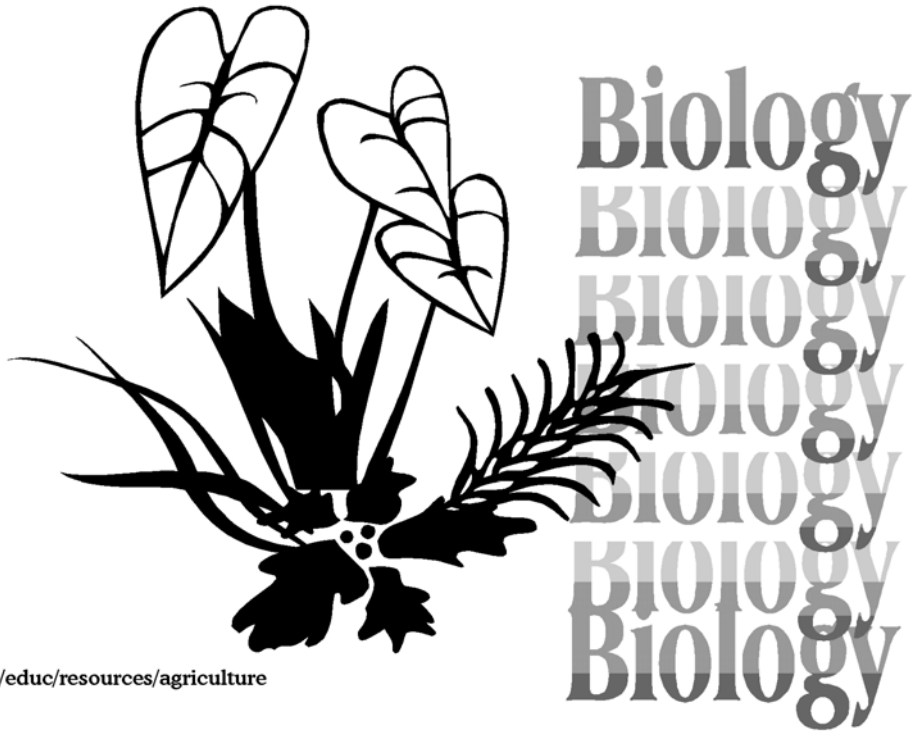
Agri-science Resources for High School Biology



www.gov.pe.ca/educ/resources/agriculture

Acknowledgments

The first edition of *Agri-science Resources for High School Biology* was designed as a an agriculture learning resource for teachers and students. Through a funding partnership between the agricultural industry, federal and provincial governments, this handbook will be made available to teachers and students in high schools across Prince Edward Island.

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for High School Sciences

Biogas

Biology

Science

Grade 10-12

Biology Lab

Teams of 2 or 3

DESCRIPTION

Biogas is a fuel which is produced from the breakdown of organic matter. Students will have an opportunity to create their own biogas generators. At the same time, they will learn about the chemical reactions which occur during the breakdown of organic material.

READINESS ACTIVITIES

Students should:
- have some knowledge of the types of energy sources which are currently being used.
- have a basic understanding of the biology behind composting.

LEARNING OUTCOMES

Students will:
- discover a valuable alternate energy resource

MATERIALS

- a large plastic milk or water jug (about 4 L)
- one rubber stopper containing two holes that fits the jug opening
- one manometer tube (see illustration)
- one pipette
- one burner tip that can be opened or closed (see illustration)
- about 3 L of prepared slurry
- lab aprons, safety glasses, and rubber gloves
- matches
- felt-tip pens and tape or labels

Biogas

Agri-science Resources
for High School Sciences

Biology

Introduction

A major concern for most people these days is the use and availability of energy. Canadians spend a large portion of their earnings on gas, propane and oil. These **fossil fuels** are being continuously used to a large extent. Because these forms of energy are non-renewable, their availability will continue to decrease and costs will continue to go up. This has led to a search for new energy sources.

Biogas

One excellent source of energy is Biogas. This is produced when bacteria decompose **organic material** such as garbage and sewage, especially in the absence of oxygen. Biogas is a mixture of about 60 percent methane and 40 percent Carbon dioxide. **Methane** is the main component of natural gas. It is relatively clean burning, colorless, and odorless. This gas can be captured and burned for cooking and heating. This is already being done on a large scale in some countries of the world. Farms that produce a lot of manure, such as hog and dairy farms, can use biogas generators to produce methane.

Advantages

Biogas energy offers many advantages. Biogas-powered electricity plants can be built quickly, simply, and for much less money per **kilowatt** than coal, oil, or nuclear power plants. Unlike these other current energy sources, Biogas is a **renewable resource**. Methane is going to be produced by **decomposition** whether it is used or not. Methane is also an important greenhouse gas and is a major contributor to the global warming problem. Biogas provides an excellent source of energy that is helpful to the environment. Finally, the residue from the burning of Biogas, called activated sludge, can be dried and used as fertilizer.

In this lab exercise, teams of 2 students will set up their own biogas generators.

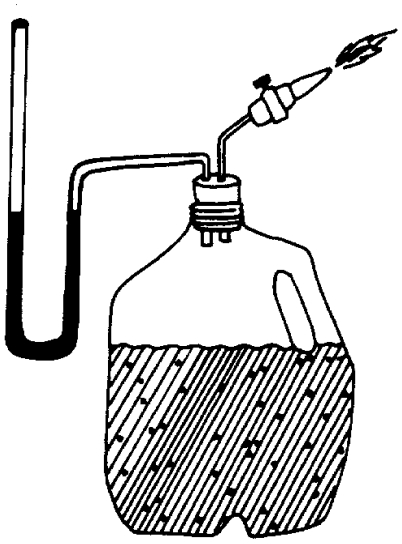

Figure 1. Completed biogas generator. The bent glass tube is called a manometer. It contains water which rises in the tube as gas is produced.

Safety Precautions

There are a few safety considerations to keep in mind during this experiment:

- Be sure to use a plastic jug as the generator. The pressure build-up inside the generator may cause a glass bottle to explode.
- Students should always wear aprons and safety goggles when testing for flammability.
- When testing for flammability, be sure that the burner tip is pointed away from people or flammable materials.
- It is a good idea to wear gloves when handling the slurry and to wash your hands after handling it.

Procedure

1. Collect the slurry material and bring it to the lab. This is used to fuel the generator. It can be manure, household garbage, grass clippings or other green plant material, or dried manure from a garden supply store.

2. Build the generators and label them. Use figure 1 as a guide. The bent glass tube is called a manometer. Insert this into one of the stopper holes. It is used to indicate how much gas is being generated. It also allows for release of pressure if too much gas is produced. The burner tip goes in the other hole.

3. Mix the fuel with water until it has the consistency of cream. This liquefied fuel is called a slurry. Put the slurry into the container. Fill it about three-quarters full. This will prevent foam from clogging the generator. The foam develops as gas is produced. Use funnels if possible.

4. Plug the generator with the stopper and store it in a warm place. Optimum temperatures are about 32-38 ^{o}C. Be sure the stopper fits the opening tightly. The only opening should be through the manometer.

5. Record the types and amounts of components in the slurry. Record the date the generator was created.

6. Check for gas production every day. Keep track of the date and any observations. When the water in the manometer has risen, gas has been produced. Test that gas for flammability by holding a match near the burner tip. BE VERY CAREFUL. The gas should not burn at first. Keep testing every day or two until methane is produced.

7. When methane production stops, discuss possible uses for the remaining sludge. Answer the following questions to help understand the lab.

Questions

1. Was the first gas produced flammable? What was the first gas?
2. The chemical formula for carbon dioxide is CO_2. Methane is CH_4. Why is methane produced better in the absence of air (anaerobically)?
3. Did different materials produce methane at different rates? Which materials produced the most methane or produced methane first?
4. What could methane biogas be used for?
5. Methane biogas is a renewable resource. What does that mean?
6. What are some advantages of biogas as a fuel source?
7. What are some disadvantages of biogas as a fuel source?
8. Can you think of any places on Prince Edward Island where biogas could be used?

Glossary of Terms

decomposition	the decay or breaking down of materials into smaller components
fossil fuels	a non-renewable resource such as gas which is created by the decomposition of organic material
kilowatt	a unit of electrical power equal to 1000 watts
methane	a light, colorless, odorless, highly inflammable gas
organic material	dead plant and animal tissues that originates from living sources such as plants, insects, and microbes.
renewable resource	resources that can replace themselves

NOTE: It could be helpful to create a sample biogas generator in advance. This could serve as a model and help to iron out any problems with the procedure.

Answers to Questions

1. The first gas produced is carbon dioxide (CO_2) which is not flammable.
2. Most bacteria grow more rapidly when they have a source of oxygen. When they run out of "free oxygen" in the air, some can obtain it from other compounds. Bacteria which use these compounds produce methane gas (CH_4) as a waste product.
4. Methane can be used for anything that natural gas is used for. This includes cooking, heating, generating electricity, and for various industrial processes.
5. Renewable resources are those that can be regenerated (such as methane, wood, running water, wind, or geothermal steam) or which aren't used up, such as the sun.
6. Advantages of biogas include its renewability, abundance, the fact that methane is a relatively clean burning fuel, and low cost. Also, it helps with the problem of disposal of organic waste.
7. The main disadvantage of biogas is the loss of the organic waste for compost or fertilizer.

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Agri-science Resources
for High School Sciences

Biotechnology 

Biology

Science

Grade 10-12

Biology Classroom

Individual reading

DESCRIPTION

Biotechnology is a relatively new science with direct applications to the Agriculture industry. This article describes some of the pros and cons of Biotechnology. A few modern breakthroughs are described which apply to Prince Edward Island. These include genetically altered potatoes and tomatoes. Bovine Somatotropin and Pharming in animals are also described.

LEARNING OUTCOMES

Students will:
• learn about new advances in biotechnology
• see how this technology applies to the agriculture industry on Prince Edward Island

READINESS ACTIVITIES

Students should:
• discover the attitudes of friends, parents, or relatives towards biotechnology
• examine their own opinions and see if they change after reading the article

MATERIALS

• copy of article

Biotechnology

Agri-science Resources
for High School Sciences

Biology

Introduction

One of the newest, yet controversial fields in science today is **biotechnology**. Biotechnology began in the 1970s after the development of **genetic engineering** that allowed scientists to modify the genetic material of living cells. Genetic engineering is the manipulation of DNA molecules to produce modified plants, animals, or other organisms. DNA is the part of a cell that controls the genetic information of an animal or plant. DNA is a double-stranded molecule that is present in every cell of an organism. The genetic information is contained in individual units or sections of DNA called **genes**. The genes that are passed from parent to offspring determine the traits that the offspring will have. Scientists are now able to isolate the gene or genes for the traits they want in one animal or plant and move them into another. The movement of a gene from one organism to another is called **recombinant DNA technology**. This technology is advancing at a very rapid pace.

Why?

There are people who question why the world needs biotechnology. Countries like Canada have a surplus of quality food. There are many countries in the world that do not have enough food to go around. One major challenge of the future will be meeting the growing demand for food as the planet's population expands. Farmers have been improving their crops for many years by developing new practices. Now the search is on for ways to speed up the process and create new crops which display distinctive advantages over current strains. The goal of scientists is to improve crop yields and to diminish further damage to the environment through the over-use of chemicals. Scientists have turned to biotechnology to develop these new crops. Many of these plants are able to protect themselves from the viruses and insects which damage them.

Agri-science Resources
for High School Sciences

Causes for Concern

Not everyone views genetically engineered foods as a welcome development. Several organizations have expressed concerns in many areas. This is a list of some of these concerns, followed by the counter argument:

✗ - some people are concerned that genetically altering foods could change their nutritional value by lowering vitamin content or other nutrients.

✔ - others point out that several genetic engineering projects are designed to increase, not lower the health attributes of foods.

✗ - There is some concern that the process of inserting genes is not precise. Scientists can not tell exactly where they go or how many reach their target.

✔ - supporters of genetic engineering insist that it is more precise than traditional **crossbreeding** methods and carries less risk of undesired traits being transferred.

✗ - Some fear that a foreign gene may not behave in a new crop the way it did in the original species. It may interact with genes around it or with its new environment to produce undesirable traits.

✔ - Others point out that traditional plant breeders use well-established practices to eliminate plants with adverse traits prior to commercial use and that transgenic plant breeders can do the same.

✗ - Concerns have been raised about the effect of genetically engineered foods on special populations, such as infants or people suffering from other conditions or diseases. Testing is done on healthy adults, so effects that might emerge in other populations could be missed.

✔ - This situation is not unique to genetically engineered foods. It would be very difficult to test any new product on every specialized population before it is marketed.

✗ - A reaction might occur between two food compounds that may be harmless separately, but together could be **toxic**. There are also concerns that harmless plants that have toxic relatives may have the toxic gene turned on in a recombinant plant.

✔ - Genetic changes that can lead to unexpected toxins can occur not only in genetically transformed plants, but also in plants developed through traditional breeding practices or as a natural part of growth.

✗ - Some people fear that the genes for **resistance** which are inserted into plants will somehow be passed to weeds. Insects may build up resistance to the new **pesticide**. Some think that a gene that is intended to be toxic only for insects will somehow **mutate** and become toxic to humans as well.

✔ - Others cite the fact that the potential of pests to develop resistance against defence mechanisms of crops is well-known and is not unique to genetically engineered plants. Insects may develop resistance to a crop defence no matter how it was developed.

✗ - There are individuals who see a conflict of interest where a company's own scientific data is used to determine food safety. They would like to see a great deal more independent testing.

✔ - Some companies resent this implication that test results from their own laboratories are false. They argue that it is to their benefit to produce safe, beneficial food products because there is no profit in bad products.

✗ - Others fear that new plant species may upset the balance of nature, changing the delicate relationships between crop plants, weeds, and the animals that consume them.

✔ - Supporters of biotechnology foresee a different day when not one, but many improved crop varieties could flourish in areas of the world that currently can not produce enough food crops for the entire population.

Of course there are many more points for both sides of the issue. Debate about genetically engineered foods is a good thing. It helps assure that the companies developing genetically engineered products will continue to address consumer concerns. This way the products will undergo rigorous research, and thus increase food safety. This article will describe some new biotechnology that relates to Prince Edward Island. Remember that there are two sides to each issue. Hopefully, this will read as unbiased as possible and enable students to develop their own opinions.

Plant Products

There are numerous engineered crops being developed and made available for public consumption. Farmers have their choice of several **herbicide**, insect, and disease resistant **hybrids** and varieties. Herbicide tolerance and insect resistance are the major genetic developments in field crops, while delayed ripening and flavour enhancement are the novel properties in vegetables such as tomatoes. Most of this technology began with major field crops such as corn, soybeans, cotton, and potatoes. Now work is being done on specialty crops such as fruits, vegetables, and forages. The amount of acreage occupied by these plants is expected to increase rapidly over the next few years.

Potatoes

The potato is the most popular vegetable among North American consumers. On Prince Edward Island, the mineral rich red soil, warm days, cool nights, and plentiful rainfall provides ideal conditions for growing potatoes. In 1998, approximately 1,300,000 tonnes of potatoes were produced on Prince Edward Island. This accounts for about 30 % of all the potatoes grown in Canada; fairly impressive for such a small province. However, potatoes are not especially easy to grow. Each year, a significant amount of crops are lost to disease and **pests**.

Bt Protein

Plants are now being engineered to produce Bacillus thuringiensis (Bt). This is a bacterium which occurs naturally in the soil. There are **strains** of Bt that produce proteins that kill certain insects. When these insects ingest the protein, the function of their digestive system is disrupted, producing slow growth and eventually death. Another positive feature of Bt is that it is not harmful to humans, other mammals, birds, fish, or beneficial insects. It is not a very effective pesticide for several reasons. It is relatively expensive, it must be eaten by insects as opposed to simple exposure, it is broken down by sunlight, and rain washes it away from plants. This is why Bt is most effective when it is actually contained in the plant itself.

Colorado potato beetle

The Colorado potato beetle is very harmful to the potato industry. The beetle feeds on the growing plant leaves and stems during the growing season, stunting the plant and cutting yields. Many applications of insecticides are usually needed to control the pest. Bt is especially effective against the Colorado potato beetle. When the Bt gene is inserted into the potato plant, the plant produces a protein that is toxic to the beetle. Therefore, when the beetle feeds on the genetically improved plant, the toxic protein interferes with its digestive system and it dies.

NatureMark potatoes

Because the potato is so important to the Island, any new developments in technology will have an impact here. The NewLeaf products are marketed by NatureMark potatoes, a division of the multinational Monsanto company. It has taken many years for these products to reach the produce aisle. Health Canada has concluded that NewLeaf potatoes are as safe and nutritious as other commercially-available varieties.

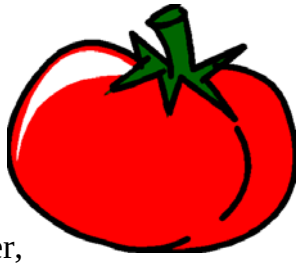
NewLeaf varieties have built-in resistance to the Colorado potato beetle, potato leaf roll virus and Potato Virus Y (PVY). This PVY virus is well-known by Islanders because of its tremendous effect on the potato industry a few years ago. Before 1997, only one farmer from Prince Edward Island had grown a NewLeaf variety. Now, in 1999, there are a number of farmers trying the NewLeaf varieties and in 1998 there were approximately 9800 tonnes of NatureMark potatoes grown on PEI.

The Future

There are more genetically-altered potatoes on the way. Several virus-resistant potato varieties are planned for release in 2000+. These include potatoes stacked with both Bt, resistance to potato leafroll virus and potato virus Y as well as resistance to late blight and bacterial soft rot.

Genetic engineering is also being used to develop potatoes with more starch and less water to prevent damage during harvesting. A potato with less water content may absorb less oil when it is fried, producing healthier french fries or potato chips. Other researchers are using genes from chicken embryos and insect immune systems to try to make potatoes more disease resistant.

Tomatoes



Although the tomato industry is not as important to Prince Edward Island, there are many home gardeners who grow them. Many people eat tomatoes in salads and sandwiches. There are also many other tomato products such as ketchup, spaghetti sauce, and soups. However, tomatoes found in local supermarkets are not very tasty compared to garden-grown, vine-ripened tomatoes. Consumers in Northern regions must rely on tomatoes shipped from the south to get fresh tomatoes at most times of the year.

Taste Problem

In order for tomatoes to be shipped, they must be picked at the mature-green stage. Mature-green tomatoes have already absorbed all the vitamins and nutrients from the plant that they can, but have not started to produce the natural **ethylene** gas that triggers ripening. The green tomatoes are then put into ripening rooms, where ethylene gas is released. They spend 3 to 4 days in the ripening room before being shipped at temperatures not lower than 10 ^{o}C. Cooler temperatures destroy tomato flavour. When tomatoes arrive at the grocery store, they are still 3 to 4 days away from being ripe. A company in California, genetically engineered a tomato to help overcome this problem. The name of the vegetable they developed is the Flavr Savr Tomato.

Flavr Savr

The scientists have developed a tomato with a gene that slows the natural softening process that accompanies ripening. **Pectin** occurs in many fruits and contributes to their firmness. The pectin in ripening tomatoes is broken down by an enzyme called polygalacturonase. As the pectin is destroyed, the cell walls of tomatoes break down and then soften. The scientists were able to reduce the amount of this enzyme in tomatoes, which slowed the rate of cell wall breakdown and produced a firmer fruit for a longer time. Therefore, the Flavr Savr tomato spends more days on the vine than other tomatoes. This allows sugars to be transported to the fruit, resulting in more flavour. At the same time, the tomato remains firm enough to be shipped. Because of the genetic modifications, the Flavr Savr also has a longer shelf life than regular supermarket tomatoes.

Animal Products

Biotechnology can also be applied to animals. This is where animal rights' groups become involved in the debate. They believe that animals should not be modified genetically. These are two examples of biotechnology involving animals.

Milk Industry

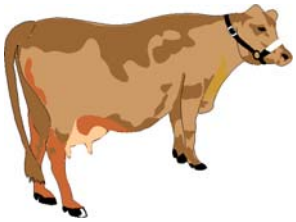
The milk industry is also very important to Prince Edward Island. Many dairy farms on the Island have been owned by the same family for several generations. On a national level, Quebec and Ontario account for most of the milk production in the country. Still, according to Statistics Canada, in 1995 the cows in this small province were able to produce about 95,400,000 litres of milk and cream. New technology and advancing farming practices continues to increase production. None of these past discoveries have had such a dramatic impact as Bovine somatotropin.

Bovine Somatotropin

Bovine Somatotropin (bST) is a metabolic protein **hormone** used to increase milk production in dairy cows. Hormones are chemicals that are secreted by glands within the body. **Somatotropins** (growth hormones) are protein hormones made in the **pituitary gland** located at the base of the animals brain. These substances play a key role as the master hormone that regulates both growth in mammals and the metabolism of nutrients in the diet. Milk production in cows is under hormonal control. In order for cows to continue producing milk, these growth hormones must be continuously secreted. In the 1930s, it was discovered that injecting bST into milk-producing cows can significantly increase milk production.

Source of the Hormone

Until recently, the only source of bST was from the pituitary glands of slaughtered cattle. Only small quantities of bST were available, and it was very expensive. Using biotechnology, scientists were able to produce a great deal of the hormone at a much lower cost. First they determined which gene in cattle controls the production of bST. They removed the gene from cattle and inserted it into a bacterium called Escherichia coli. This bacterium acts like a tiny factory and produces large amounts of rbST (recombinant bovine somatotropin) in controlled laboratory conditions. The rbST produced by the bacteria is purified and then injected into cattle.



Mode of Action

To affect a cows milk production, rbST must be injected into the animal on a regular basis. Feeding rbST to cows will not work because the hormone is broken down in the digestive system of the cow. Although most of details have been explained, scientists are still not exactly sure how rbST increases milk production. This is why there are some concerns. It is thought that the hormone increases blood flow to the gland responsible for producing milk (mammary gland). This increases the amount of nutrients available for milk production. Researchers have found a milk production increase of 8.4 pounds per day. To meet the needs for this increased milk production, treated cows consume from 10 to 20 percent more food in the form of grain and **forage**. There are many factors which affect the response of cows to rbST. These include quality of management, milking practices, nutrition, cow condition, and environmental conditions.

World Debate

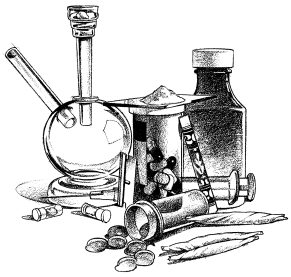
The commercial use of rbST in dairy cattle is controversial and has stirred heated debate among the dairy industry, activist groups, and consumers. The status of the hormone drug is different in many countries. The company Monsanto was licensed to sell Posilac, the trade name for bST, by the US Food and Drug Administration in November, 1993. BST is also allowed in Mexico. The European Union has already imposed a moratorium on the drug until the year 2000. This means release of the drug is delayed until more research and testing can be done.

Canada

In Canada, for a new veterinary drug to be approved, it must be investigated by Health Canada. A demonstration must be made that there is no risk to humans who consume animal products from treated animals, that animal health is not adversely affected, and that the drug is effective. If these questions are answered satisfactorily, Health Canada approves the drug. The Ministers of Agriculture and Health then formally approve the products for sale or use. This whole process can take up to several years. However, the process has enabled Canada to become recognized around the world as a leader in the standards of health of its human and animal populations.

With respect to bST, the approval process was much more complex. On August 17, 1994, in response to the recommendation that a moratorium be put in place, the government obtained a commitment from the manufacturers of rbST for a one-year voluntary delay on the use and sale of rbST in Canada. In May of 1995, the rBST Task Force presented a "Review of the Potential Impact of Recombinant Bovine Somatotropin in Canada" to the Minister of Agriculture and Agri-Food Canada. Health Canada is still in the process of investigating rbST hormone. As of July 14, 1997, The Dairy Farmers of Canada, a national organization that represents all dairy farmers in Canada, passed a resolution asking the federal government to fulfill three specific conditions before finalizing its authorization for the licensing of rbST in Canada. The dairy farmers requested that the Auditor General of Canada complete a comprehensive audit of the approval process of rbST to ensure that any claims questioning its integrity are fully dispelled and that the safety of the product be confirmed by recognized international health organizations such as the FAO/WHO Codex Alimentarius Commission. Finally, Health Canada must agree to fully inform the public about the assessment process and the rationale it used in its evaluation of rbST. What the future holds for this product is still unclear. It is certain that it will take more time before rbST-derived milk products appear in grocery stores across Canada.

Pharming



Another application of biotechnology involving animals is Pharming. Pharming is the production of human pharmaceutical drugs in farm animals. There are many drugs that are needed by humans which are made of protein. **Insulin** is a good example. This protein is used to treat diabetes. Previously, the only way of obtaining insulin was to collect it from slaughtered pigs. Therefore, protein drugs such as insulin, were available in extremely limited supplies.

Human Drugs

Using genetic engineering, the DNA gene for a protein drug of interest can be transferred into another organism that will produce large amounts of the drug. Human genes can be transferred to microorganisms or other animals to make human proteins. The first successful products of this technology were protein drugs like insulin and growth hormone. These drugs do not have to be produced by mammals to be active in mammals. Genetically engineered bacteria can be used to manufacture these drugs. Bacteria have already been used in the production of insulin.

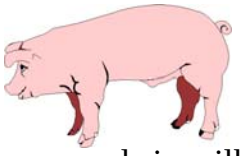
Pharm Animals

Unfortunately, microorganisms such as bacteria are not able to produce all human proteins. Some protein drugs require modifications that only cells of higher organisms like mammals can provide. This is why pharm animals are used. These animals are used as simple factories that can produce any human protein. A transgenic animal for pharmaceutical production should produce the desired drug at high levels without endangering its own health. The animal should also pass its ability to produce the drug at high levels to its offspring.

Why the Milk?

Livestock are the best subjects for this technology. The current strategy is to insert the DNA gene for the protein drug into the animal so that the drug is made only in the milk. Since the **mammary gland** and milk are not involved in the main life support systems of the animal, there is virtually no danger of disease or harm to the animal in making the foreign protein drug. The drug can then be purified from the milk which can easily be obtained from the animal.

Blood Donors



Although most protein drugs are made in milk, one exception is human **hemoglobin** that is being made in pig blood. The human hemoglobin is then extracted and used as a blood substitute for human blood transfusions. This method will be one of the few exceptions to the whole process. This is because to recover the human hemoglobin, the animal producing it must be slaughtered. That is a costly procedure considering how difficult it is to obtain a successful transgenic animal and the long time periods involved for the animals to mature. Obtaining the drugs from milk is a much better solution because the animal is not harmed. Still, this does offer an emergency supply of blood which may not be available from blood donors.

Future of Pharming

Transgenic animals will likely be raised by the pharmaceutical companies. The technology is still in the development stage and may be available to the public by the year 2000. Human drugs purified from animal milk or blood are likely to required exceptional levels of safety testing before animal and human health concerns are addressed to the satisfaction of consumers. In the future, animals may be used to produce human organs.

Activities

Organize a debate in the classroom about one or all of these issues. What you have just read only touches on all the new discoveries being made in biotechnology. The subject has been in the news quite often. Use magazines, old newspapers, books, or whatever to find your information. Any students in your class that live on a farm would also be a good resource. Every issue has a good argument for each side. This should make for a very good debate. It should also give students an idea of the kinds of arguments which are in the process of being formed over this issue.

The class could also arrange a forum or panel presentation on the subject of Biotechnology. Arrange for several volunteers from the agriculture industry to participate in this activity. It should be possible to get several individuals on both the pro and con sides of the issue.

Glossary of Terms

biotechnology	use of cells or components of cells to produce products or processes
crossbreeding	with animals, the breeding of one recognized breed of animals to another recognized breed.
ethylene	gas used in the process of ripening tomatoes and other fruit
forage	crop plants grown for their vegetative growth and fed to animals
gene	a unit of hereditary material located on a chromosome
genetic engineering	movement of genes from one cell to another
hemoglobin	the pigment found in red blood cells
herbicide	a substance used to kill weeds
hormones	chemicals released by cells that affect cells in other parts of the body. Only a small amount of hormone is required to alter cell metabolism.
hybrids	plant or animal offspring from crossing two different species or varieties

Biotechnology

insecticide	agricultural chemical used to kill insects or prevent them from destroying crops
insulin	chemical used to control blood sugar levels. In most people, insulin is secreted when blood sugar levels are high
mammary gland	gland of the milk-producing system in the female
mutate	when the DNA within a chromosome is altered. Most mutations change the appearance of the organism
pectin	material which gives structure and firmness to fruits and vegetables
pesticide	chemical used to control pests
pests	any organism that adversely affects man's activities
pituitary gland	gland which secretes chemical hormones in the body
recombinant DNA technology	an application of genetic engineering in which genetic information from one organism is spliced into the chromosome of another organism
resistance	power to ward off disease
somatotropins	growth hormones secreted from the pituitary gland
strains	a certain stock or specific breed of an organism
toxic	a substance which causes injury to animals or plants

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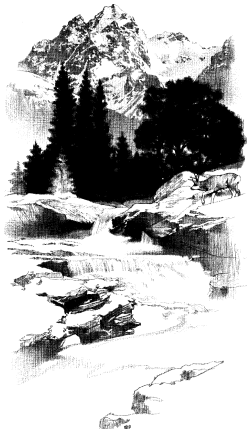
Agri-science Resources
for High School Sciences

Eco-Enrichers

Biology



Science

Grade 10-12

Biology Lab

Teams of 2 or 3

DESCRIPTION

Wildlife is an important contributor to a healthy ecosystem. Each member plays a crucial role from the bottom to the top of the food web. This activity is designed so that students will recognize one example of the kinds of significant contributions from wildlife. Earthworms will be the model example. These animals are not thought to play a very large role in any ecosystem. The exercise will demonstrate that they do have an important role when it comes to enriching a growing medium such as soil.

MATERIALS

- three 30 cm x 30 cm x 30 cm containers
- enough soil from the soil from the same source to fill these containers
- earthworms
- composting material (kitchen scraps, yard leaves, etc.)

LEARNING OUTCOMES

Students will:
- evaluate the importance of plant and animal matter as contributors to soil.
- recognize that wildlife in many forms contributes to the diversity and balance of ecosystems.

READINESS ACTIVITIES

Teachers should:
- find an appropriate place in the lab to leave the containers. The containers should be kept away from any type of disturbances.

Students should:
- have some idea of how to catch earthworms
- become familiar with composting

Introduction

There are many different types of living organisms on this planet. This is a fact which is often forgotten by many humans. The truth is that humans could not survive without these other organisms. For example, plants convert solar energy into a form of energy that can be consumed by other animals. Humans consume plants or plant-eating animals to survive. Everything is connected in many different ways. Plants, human, and many organisms can all belong to the same ecosystem.

Ecosystem

The term ecosystem is used to describe a system of plants, animals, and the physical environment in which they live. Some examples of ecosystems are lakes, woodlots, estuaries, farm fields, or even cities. An ecosystem can be of any size, depending on what is going to be studied. They can range in size from the water in a plant, to a tropical rain forest system. Ecologists are scientists who often study ecosystems. They commonly view an ecosystem in terms of energy flow, carbon flow, or nutrient cycles.

Soil

A part of any terrestrial ecosystem is the soil in which the plants grow. To an ecologist, soil represents a thin layer of the earth's crust that has been remade by life and weather. Different ecosystems have different soils, with their own mixtures of organic matter and their own layering. Soil, to an ecosystem is a nutrient delivery system, a recycling system, and a waste-disposal system. For plants, soils are sites of germination, support, and decay. For animals, soils are a shelter, a sewer, or an whole habitat. Soils are a resource for decomposers.

Worms

Although many people rarely think of worms as more than fish bait, they are actually very valuable to soil. But the earthworm has all but been forgotten in modern agriculture. So much of what the earthworm used to do for free is now done by tractors and chemicals. Many of these modern farming practices decrease the abundance of earthworms. Cultivation of the land, as well as pesticide and fertilizer applications can adversely affect earthworm populations. If soil does not have a high number of earthworms, they can return if conditions are improved. They are certainly a valuable component of any soil. Here are some of the advantages of having earthworms:

- Earthworms churn the soil and make it porous for maximum plant growth.
- The maze of tunnels created by earthworms increases the soils ability to absorb water.
- Earthworms neutralize soil pH with their castings, or manure. Soil that comes out of an earthworm in this form is closer to neutral pH, regardless of whether the existing soil is above or below pH 7.
- Earthworms bring up minerals and make plant nutrients more available.
- Earthworm burrows stimulate the growth of nitrogen fixing bacteria, which are very important for plant growth.
- The gut of an earthworm mixes, conditions, and inoculates plant residues, turning it into free manure.
- Earthworms are a good indicator of healthy soil. Soil with earthworms tends to have less plant-eating invertebrates than soil without earthworms.

It is obvious that earthworms are always working to make the soil better. They do this not only for their own survival, but for the healthy survival of their primary food source, the residues from crops. ***They are truly a farmer's best friend.***

In this lab exercise, students will gather soil and combine it with some type of organic matter. Worms are then added to this mixture. Analysis will be done on the soil before the worms are added and after they have had a chance to work the soil. This will give students an idea of the valuable role that worms play in an ecosystem.

First a Word on Worms

Worms can live in a plastic bin or wooden box, with plenty of air holes punched in the sides and top. Don't make the holes too big or the small ones will get out. Loam or black topsoil is good material for the containers. This is available at local garden centres. A mixture of sawdust, peat, shredded leaves, and soil would also be good. The organic material will be mixed into this material.
The kind of worms available for fishing bait would be the most appropriate for this experiment. Field worms are better at digesting organic materials that are already well decomposed and aren't likely to survive in a worm bin on a diet of kitchen scraps. If field worms are the only type available, the ones that die will have to be replaced by new ones.

Coffee ground, vegetables, and fruit are good worm food. A varied diet is important. Avoid using bones, dairy products, meats, garlic, and potato peelings. Eggshells are important for preventing the mixture from becoming too acidic for the worms.
Worms can survive at temperatures from 4 to 32 ^{o}C, but prefer a temperature at or above room temperature. The worm bins should also be place in an area that is free from disturbances. Most importantly, **keep the worms out of the light.**

Procedure

1. Try to select a poor quality soil. This type of soil might be heavily compacted and found by a roadside or in an area where there has been a lot of erosion. Remember to take a large enough sample of soil to be able to fill the three containers (30x30x30cm).

2. Analyze the soil quality by performing a few simple tests. Record your results.
   - Try testing the acidity or alkalinity with a pH meter or litmus paper
   - Look for signs of plant or animal matter in the soil. Count the number of species you can identify. You could also try examining a sample under a microscope. See if you can find any small organisms.
   - Check porosity by determining how fast water will run through it.
   - Conduct a settling test by simply combining the soil with water in a vial. This will indicate the general proportions of soil components which are present (sand, silt, clay, or organic matter).

3. Divide the soil into the three containers. One of these will be the control. The second will contain soil and compost only. The third is for soil, compost and earthworms.

4. Add the composting materials like table scraps, grass clipping, leaves, or whatever to the second and third containers. Now add earthworms to the third container.

5. Water the soil occasionally, but very lightly. You can do this to each box to simulate a rainstorm. Do nothing else to the first box of soil.

6. You will need to keep adding food and other composting material to the second and third containers. It would be good to add materials once a week for three weeks. All the containers have to be watered lightly about once a week. Record any observations during this time.

7. After three weeks, perform the same soil test again. Conduct each test on all three boxes.

- You could also try planting seeds in the containers. Plant the same number of seeds in each container. Record the date of planting, as well as watering procedures and any observations. After three weeks, compare and discuss the results.

Questions

1. Discuss the finding from the earthworm experiment. What are the differences between the three soil samples?

2. Describe the importance of plant and animal matter as contributors to soil.

3. List three ways that earthworms have a positive effect on soil.

4. Name three other types of wildlife, and describe briefly how each contributes to improving or maintaining soil.

Notes

- To speed up the entire process, use a larger number of earthworms with a larger soil box.

- Some of the earthworms may die during the course of the experiment. You may have to add new worms in case this does happen.

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Agri-science Resources for High School Sciences

Science

Grade 10-12

Biology Classroom

Individual Reading

Pesticides

Biology

DESCRIPTION

Pesticides are used extensively to control pests, which can harm crops and other plant species. There are many different types of pesticides. They are mostly synthetic chemicals designed to affect a specific target. Concern over pesticide use is a major issue among many organizations. This article describes pesticides, why they are used, and why they generate so much concern.

LEARNING OUTCOMES

Students will:

- examine the impact of pesticides on the environment, the economy, and the health and well-being of society
- recognize the significant role of synthetic chemicals in today's agriculture
- identify how public concern for the environment affects agriculture

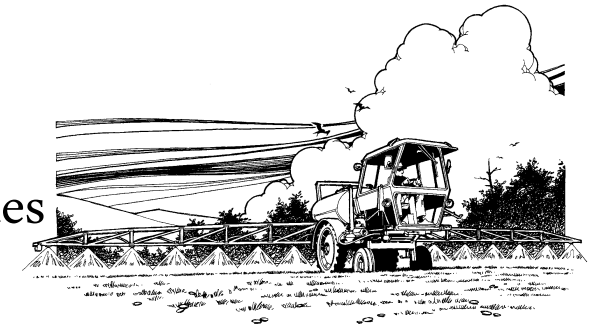
READINESS ACTIVITIES

Students should:

- read some recent newspaper or magazine articles for updates on the pesticide issue
- see if there are any types of pesticides around their own homes and what they are used for

MATERIALS

- Copy of article

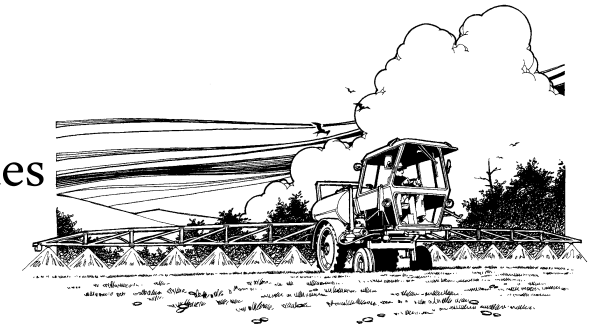


Introduction

There are many plants and animals which co-exist with crops in a farmers field. Less than one percent of these plants and animals are **pests**. Pests are organisms which attack crops and harm them in some way. It is critical that these pests are controlled for a farm to earn the best income. The use of synthetic **pesticides** in agriculture world-wide is still the most widespread method for pest control. Farmers could not achieve the same yields without the use of synthetic pesticides. It is estimated that without them 30% of world crops would be destroyed by harmful organisms such as insects, weeds, or plant diseases even before they were harvested. Pesticides prevent these loses by controlling such pests. Pests can also render food unfit for consumption, harm human health and also harm the environment. In crops like cotton, tomatoes or melons, difficulties in pest control have forced farmers in some countries to abandon these crops completely.

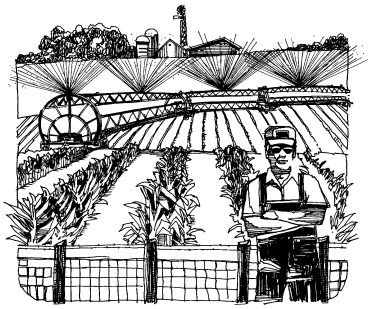
Pesticides

Chemical control is the use of pesticides to reduce pest populations. The three major pesticide categories are **herbicides**, **insecticides**, and **fungicides**. Herbicides are chemicals that are used to control weeds, insecticides are chemicals used to control insects and fungicides are chemicals used to control plant diseases caused by fungi. There are many different types of these pesticides which affect pests in many different ways. Within each pesticide group are numerous chemicals for use in specific applications. Depending on the chemical structure, the pesticide may interfere with the growth, reproduction or development of the pest or may induce damage to the internal systems, resulting in death. Some pesticides are more popular than others for reasons such as potency, availability, cost, and safety. There are usually a few brand names of pesticides which dominate the market. It is important to remember that no pesticides kill 100% of the pests all the time. They simply kill enough pests so that the few remaining are no longer a problem. Most pesticides commonly used for agricultural, home and garden use belong to chemical families that are not toxic to humans or animals, do not pose cancer risk to humans and do not accumulate in the environment.



Application

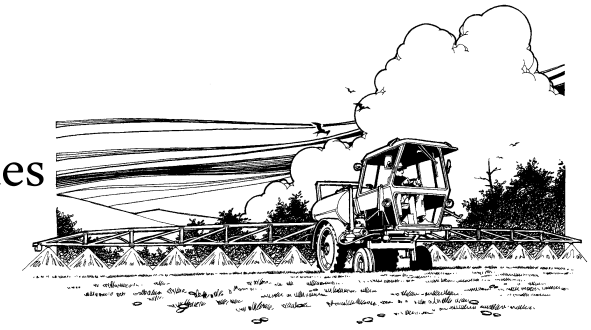
When farmers spray pesticides, they try to distribute a small amount of active ingredient to the appropriate biological target without contaminating other areas. There are many different types of targets for pesticides. These include insects, plants, or soil. A variety of application techniques are required to affect these targets while using as little pesticide as possible. The equipment used for pesticide application ranges in price and complexity. Some application techniques include:



- release from the air in the solid state as dusts or granules or in the liquid state as sprays
- injection into the plant
- injection into the soil
- release into water which is then used for **irrigation**
- release from aircrafts when the areas to be treated are large and when operations on the ground are either not possible or will cause damage

Not Just on the Farm

Pesticides are more widely known for their use on farms to protect crops. Chemicals are used by people everyday to get rid of pests. Remember the last time you used Raid or Off? Pesticides are used mostly to control insects, in homes, office buildings, schools, hospitals, supermarkets, and many other common areas. Most of these products are in the form of aerosols, pest strips, baits, pet products, and insect repellents. Pesticides are also used on lawns, gardens, golf courses, parks, and recreational areas.

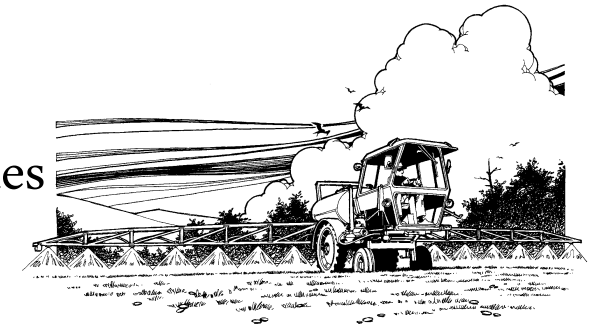


Pesticide Safety

Because pesticides can kill pests, they also pose a potential risk to other organisms such as humans. For this reason, they are not allowed to be used without the most thorough checks and safeguards to ensure that they do not harm humans, other species, or the environment. Because of the concerns, synthetic pesticides have undergone a development process to match with today's requirements. They have become less toxic for humans, they have become more specific, and they have become more powerful. For example, 40 years ago pesticides were applied in kilograms of litres of active ingredients per hectare. Modern pesticides only require grams or millilitres to achieve the same of better results. Remember that pesticide residues remain only on the surface of produce. Rinsing with clear water will remove most of any trace residues.

Pesticide Problems

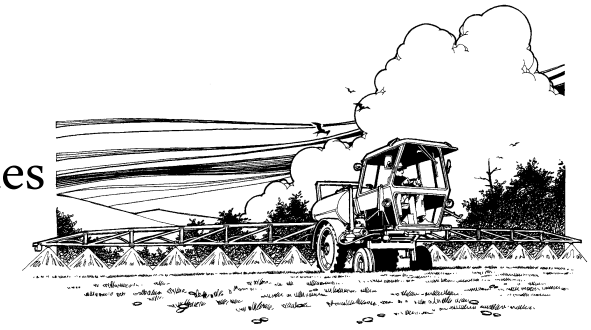
There are various problems which can occur when using synthetic chemicals to control pests. Some pests can build up **resistance** to pesticides. Pesticide resistance is the ability of an organism to tolerate a lethal level of a pesticide. This results in larger applications and a reduction in the effectiveness of the pesticide. Many of the chemicals used are not selective. They may also kill beneficial species, such as bees which pollinate crops. Synthetic chemicals may end up hurting the plant the farmer is trying to preserve. Environmental pollution is another problem as pesticides may build up in the soil or run off in the water supply. Pest **resurgence** may also occur. Pest resurgence occurs when a pest population level can establish itself after control measures against the population have been eliminated or reduced.



In some countries other than Canada, the irrational use of pesticides and equipment has led to serious problems. In some crops, the costs of pesticide use are already higher than the benefits. While modern pesticides have reached the most remote parts of the world, the application equipment matches that which existed 40 years ago. This has resulted in large wastes of pesticides and unnecessary environmental contamination. Farmers and application equipment operator's knowledge of pesticides and the correct method of application is usually deficient or non existent. In many cases they do not receive any training on the issue. Sometimes, the only specialists are representatives of pesticide companies. Of course it would be a poor business move for them to show farmers how to save money by using less of their product. Some farmers and spray equipment operators still believe that the more pesticides you use, the better. The lack of technical knowledge and awareness of farmers and manufacturers are the main reasons for the low quality of equipment found in some countries. There are also many cases of poor equipment maintenance. Many products which are considered to be highly or even extremely toxic and can lead to a considerable amount of poisoning are still used in some countries.

Pollutant

After a pesticide is applied not all of the pesticide remains where it is needed. When a pesticide leaves the target area, it is often considered to be an environmental **pollutant**. Movement of pesticides can occur in several ways. Drift, soil leaching, run-off, improper disposal and storage, and improper application are some of the major causes. Pesticide drift is a major cause of soil and air contamination. Drift occurs at the time of pesticide application when small spray particles are moved by air currents to nontargeted areas. Most of these sources of contamination can be avoided with proper care and handling on the part of the farmer.

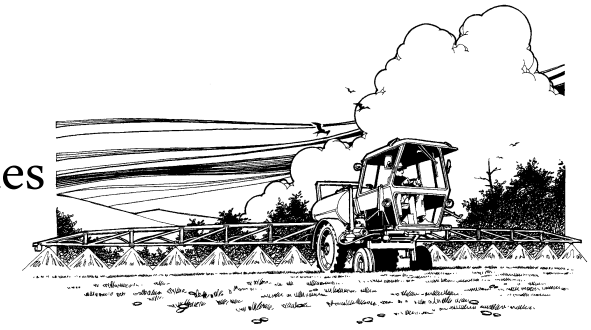


New technology

Pressure for the use of pesticides in a manner that is safer for environment and humans has led to new approaches to pest control. Modern application equipment allows a fairly safe and efficient application of pesticides of all kinds. Legal requirements and farmer's demands have forced equipment manufacturers in Europe to offer only state of the art machinery. The equipment is designed to help prevent unnecessary contamination, accidents, losses and spills. The use of modern electronics has improved the accuracy of pesticide spraying. The Global Positioning Systems (GPS) for precise tracking has improved the safety of aerial pesticide spraying. GPS technology also allows patch spraying against certain weeds. If a weed is detected by the GPS system, the nozzle on the sprayer is opened only at that point. Therefore, lower amounts of pesticides are used. The entire field does not need to be dosed, which saves money for the farmer.

Alternatives

Non chemical alternatives for pest control have existed for quite some time. Some non-chemical alternatives include cultural practices such as **crop rotation**, choice of resistant plant varieties and use of biological products and agents. The concept of pest management, where synthetic pesticides are only applied as a last resort, is now considered common practice in professional agriculture. The development of plants with built-in pest resistance is a valuable alternative. This can be done by selecting plants with pest resistance, by **crossbreeding** a crop plant and a plant with a desirable characteristic, or by using plant **biotechnology**. However, some of these new developments have also encountered significant opposition.



Biological Control

Biological control uses natural agents such as predators, parasites, and pathogens to control pests. The natural enemy of an insect can be introduced to the crop. For example, the aphid is a pest which eats many crops. Lady bugs eat aphids. Animals such as this which control pests and help a crop are called **beneficial species**. There can be some problems with this method. It might take more time than is needed for the farmer to save his crop, it may not be affordable, and it is sometimes hard to predict if the beneficial species will have other adverse effects on the environment. Biological control requires a thorough understanding of the biology and ecology of the beneficial organism, as well as the pest.

Organic Farming

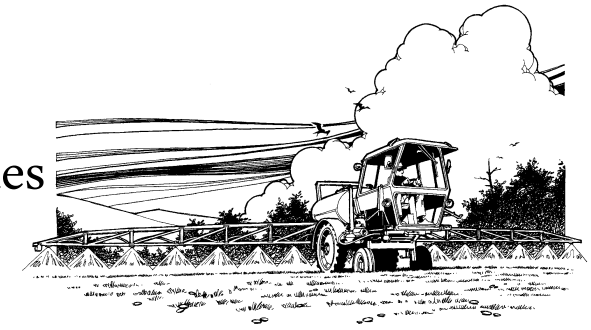
Organic farming involves growing crops without applying synthetic fertilizers, herbicides, or pesticides. Only natural products, such as composted manure, are used to improve soil quality. Many natural products are used to control pest populations. For example, insecticidal soaps and oils are effective at controlling many different insects. These soaps and oils are non toxic to humans and pets. Botanical pesticides are derived from raw plant materials like flowers, roots, and stems. They are also safe to humans. Both types of chemicals can damage plants and kill beneficial organisms if care is not taken in their use. Here are two recipes for making these chemicals:

SOAP and OIL

1 Tbsp liquid dish soap
1 cup oil (peanut, corn, soybean, or sunflower)
1 cup water

GARLIC OIL

½ cup minced garlic
2 tsp mineral oil
1200 ml water
1 tsp liquid dish soap



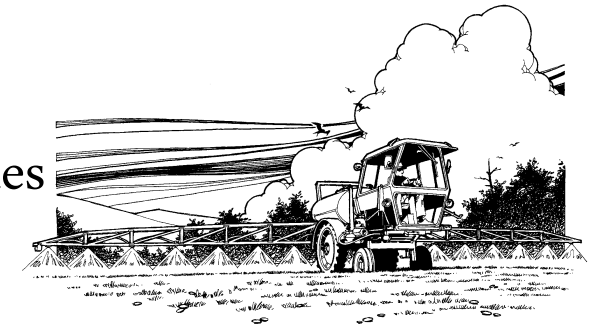
Organic agriculture appears to be gaining acceptance on Prince Edward Island. There are more than 30 certified organic growers on the Island. More than 1,000 acres of land are currently being used to grow crops such as apples, blueberries, vegetables, herbs, soybeans, potatoes, hay, buckwheat and grain.

Natural Food Substances

Many people are alarmed by the addition of man-made products, including small amounts of regulated pesticide residues, to their food. These people may be alarmed to find out that many substances which occur naturally in food can be just as harmful. Food-borne disease easily affects the most people. Usually this is due to the way food is handled or stored. Over consumption, poor food choices and less than desirable intake of many essential ingredients is also a major problem. Natural toxins in foods can be a problem when a person's diet is poor. Hazards from pesticide residues or food additives are only a minor problem when it comes to harmful foods. Most people would view these hazards virtually in reverse order of importance. Chemicals used as pesticides are popularly considered the key threat to food safety by many. Lack of education on the subject and media propaganda are responsible for this.

Carcinogens

The residues of a few pesticides used on food crops can pose potential health problems by acting as carcinogens. A carcinogen is a material capable of causing cancer. Some recent studies seem to indicate that many natural compounds in food may pose greater cancer risks than man-made carcinogens. People should rest assured that the actual cancer risk from both natural and man-made compounds is minutely small. All of the food which we eat is tested very carefully. Simply eating a balanced diet that includes most fruit and vegetables is actually a good way to fend off cancer.



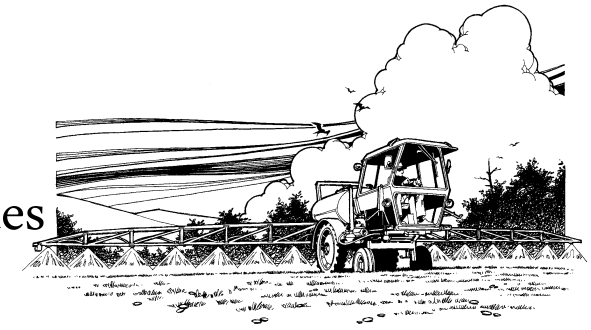
Pesticides in Canada

Canada's pesticide regulatory system is one of the most stringent in the world. The Food and Drugs Act in this country limits pesticide residues in foods to no more than 0.1 parts per million. Each year, the federal government tests thousands of fruit and vegetable samples to ensure maximum residue limits are not exceeded. Any imported produce must meet the same standards. Responsibility for pesticide regulations is administered by Health Canada. Before being registered for use, all pesticides are approved by the Pest Management Regulatory Agency under Health Canada. Pesticide use in Canada is lower than most countries. Canada uses less than one twentieth of what is used in the Netherlands, a fifth of what is used in France and less than half of what is used in the United States.

Local Concerns

There is a growing concern about the known and unknown consequences of pesticides on environment and human health. This has led to a strong public pressure to reduce their use. Some farmers on Prince Edward Island have already encountered this pressure. In 1996, some residents who live along the Mason Road in Stratford complained that drift from the spraying of nearby potato fields was making them ill. A study by the Provincial Health Officer found no relation between pesticide sprays and the symptoms experienced by these residents.

During the summer of 1997, the Town of Stratford presented its official plan to the provincial Attorney General. It called for a ban on "intensive agriculture" practices in the town's residential zone. This would put an end to potato farming in Stratford. After consulting with the town and agriculture groups, the Attorney General signed the plan in July. As of August 1997, the term "intensive agriculture" was still in the process of being clearly defined.



Many farmers around the Island are concerned about the precedent that Stratford is attempting to set. The general sentiment is that if the ban is allowed in Stratford, what will stop other communities from following the same example.

Education is the Key

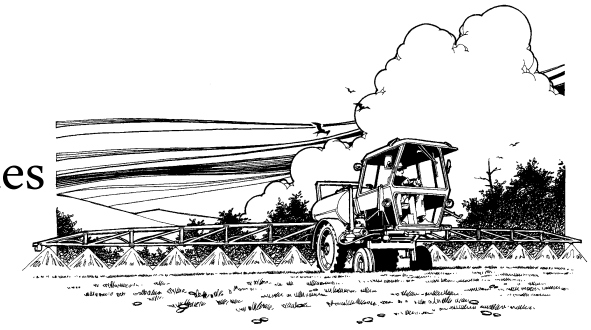
The lack of knowledge at all levels has been identified as the main reason for deficiencies in pesticide application practice. Because of the Pesticide Act on Prince Edward Island, farm owners and managers are required to be licensed as pesticide applicators. Practical training of farmers and equipment operators has been introduced. Continuing education will provide the technical knowledge necessary for a safe and efficient application by the industry. The public also needs to become educated about the benefits and drawbacks of pesticide use. This would allow them to form their own opinions instead of being influenced by what they hear on television or read in the news.

Activity

Organize a debate in your classroom. Use one group to explain the benefits of pesticide use and another to explain the drawbacks . Review any current headlines involving pesticide use. Do any of these stories have an impact on your community? Do you know any of the people associated with one view or the other? There are many other issues involved other than those presented in this article.

Glossary of Terms

beneficial species	an organism which can control pests and is helpful to a crop
biological control	pest control that uses natural control agents
biotechnology	use of cells or components of cells to produce other products
crop rotation	planting of different crops in a given field every year or every several years
crossbreeding	is the breeding of one recognized breed of animals or plant species to another recognized breed or species



fungicides	a material used to destroy and protect against fungi
herbicides	a substance for killing weeds
insecticides	a material used to kill insects or protect against their attack
irrigation	addition of water to plants to supplement that provided by rain or snow
pesticides	chemicals used to control pests
pest	any organism that adversely affects man's activities
pollutant	a substance containing harmful chemicals or organisms
resistance	the ability of an organism to develop protection against harmful substances
resurgence	the ability of an organism to re-establish itself after suffering great losses

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Agri-science Resources
for High School Sciences

PowerSeeds

Biology

Science

Grade 10-12

Biology Lab

Teams of 2 or 3

DESCRIPTION

There are many different types of plants in the world. Most common plants are angiosperms. Plants have the ability to grow through very hard structures. Although they appear fragile to humans, they are actually very powerful organisms. This lab will demonstrate the just how powerful plants really are.

READINESS ACTIVITIES

Students should:
- review the parts of a plant
- read about the process of germination

LEARNING OUTCOMES

Students will:
- review the two major angiosperm classes
- examine the factors needed for seeds to germinate

MATERIALS

- Grass seeds
- Corn seeds
- Pea seeds
- Lettuce seeds
- Plaster of Paris
- Cement mix
- Spackling paste
- Spackling knife
- Fine-point permanent marker
- Paper towel
- Trowel
- Newspaper
- Metric ruler
- Seed-starting mix
- 40 clear plastic cups (9cm tall,6 cm wide)

Introduction

Angiosperms (Division Anthophyta) make up most of the plants on the Earth. Plants such as trees, flowers, fruits, vegetables, and field crops all belong to this division. Altogether, there are about 235,000 species of Angiospersms. The division Anthophyta includes two classes; The monocotyledones (**monocots**) and the dicotyledones (**dicots**).

Monocots and Dicots

The two groups are very similar, except for a few distinguishing characteristics.

Dicots:
- flower parts are usually found in four or fives
- pollen is **tricolpate** meaning it has three pores
- they have two **cotyledons** which are food leaves in their seeds
- the leaf venation is usually netlike
- the primary **vascular bundles** or transport tissues of the stem are found in a ring
- secondary growth with **vascular cambium** is commonly present
- examples are trees, shrubs and herbs

Monocots:
- flower parts usually found in threes
- pollen is monocolpate with only one pore
- they have only one cotyledon
- the leaf venation is usually parallel
- the primary vascular bundles in the stem have a complex arrangement
- secondary growth with vascular cambium is absent
- examples are grasses, flowers and palms

Plants are able to break up rock into smaller pieces. This is demonstrated by plants which can grow in sidewalk cracks. This lab will test just how powerful these seeds are. A seeds ability to break through solid covering material of varying thickness and strengths will be tested in this lab. Monocot and Dicot seeds will be compared, as well as the size of the seed itself.

Procedure

1. Because there are many containers, students can work in groups of two or three. Each group is responsible to bring their own seeds. About 81 seeds of each type is necessary. The corn and pea seeds must be soaked in water the night before planting.

2. Using the permanent marker, label nine containers with GRASS. Print the letters near the bottom of the container. Now label nine containers with LETTUCE, nine with CORN, and nine with PEA.

3. Now draw a line around the outside of each labeled container 6 cm up from the bottom.

4. Select three containers of each seed type (3 Grass, 3 Lettuce, 3 Corn, 3 Pea = 12). Label each container with PLASTER OF PARIS just below the seed type. Now select three more containers of each seed type and label them SPACKLING PASTE. Finally, label the remaining containers SAND MIX. Now you should have a total of 36 containers. Separate the containers first by seed type and then by covering material (should have 12 groups of 3).

5. Take one container marked PLASTER OF PARIS for each seed category and draw a line 0.5 cm above the 6 cm line. Take another container marked PLASTER OF PARIS for each seed category and draw a line 1.0 cm above the 6 cm line. Take the last four containers marked PLASTER OF PARIS and draw a line 1.5 cm above the 6 cm line.

6. Repeat this entire procedure for the containers marked SPACKLING PASTE. Finally do the same for the containers marked SAND MIX. Now all the containers should be different by seed type, material, or height of line.

7. Spread out the newspaper to avoid making a mess. Now fill each container with seed starting mix up to the 6 cm line.

8. Plant nine seeds of the proper type in each marked container. Use an X-shaped pattern across the container. Plant the corn and pea seeds about 2 cm deep. The grass and lettuce seeds need to be planted just under the surface.

9. Water the contents of each container.

10. Now mix the covering materials according to the directions. Use the remaining containers to mix them in.

11. Now use the spackling knife to cover the planted seeds with the appropriate material. Fill the containers to the height of the line above the 6 cm line. Work quickly because some of these coverings harden very quickly. Make sure everything is covered and the materials touch the walls of every container.

12. Set the containers aside for a few days. Then examine each container's surface for cracks. Take a look at the starting mix to look for root growth. Record all observations for five days in the following table.

Table 1. Observations of seed growth containers over a five day period

	Plaster of Paris	Spackling Paste	Sand Mix
Sand Mix			
Day 3			
Day 4			
Day 5			
Day 6			
Day 7			
Day 8			

Questions

1. Which seeds broke through 0.5 cm plaster of Paris? What about 1.0 cm? 1.5 cm?
2. Which seeds broke through 0.5 cm of spackling paste? 1.0 cm? 1.5 cm?
3. Which seeds broke through the sand mix at the three heights?
4. Which seeds showed the greatest amount of root growth?
5. Which seeds showed the least seed growth?
6. Are dicotyledonous seedlings stronger than monocotyledonous seedlings? Justify this answer.
7. The larger the seed, the more powerful the seedling. Is this generalization true or false? Explain.

Glossary of Terms

Angiosperms	plants that produce enclosed seeds
cotyledon	a seed leaf that stores food for the germinating seedling. It is the first photosynthetic organ of a young seedling
Dicots	an angiosperm whose seeds have two cotyledons or seed leaves. Most angiosperms are dicots
monocolpate	pollen of a plant with only one pore
Monocots	an angiosperm whose seeds have only one cotyledon or seed leaf
phloem	the tissue that conducts food and other dissolved materials throughout the body of a vascular plant
tricolpate	pollen of a plant that has three pores
vascular bundles	a structure within a stem containing parallel strands of xylem and phloem
vascular cambium	the meristematic layer of cells that causes growth in width of a stem or root
xylem	the tissue that conducts water and minerals from the roots upward through the plant and helps to support the plant

Notes

- Make sure the containers are watered thoroughly before applying the covering. This is the only source of water the seeds will have for a number of days. In the meantime, too much water could be just as bad.
- It is important that the students be as accurate as possible when applying the covering. There is only half a centimeter to work with, so too much or too little could affect the results.
- Timing is very important. It would be a good idea to try to plant everything on a Friday. This will allow a growth period over the weekend and then five consecutive days to record results.
- It would be good if all the setting up could be done in one day. However, if time does not permit, then the amount of coverings or seeds can be cut back or the lab can be done in sections.
- There are a number of variations that can be used with this lab. Try using different types of coverings, or different seeds, maybe even different types of soils.

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Agri-science Resources for High School Sciences

Seed Respiration

Biology

Science

Grade 10-12

Biology Lab

Individual or teams of 2

DESCRIPTION

Plants generate Oxygen, which is essential for humans to survive. However, plants also consume Oxygen during respiration. It is acutally possible to measure the amount of Oxygen used by plants with a device called a repirometer. Germinating seeds will be used to demonstrate Plant Respiration.

READINESS ACTIVITIES

Students should:
- review the life cycle of a plant, especially during germination
- examine respiration in other organisms, such as humans

LEARNING OUTCOMES

Students will:
- examine oxygen consumption by seeds
- understand the importance of respiration to life on Earth

MATERIALS

- large test tube
- metric ruler
- germinating seeds of any kind (1g)
- one-hole stopper
- limewater
- pipette
- wad of cotton
- marking crayon
- liquid detergent
- balance
- paper towels
- spatula
- scotch tape
- support stand and clamp
- rigid polyethylene tubing or hollow glass tubing, 20 cm long and bent at right angle

Seed Respiration

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Biology

Introduction

Plants are known for their ability to convert Carbon dioxide into Oxygen. However, all **aerobic** organisms take in Oxygen and give off Carbon dioxide as long as they are alive. This is true for plants as well as animals. During **germination**, seeds use sugars and other molecules as a substrate for **respiration**.

Germination

Germination of a seed begins with water uptake by the seed. This process is called **imbibition**. The uptake of water by a seed is an essential step in order for the seed to germinate. The total amount of water taken up is about 2-3 times the weight of the seed. Whether or not a viable seed will germinate depends on a number of factors. The chemical environment of the seed must be right. Water must be available, Oxygen has to be present since the seed must repire and no dangerous chemicals should be present. The physical environment must also be favourable. The temperature must be suitable as well as the light quality and quantity. A person may wonder why seeds are often buried underground. The reason is that this helps guarantee the seeds receive the correct amount of light for germination. Full sunlight can often prevent a seed from germinating. The extent to which germination has progressed can be determined by measuring water uptake or respiration.

Oxygen Consumption

If you place a living organism in a closed system, it is possible to measure its consumption of Oxygen. In this exercise, a respirometer will be used to measure oxygen consumption. The instrument contains limewater and germinating seeds. As the seeds consume oxygen, carbon dioxide is excreted. The carbon dioxide is then absorbed by the limewater, creating a slight vacuum in the respirometer. This vacuum will draw a drop of liquid detergent in the glass tubing inward. This movement will be measured in millimeters using a metric ruler taped to the glass tubing. This will give an idea of how much oxygen the germinating seeds consume.

Seed Respiration

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Biology

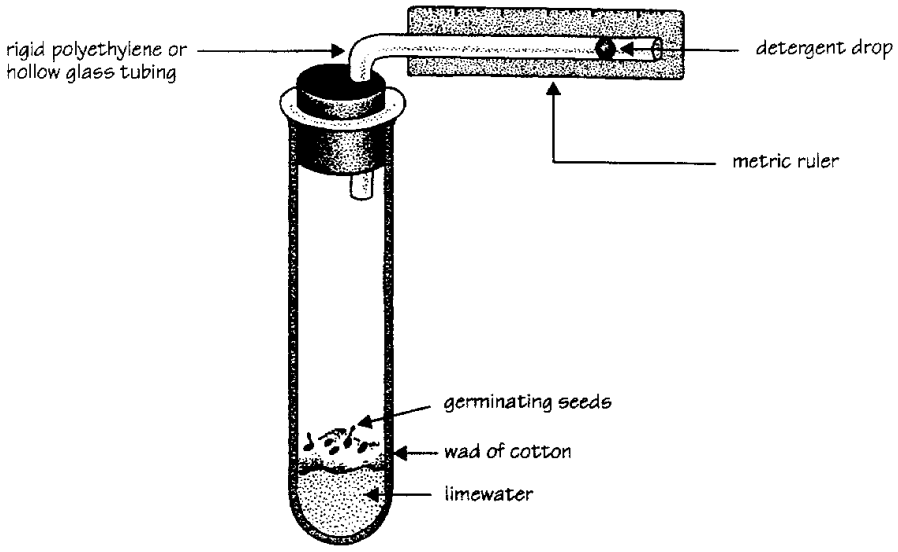

Figure 1.
The device that will be used to measure the oxygen consumption of the germinating seeds: a respirometer.

Procedure

1. Prior to the lab, obtain some small plant seeds. Try and use a different variety than your classmates. The seeds need to be germinating for the experiment. You can do this by spreading them on wet paper towel a day or two before the lab.

2. Begin by inserting the short end of the tube into the hole of the stopper. BE VERY CAREFUL if you are using GLASS. It could break easily. The long end of the tube should be sticking out at a right angle as in the diagram.

3. Draw a line 0.5 cm above the bottom of the test tube with the marking crayon. Add limewater to the tube up to this mark.

4. Moisten a small wad of loose cotton and place it on top of the limewater. Now place the gram of germinating seeds on top of the moistened cotton.

5. Tape the metric ruler to the tubing as shown in the diagram. Add a drop of detergent to the tubing with the pipette. The drop should be near the end of the tubing.

6. Insert the stopper and tubing into the test tube. Do it carefully. The air in the tube may cause the detergent drop to spill out as you press down. Keep pushing until an airtight seal is formed. Keep this setup in an airtight position. This is best done by a support stand and clamps, but if none are available, use two stacks of books.

7. Wait five minutes before taking an initial reading. This will allow any CO_2 that was in the respirometer when it was assembled to be absorbed. Take the initial reading wherever the drop of detergent is with respect to the metric ruler. Always take the measurement from the same part of the detergent drop. Record the initial reading in data table.

8. Take readings every minute for 15 minutes and record them in the data table.

Seed Respiration

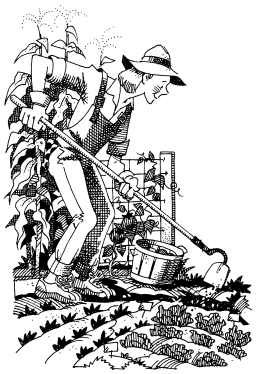

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Table 1. Measurement of Carbon dioxide production by germinating seeds over a 15 minute time interval.

Data Table

Minute	Movement (mm)	Minute	Movement (mm)
initial		**8**	
1		**9**	
2		**10**	
3		**11**	
4		**12**	
5		**13**	
6		**14**	
7		**15**	

Questions

1. Compare the respiration rate of your seeds with those of your classmates. Is there any relationship with the size of the seed itself?
2. Is there any relationship between temperature and the respiration rate of germinating seeds?

Glossary of Terms

aerobic	organisms which require oxygen to sustain life
imbibition	the initial step in germination where water is taken up by a seed
germination	occurs when a seed sprouts or starts to grow
respiration	a process in which living cells take in oxygen and give off carbon dioxide

Notes

- It would be much safer if plastic tubing could be used as opposed to glass. If o nly glass available, it might be a good idea if the instructor bends the glass, and inserts it into the stopper for the students.
- limewater is a saturated solution of calcium hydroxide. Calcium hydroxide can also be used, but it can irritate the skin, so gloves should be worn when handling it. Just fill the test tube up to the 0.5 cm mark with the powder. Add just enough water to make a paste.
- It is important to watch the placing of the drop of liquid detergent. It must be close to the opening, but if it is too close it will fall out when the stopper is put on the tube. Try and find an approximate distance that fits both conditions.
- Try and use some variables in the experiment. Some respirometers could be put at different temperatures, contain different moisture contents, and contain different seeds. The health of the seeds could also vary, by exposing them to different conditions during germination.

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