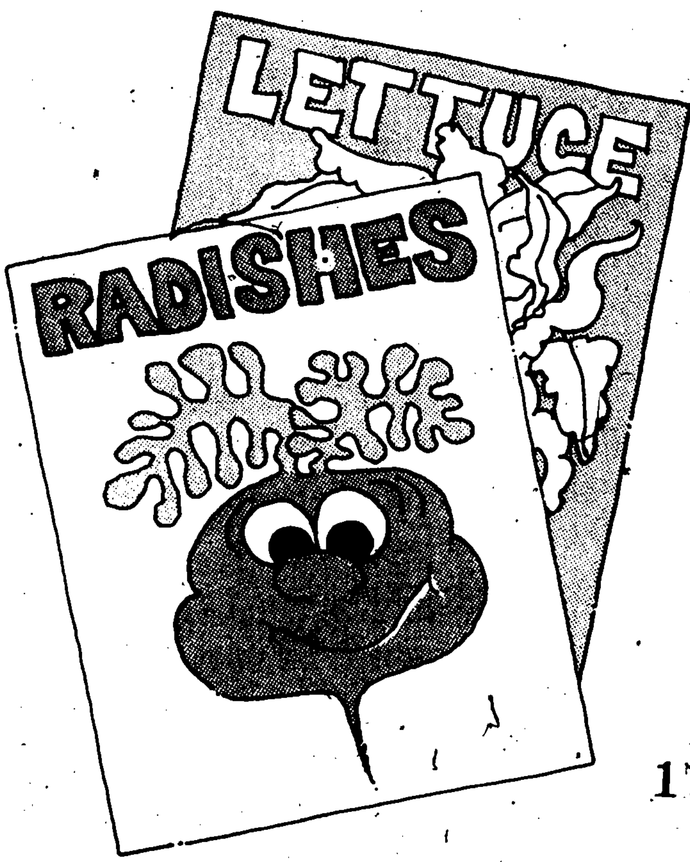
Dry the plants in the sun until they are crisp. Weigh and record.



Summary question:

Which method produces more biomass?

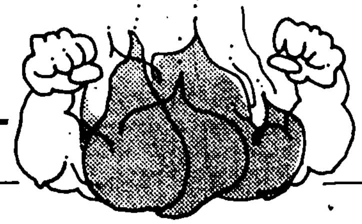
OTHER IDEAS TO EXPLORE:



Would you get the same results with lettuce or radishes?

WHICH HAS MORE HEAT ENERGY: VEGETABLE OIL OR PETROLEUM OIL?

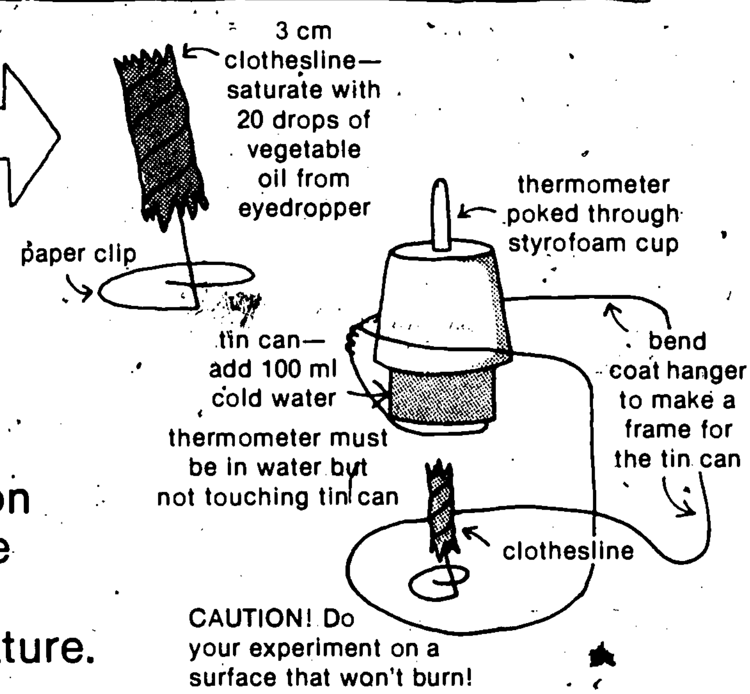
8



MATERIALS:

Vegetable oil; #20 or #30 automobile oil
2 Pieces cotton clothesline, 3 cm each
Glass eyedropper; thermometer
Matches; tin can; paper clips; metric measuring cup
Styrofoam cup; wire coat hanger or ring stand

Prepare your experiment like this.



Which do you guess has more heat energy?

Measure the temperature of the cold water and record. Light the oil on the clothesline and let the oil burn completely. Record the water temperature.

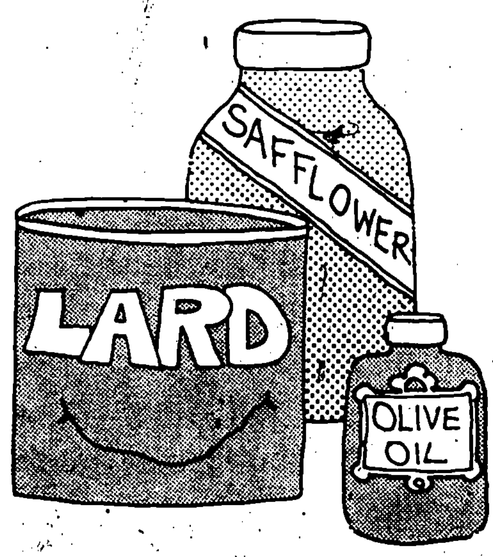
Run the experiment again using automobile oil. Record the water temperature and compare results.

oil tested		temperature of cold water	temperature after burning	difference in temperatures
	VEGETABLE OIL			
	AUTOMOBILE OIL			

Summary question:

Would vegetable oil be a good substitute for petroleum oil as fuel? Why?

OTHER IDEAS TO EXPLORE:

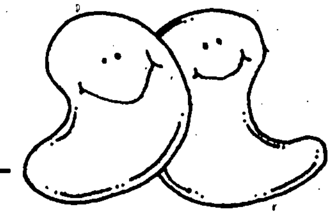


Try different kinds of oils (peanut, olive, safflower, etc.) to see if they have different heat contents.

Is there a difference in the heat content of solid animal fats (such as lard) and vegetable oil?

Where does the energy stored in the oils originally come from?

WHICH HAS MORE HEAT ENERGY: PEANUTS OR PAPER?

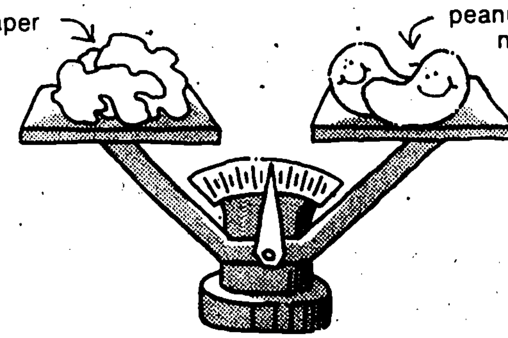


9

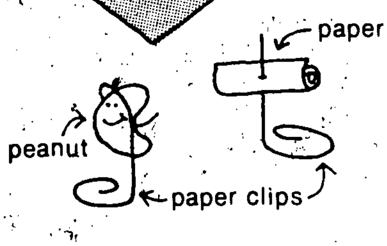
MATERIALS:

Peanuts; paper; paper clips
Tin can; styrofoam cup; metric measuring cup
Wire coat hanger or ring stand; matches (Teacher's Discretion)
Balance scale; thermometer

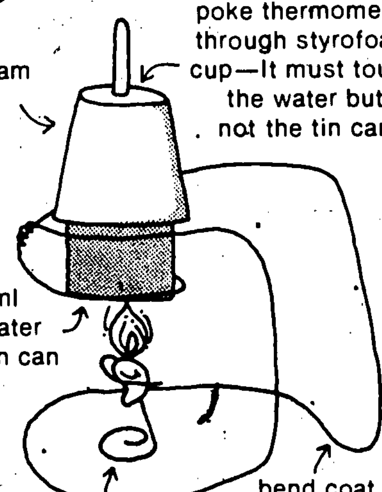
Weigh equal amounts of peanuts and paper.



Attach paper clip stands to each.



Set up your experiment like this.

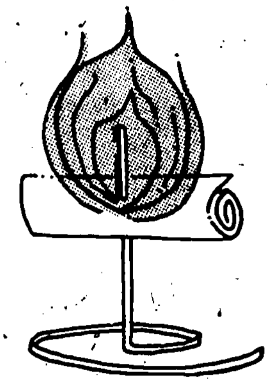


Read and record the temperature of the cold water.

energy source	temperature of cold water	temperature after burning	difference in temperature
(peanut)			
(paper)			

Burn the peanut, then record the temperature again.

Refill the can with 100 ml cold water.
Record the temperature.

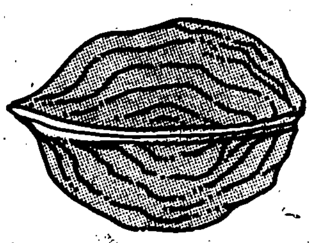


Burn the paper and record the temperature.

Summary questions:

How do you explain the results you obtain? Do you think your results would be exactly the same if you did the experiment again?

OTHER IDEAS TO EXPLORE:

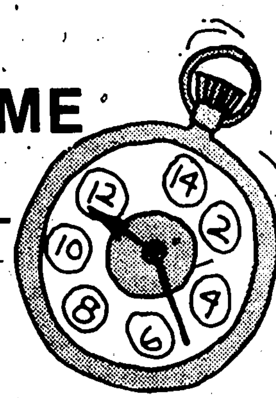


Would a walnut produce more or less heat than a peanut?

Would sesame seeds or sunflower seeds produce more or less heat than a peanut?

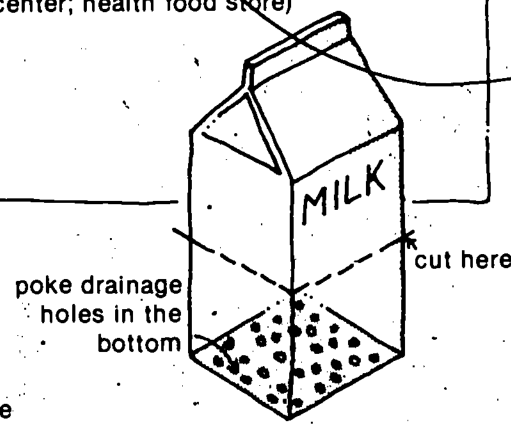
WHICH GRASS PRODUCES MORE BIOMASS IN THE SAME AMOUNT OF TIME?

10



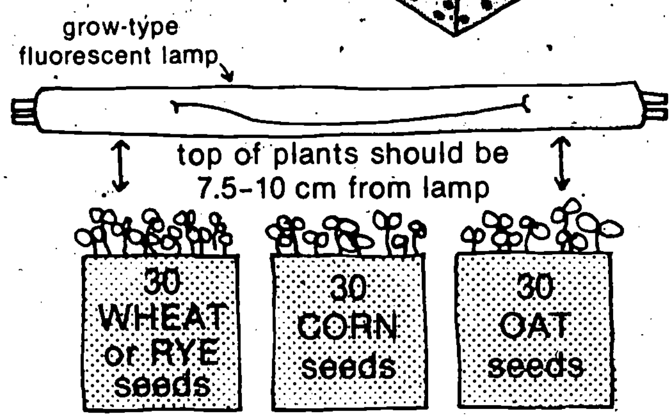
MATERIALS:

Wheat or rye seed (garden center; health food store)
Corn seed (garden center; feed and grain store)
Oats (whole only, not milled) (garden center; health food store)
Potting soil; balance scale
3 Half-gallon milk cartons
Grow-type fluorescent lamp



Cut the milk cartons in half. Fill with potting soil, and plant the seeds. Keep moist.

Grow the plants under a grow-type lamp. Record your results.



		Plant growth and development									
		germination			average height						
Plant	date planted	date of 1st sprout	date of 10th sprout	date of 20th sprout	2 days	4 days	6 days	8 days	10 days	12 days	14 days
WHEAT or RYE											
CORN											
OATS											

After 14 days pull the plants. Wash off the dirt and dry with a paper towel.

Weigh the plants and record. Dry the plants in the sun until they're crisp, and weigh them again.

Test plant	Weight	
	fresh weight	dry weight
WHEAT or RYE		
CORN		
OATS		

Summary question:

Which plant is the best converter of light energy to biomass?

OTHER IDEAS TO EXPLORE:

Try burning the biomass produced. Set up and conduct your experiment as in Activity 12.

Would the results be better if your plants were allowed to mature?

Do other grasses produce more biomass? (Try using barley, triticale, rice, etc.)

What is done with most of the corn and wheat grown in this country? What might happen if a major portion of our grain was used to produce energy?

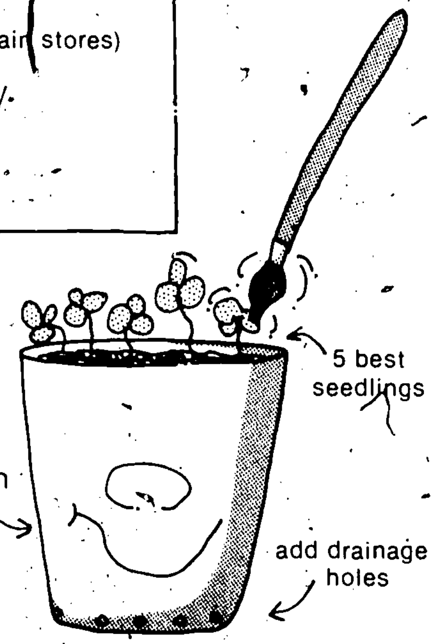
HOW MUCH CAN GIBBERELLIN INCREASE THE BIOMASS PRODUCED BY BARLEY?

11

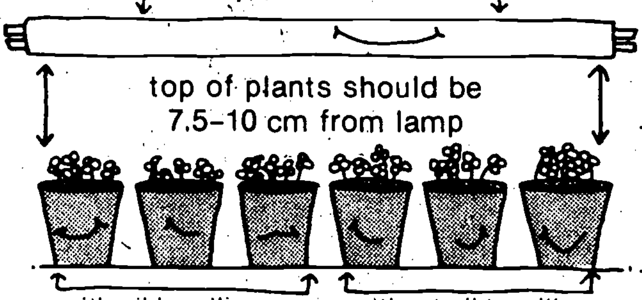
MATERIALS:

Gibberellin (garden centers; feed and grain stores)
Styrofoam cups or milk cartons
Barley seed or tomato seed (feed and grain stores)
Potting soil; balance scale
Grow-type fluorescent lamp
Small paint brush

Plant 8–10 seeds in each cup.
Keep moist.
When each plant has 3 leaves, thin to 5 plants per cup.



Paint gibberellin on the leaves and stems of half the plants once only.
Keep the plants moist.



treatment		fresh weight	dry weight
	with gibberellin		
	without gibberellin		

After 14 days pull the plants.
Wash the soil from the roots and dry with a paper towel. Weigh the plants and record.
Dry the plants in the sun until crisp and weigh again.

Summary question:

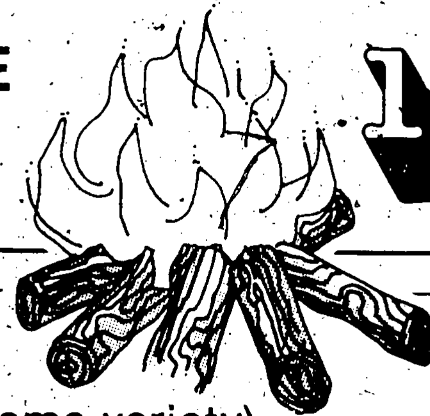
How can you be sure that the results you obtained in this experiment are correct?

OTHER IDEAS TO EXPLORE:

Do you think this chemical treatment would work on all plants? Is it worth the expense?

What might happen to your plants if you use more gibberellin? Would they grow faster and faster forever?

WHICH WILL GIVE MORE HEAT ENERGY: GREEN OR DRY WOOD?

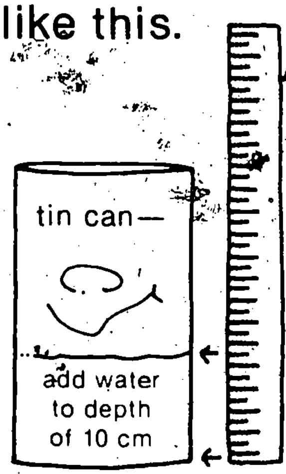


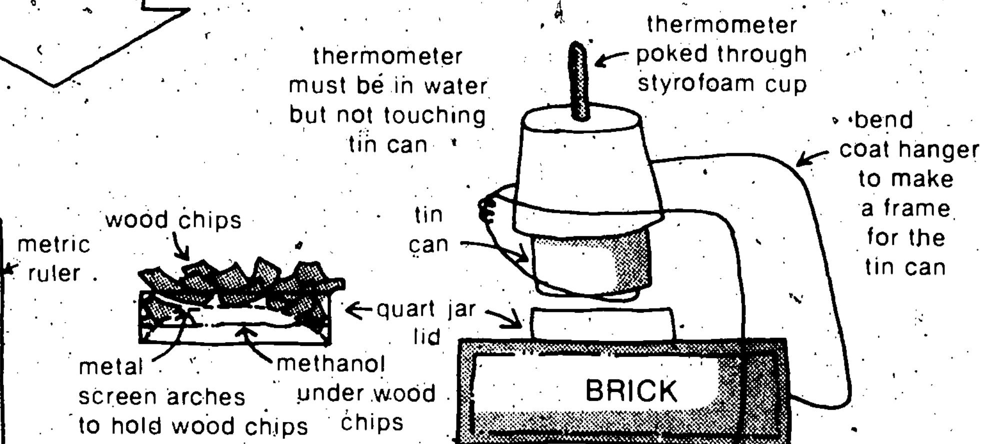
12

MATERIALS:

Green and dry wood shavings (same variety)
Methanol (hardware or paint stores)
Large tin can; metric ruler; balance scale
Teacher's Discretion ▶ Matches; thermometer; small piece metal screen
Quart jar lid (remove paper liner); styrofoam cup
Brick; eyedropper; metal coat hanger

Prepare your experiment like this.





Measure and record the cold water temperature.

Add 1 eyedropper full of methanol and 10 grams of dry wood chips to the jar lid and ignite.

Measure and record the water temperature after burning.

Repeat using green wood and fresh water.

	temperature of cold water	temperature after heating	difference in temperatures
DRY WOOD			
GREEN WOOD			

Summary questions:

How do you account for the results you obtain?

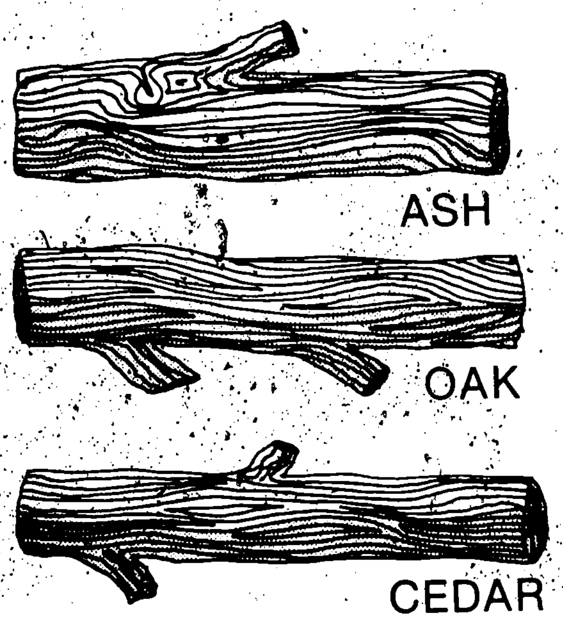
How do you make dry wood from green wood?

OTHER IDEAS TO EXPLORE:

Is green wood at one-half the price of dry wood a good buy for your fireplace?

How long does it take to change green wood to dry firewood?

How could you speed up the process of drying wood?



Would you get the same results in your experiment if you used different varieties of wood?

Measure the size of the can you used and calculate the volume of water heated by the wood. How many calories of heat are produced by burning 10 grams of wood?

$$\text{Volume} = \frac{3.14 \times \text{diameter of can}^2}{4}$$

Calories = Volume × change in temp.

Science Activities in Energy was developed by Oak Ridge Associated Universities under contract with the U.S. Department of Energy. Mr. Mauri Gould, with the assistance of Ms. Marilyn Schuette and Memphis State University faculty Dr. Ron Cleminson and Dr. John Thompson, directed the development of the series.

Copies of *Science Activities in Energy* can be obtained by writing:
U.S. Department of Energy
Technical Information Center
P.O. Box 62
Oak Ridge, TN 37830

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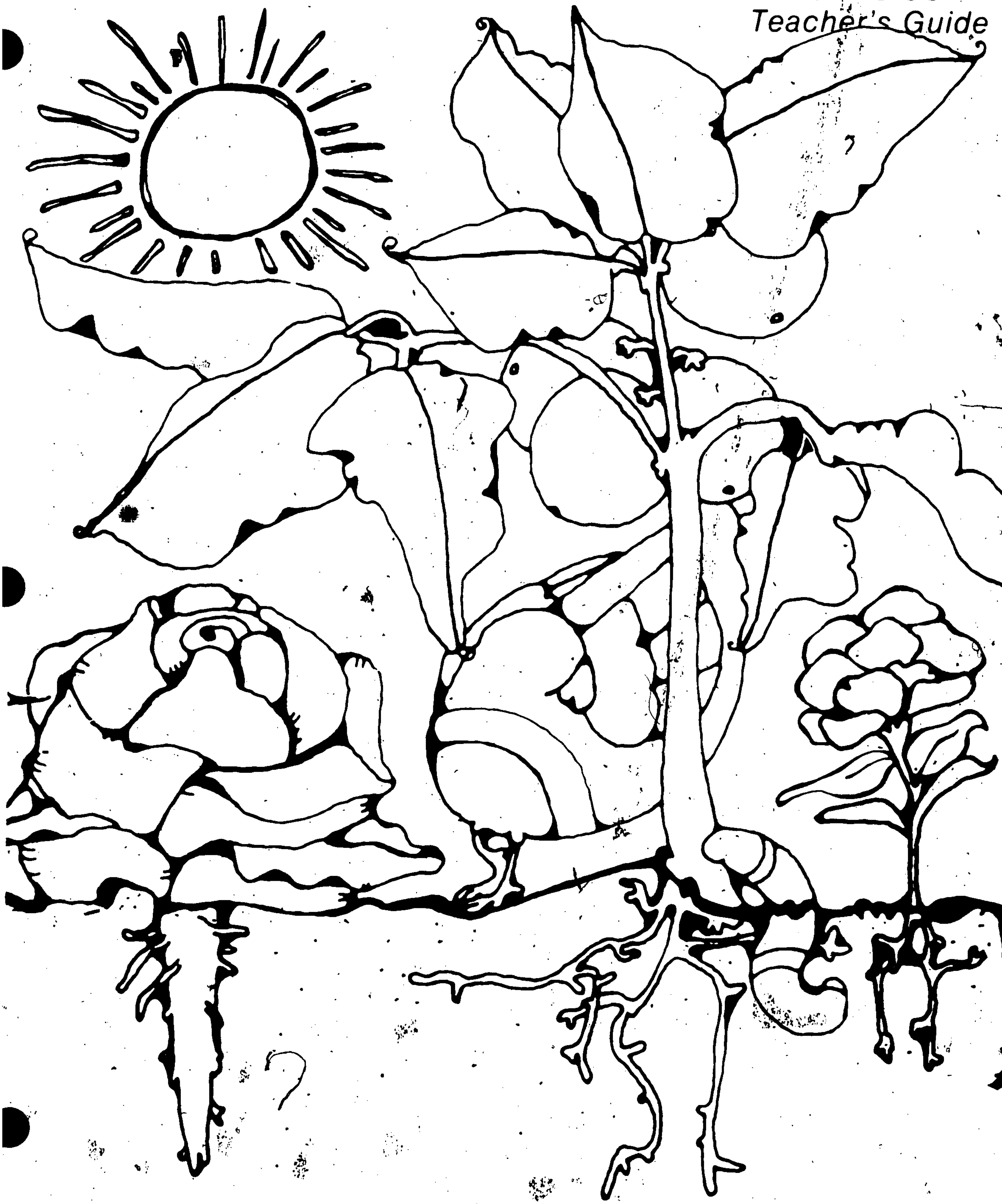

Science Activities in Energy

Science Activities in Energy, a series of simple, concrete, revealing experiments, was developed especially for fourth, fifth, and sixth grade students.

The purpose of the series is to illustrate principles and problems related to various forms of energy and their development, use, and conservation.

More importantly, *Science Activities in Energy* was designed to help you directly involve students in exploring intriguing scientific questions and in making discoveries on their own.

You don't need to be an expert in science to use these materials. In fact, many of the activities use art, economics, arithmetic, and other skills and disciplines. Since the series stresses investigation and exploration, you are not expected to know the "right" answer to every question.

Each unit in *Science Activities in Energy* forms a cohesive program of instruction on a single topic. Presently, there are units in the following areas: Biomass I, Chemical Energy, Conservation I, Solar Energy I, Solar Energy II, and Wind Energy. Units in Biomass II, Conservation II, and Energy Storage are under development.

Most activities in the series can be conducted in the classroom, using materials readily available in any home or school. A few activities require materials purchased from a local or national supplier. The series' developers have made a concerted effort to design activities which use the same materials or materials that can be saved for use in other units.

Each activity begins with a question. At the beginning of the activity, try to get your students to predict the outcomes, even if they lack experience or knowledge to justify their predictions. Urge them to guess! This helps them to become more interested and involved in the activity.

When working on answering a question, each student (or the class as a group) follows the instructions which lead him or her through the activity. This kind of direct participation leads students to other questions—some of which are suggested on the activities and others they generate themselves. The activities encourage exploration by the experimenters on their own.

The series' developers have purposely used metric measurements throughout the experiments. They believe that this will be part of the learning process for many young people and also for some adults.

Each activity is outlined on a single sheet. The sheets can be photocopied for distribution or easily projected on a screen or a wall.

Published: January 1981

Biomass I - 1

Question
Do bean plants grow more in the dark or in the light?

Process Skills
Observing, measuring, making inferences, and controlling variables.

Time
Thirty minutes for each initial and final discussion. Five minutes daily for measuring height. 3 to 4-week activity.

Materials & Procedure Clues
Plant seeds about 2.5-5 cm deep. The beans should germinate within 7-10 days. Use a south-facing window for a light source. Unless you have a delicate scale, weigh the entire class's material together.

Objective
The student will conduct an experiment to test the effects of light in producing biomass.

Concept
Light is essential for the production of biomass.

Background
Light is an essential ingredient for producing biomass. In the absence of light, plants experience a quick increase in height, remain white to pale yellow in color, and may begin to wither and die within two weeks.

Note: If sunlight is not available, dry the plants by placing them in a warm oven or under a lamp.

Precautions
None.

Strategies
Before: How do we measure plant growth? Discuss what plants need for growth. Have students predict which plants will grow taller, which will produce more biomass.

After: Discuss summary questions. Ask students to describe the effects of light or the absence of light on plants.

Results
Plants grown in the dark will weigh less than those grown in the light.

Biomass I - 2

Question
Which lubricates better: cooking oil or automobile oil?

Time
Fifteen to twenty minutes for the activity. Twenty minutes for discussion.

Objective
Students will compare the effectiveness of vegetable oil to automobile oil as a lubricant.

Process Skills
Observing, making inferences, and controlling variables.

Materials & Procedure Clues
Eyedroppers are helpful in controlling the amount of oil for lubricating cars.
Students may wish to bring matchbox cars from home.
Have a variety of oils available for experimentation.
The board for the incline should be as thin as possible.

Concept
Cooking oil combines with oxygen in the air and becomes a nonlubricant.

Background
Automobile oil is a stable material that retains its lubricating properties for a long time. Cooking oil is unsaturated, which means it combines readily with oxygen in the air. This tends to thicken and solidify the oil.

Since vegetable oil forms a solid film when exposed to air, it is used in paint. Special chemicals are added to the paint to speed up this process.

Although adding anti-oxidants to vegetable oil slows the solidification process, it is not a good automobile lubricant. High engine temperatures would break down the vegetable oil.

Keep the remaining vegetable and automobile oil for use in *Biomass I, Activity 8*.

Precautions
Students should not taste the automobile oil.

Results
Both oils should work equally well at first. Automobile oil will continue to work well, but cooking oil eventually will cause the cars to run poorly.

Strategies
Before: Discuss the possible effects of lubricating one car more than the other. Discuss how to control the amount of lubrication.

After: Discuss summary questions. Have students predict the effects of using different vegetable oils.

Biomass I - 3

Question
The Great Radish Contest!

Process Skills
Controlling variables, measuring, observing, and organizing data.

Time
Thirty minutes each for initial and final discussions. A few minutes daily for measuring and watering plants. Allow 4-5 weeks for radish production.

Materials & Procedure Clues
Prepare or have students design and create a badge for the withering radish.

South-facing windows or grow lamps are best for radish production. Plant the seeds about 6mm (¼") deep.

Objectives
Students will plant and care for their own radish plant. They will compare the growth of their radishes and draw conclusions about the best soil combination for growth.

Concept
Soil composition, fertilizer, and watering will influence the size of plant growth.

Background
Nitrogen, potassium, and phosphorus are the main nutrients for plant growth and production.

Nitrogen is responsible for rapid growth and dark green leaves. All plants need it.

Phosphorus is important for the root growth of every type of plant. It helps plants develop sturdiness and aids in the production and maturation of flowers and fruit. Potassium balances the growth and ripening influences of nitrogen and phosphorus. Potassium is necessary for all growth, especially in the roots and buds. It is important for root crops such as radishes, beets, and potatoes.

Too much fertilizer is as bad as too little. In fact, it is very easy to prevent germination of seeds and to kill a plant by using too much fertilizer.

Also, overwatering will deter growth since a plant's roots cannot get needed air. Be sure to give the plants plenty of light.

Precautions
None.

Strategies
Before: Have the class determine the rules for the contest. What will make a fair race?

Discuss how to know when to water a plant.

After: Discuss the summary questions.

How would smaller amounts of light affect radish growth?

Results
Soils balanced with nitrogen, potassium, and phosphorus produce the biggest radishes.

Biomass I - 4

Question
Which growing medium produces more biomass: plain soil or hydroponic solution?

Time
Twenty minutes each for planting and final discussion. A few minutes daily for watering. Four-week activity.

Objective
Students will test the effects hydroponic solutions have on plant growth.

Process Skills
Measuring, organizing data, and controlling variables.

Materials & Procedure Clues
See *Background* section for basic hydroponic solution if you wish to make your own.

Plant seeds about 6mm (¼") deep.

Unless you have a delicate scale, weigh the entire class's material together.

Obtain concentrated complete plant fertilizer. Regular 10-10-10 fertilizer will not work.

Concept
Hydroponic solution is a successful growing medium for producing biomass.

Background
There are many hydroponic chemicals available, but you can make your own formula if you wish. There are many possible variations. A simple hydroponic solution can be made as follows:

Ingredients*
- 3 Tbs. potassium nitrate
- 2 Tbs. calcium sulfate
- 2 Tbs. magnesium sulfate (Epsom salt)
- 1 Tbs. monocalcium phosphate
- 1 tsp. ammonium sulfate
- 10 gallons of water

Directions

Mix all dry ingredients together and dissolve them in water. Cover and store in a glass or impervious plastic container.

*These agricultural chemicals are available in most garden shops.

Be sure to check the pH of the solution and adjust it to about 6.5.

Usually the pH is higher than 6.5, so acid has to be added. Hydrochloric acid used for swimming pools can be used to lower the pH. A pH of 7 is neutral; above 7 is alkaline; and below 7 is acid. (Obtain hydrochloric acid and pH paper from a local high school.)

Note that the hydroponic fertilizer flows through the vermiculite and collects in the container under the cup. Air then is able to reach the roots between waterings. It is important to use a fresh solution each week because the plants use the nutrients in the solution.

Note: If sunlight is not available, dry the plants by placing them in a warm oven or under a lamp.

Precautions
Students should not taste or drink the hydroponic solution. They should wash their hands after watering the plants.

Results
The hydroponic solution may produce considerably more biomass.

Strategies
Before: Explain hydroponics. Ask students to predict which method will produce more biomass.

After: Ask students about other advantages to using hydroponics for vegetable growth.

Biomass I · 5

Question
How much biomass is produced by 1 square meter of a weed?

Time
About one hour, depending on distance to weed patch. Twenty minutes for final discussion. Five-day activity.

Objective
Students will draw conclusions about biomass as a source of energy produced from weeds.

Process Skills
Measuring and making inferences.

Materials & Procedure Clues
Identify an area where you and your students can gather a local weed.

You may wish to send a small group of students to gather weeds for the entire class.

An acre contains 4085 square meters.

Concept
Weeds produce biomass and are a source of energy.

Background
There is ongoing experimentation with using weeds as a source of fuel. Methane gas is produced when anaerobic bacteria digest biomass material. It is estimated that one acre of kudzu, when converted to methane gas, would heat and cool a four-person home for one year.

Cutting and collecting the weeds makes the biomass-derived methane gas very expensive compared to natural gas. Using weeds which need to be cleared, such as waterweeds which clog waterways, might be more economical for methane production, especially as the cost of natural gas continues to rise.

Note: If sunlight is not available, dry the plants by placing them in a warm oven or under a lamp.

Precautions
Watch out for poison ivy!

Results
Generally, the weight loss ranges from 40 to 60 percent less than the original weight.

Strategies
Before: Discuss measuring techniques.

After: Discuss summary question.
Calculate the weight of one acre of the weed.

Biomass I · 6

Question

How long will gas burn that is produced by heating 10 grams of wood in the absence of air?

Time

45 minutes.

Objective

Students will learn how gas can be made from the destructive distillation of biomass.

Process Skills

Observing, measuring, and making inferences.

Materials & Procedure Clues

Be sure the test tube and the eyedropper are dry before putting the wood chips in the test tube.

A propane torch can be used if a Bunsen burner is not available. Candles and alcohol lamps do not produce enough heat for this activity.

Concept

Gas used in homes and industry can be produced by distilling wood and other biomass material.

Background

When the wood is heated in this way, the heat forces the air from the test tube so the wood will not burn. Other gases given off include carbon dioxide and water vapor. The gas that is given off and burns is either methane or other hydrocarbons. Wood charcoal is left in the test tube.

Note: This activity can be used as a demonstration for very young students. It is also a good group activity for older students.

Precautions

Be sure to leave a space between the wood and the rubber stopper. Do not heat the test tube near the rubber stopper, or you will distill it also. Be careful of all flames!

Results

The amount of gas produced by this method is small. Other products, such as wood alcohol, charcoal, etc., make it practical for consideration as an alternate energy source.

Strategies

Before: Have students predict if the wood will burn and if so, how long.

After: Discuss how garbage, waste paper, or sawdust could be used to alleviate energy shortages.

Biomass I - 7

Question
Which grows turnips better: compost and soil or fertilizer and soil?

Time
Twenty-five minutes for initial discussion and planting. Four-week activity.

Objectives
Students will make two soil mixtures and will plant and tend the growth of a root vegetable. They will compare the effects of two different growing mediums.

Process Skills
Observing, measuring, organizing, and replicating.

Materials & Procedure Clues
Southern exposure or grow lamps produce the best results.
Plant the seeds about 1.25 cm (½") deep.
Follow the directions on the box for the amount of fertilizer to use. Drying time is about one week.
See *Biomass II, Activity 10* for procedures to make compost.

Concept
A soil and compost combination is as effective as an energy-intensive chemical fertilizer.

Background
Both compost and soil and soil and fertilizer will give excellent results in growing turnips. The amateur will get better results with compost since one has to be more careful with fertilizer.

The important point to be made here is that compost costs essentially nothing and uses less energy in its production. Fertilizer is a very energy-intensive product and, in large part, is made from natural gas and/or petroleum. For biomass to be a viable substitute for nonrenewable energy resources, it should ideally be grown with a minimum of energy-intensive materials and methods.

See *Biomass I Teacher's Guide, Activity 3* for general information on growing plants.

Note: If sunlight is not available, dry the plants by placing them in a warm oven or under a lamp.

Precautions
Fertilizer is harmful if swallowed. It is also an eye irritant. Students should wash their hands after using.

Results
All methods give equal results if used properly.

Strategies
Before: Discuss the dangers of using chemical fertilizers.
Have the students predict which growing medium will be more effective.

After: Compare the results of growing turnips in the two soil mixtures.
Make a composite bar or line graph of the class's results.
Discuss the summary questions.
Review predictions and reasons for accurate and inaccurate predictions.

Biomass I - 8

Question

Which has more heat energy: vegetable oil or petroleum oil?

Time

45 minutes.

Objectives

Students will compare two kinds of oil for producing heat.
Students will conduct a controlled experiment.

Process Skills

Measuring and making inferences.

Materials & Procedure Clues

Have the vegetable and petroleum oil in separate, marked containers with several eyedroppers available.

Wooden matches work well for igniting the oil-soaked, cotton clothesline. Plastic clothesline will not work.

For younger students, provide the coat hanger frame and the clothesline frame.

Concept

Vegetable oils produce similar quantities of heat when compared to petroleum oils.

Background

All oils produce a great deal of heat when burned. Hydrocarbons, present in this experiment, produce more energy per given weight than oil, but are not measurable with this equipment. Vegetable oils could be burned for energy if they could be produced cheaply enough to compete with petroleum.

Plants, such as the "gopher plant," produce a substantial amount of oil. Tests are being conducted to increase the yield of oil-producing plants, making their use as a fuel more economically attractive. Someday, farmers will be producing oils and other materials for use as energy sources.

Keep the remaining vegetable and automobile oil for use in *Biomass I, Activity 2.*

Precautions

Make sure the coat hanger is stable.
Work in a well-ventilated place.

Results

The temperature changes are equal. Small temperature differences are due to the crudeness of the equipment and heat losses.

Strategies

Before: Have the students predict which oil will produce a greater temperature rise in the water.

After: Discuss the summary questions.

Biomass I - 9

Question
Which has more heat energy: peanuts or paper?

Time
30 minutes.

Objective
Students will measure the relative heat content of vegetable oil and cellulose.

Process Skills
Measuring and making inferences.

Materials & Procedure Clues
Students may need help constructing the coat hanger frame.

Try the same experiment using other nuts, such as cashews, walnuts, or almonds.

Concept
Given equal masses of peanuts and paper, the peanuts will produce more heat.

Background
Both the peanut and paper are made of carbon, hydrogen, and oxygen. Carbon and hydrogen burn; oxygen does not.

Paper is made primarily of cellulose, while most of a peanut is made of oil. A greater proportion of the peanut is made of combustible materials. Therefore, it produces more heat than paper when burned.

For a given weight, oil produces twice the calories when burned compared to any other vegetable material.

Precautions
Make sure the coat hanger stand is stable.

Work in a well-ventilated area.

Results
The water temperature will rise about twice as much when burning peanuts.

Strategies
Before: Have the students predict which container of water will show the greatest change in temperature.

After: Discuss the summary questions.

Biomass I · 10

Process Skills
Observing, measuring, and making inferences.

Question
Which grass produces more biomass in the same amount of time?

Time
Thirty minutes each for initial discussion, planting, and final discussion. Ten minutes every two days for measurements. Thirty minutes for weighing. 15-day activity.

Materials & Procedure Clues
South-facing windows or grow lamps are the best light sources for plant production.
Plant the seeds about 6mm (¼") deep.

Objectives
Students will determine the relative efficiency of plants as converters of light energy to biomass. They will draw conclusions about plants as energy converters.

Concept
Corn is an efficient converter of light energy to biomass.

Background
All green plants use photosynthesis to produce biomass. The average efficiency of photosynthesis is about 3%. (A plant converts about 3% of the sun's energy to plant material.) Not all plants use sunlight with the same efficiency since plant growth depends on many factors.

Using biomass as an energy source will require finding the most efficient energy-converting plants and the most suitable growing environments.

Note: If sunlight is not available, dry the plants by placing them in a warm oven or under a lamp.

Precautions
None.

Strategies
Before: Have students predict which plants will weigh the most at the end of the experiment.
Discuss how to determine the average height of the plants.

After: Discuss the summary question.
Have the students predict what might happen if the plants were allowed to mature.
Have the students research what is done with most of the corn and wheat in this country.

Results
Corn produces about seven times more biomass than the other grains.

Biomass I - 11

Question

How much can gibberellin increase the biomass produced by barley?

Time

Twenty minutes for initial discussion and planting. 15-day activity.

Objectives

Students will compare the growth of chemically-treated and untreated plants. They will draw conclusions about the effectiveness of chemical treatments and their relative expense.

Process Skills

Observing, measuring, and replicating.

Materials & Procedure Clues

Plant the seeds about 6mm (¼") deep.

Paint gibberellin on the plants only one time.

Substitute tomato seeds if barley is unavailable.

Concept

Chemical treatments are often expensive and may not produce significant additional plant growth.

Background

Gibberellin acid, when applied in very dilute amounts to certain plants, will greatly stimulate their growth. However, not all plants respond to this hormone. In fact, gibberellin acid can kill certain types of plants. Students can rerun the experiment to make sure the initial results were correct.

Using a plant hormone like gibberellin may increase the amount of biomass obtained in a given area, thus reducing the cost of biomass as an energy source.

Note: If sunlight is not available, dry the plants by placing them in a warm oven or under a lamp.

Precautions

Gibberellin is poisonous.

Have students wash their hands after applying.

Do not use on food plants that will be consumed.

Results

Results will vary with the kind of plant and growing conditions.

Strategies

Before: Discuss gibberellin and its advertised properties.

Have students predict which plants will produce the most biomass.

After: Compare the biomass of painted and unpainted plants.

Discuss the summary questions.

Make a graph comparing plant weight and the cost of production for treated and untreated plants.

Biomass I - 12

Question
Which will give more heat energy: green wood or dry wood?

Process Skills
Measuring, observing, and making inferences.

Time
45 minutes.

Materials & Procedure Clues
Collect various kinds of wood shavings ahead of time.

Methanol is used in this activity as a starter fluid to get the wood to burn.

Visit a lumberyard to obtain a variety of green and dry wood samples.

Make your own samples by collecting branches and drying some in an oven.

Objectives
The student will make comparisons between the amount of heat produced from green and dry wood. They will compare heat produced from different kinds of trees.

Concept
Given equal amounts of green and dry wood, dry wood will produce more heat.

Background
If you start with equal amounts of green and dry wood, both have the same amount of cellulose to burn. Green or freshly cut wood, however, is heavier since it contains a great deal of moisture.

Burning dry wood produces more heat than green wood because much of the stored energy in green wood is used to heat the contained moisture. This energy is wasted.

Freshly cut wood should be left to dry naturally for at least six months to a year before using it in a fireplace.

Wood has been and still is a very useful biomass material for supplying heat energy.

Precautions
Methanol is highly flammable.

Strategies
Before: Have the students compare the amount of dry wood necessary to equal the same weight of green wood.

Have students predict which can of water will have the greater temperature increase.

After: Discuss the summary question.

Have students predict the effects of using different kinds of woods.

Results
Dry wood produces about twice as much heat as green wood.

As the developer of *Science Activities in Energy*, Oak Ridge Associated Universities is anxious to learn how you and your students use the activities, what variations you develop, and any results you find extraordinary.

Please let us know your reactions to the activities. Also, feel free to ask for information on any energy-related topic.

Prepared for the U.S. Department of Energy by Oak Ridge Associated Universities, P.O. Box 117, Oak Ridge, TN 37830, under Contract No. DE-AC05-76OR00033.