UNIT VI - PLANT TECHNOLOGIES

Lesson 1: Traditional Plant Breeding

Competency/Objective: Describe traditional plant breeding processes.

Study Questions

1. **What is natural crossbreeding?**

2. **What is selective breeding?**

3. **What are the advantages and disadvantages of selective breeding?**

4. **What is a hybrid?**

References:

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.

2. Activity Sheet

   a) AS 1.1: Hybrids and Their Offspring

UNIT VI - PLANT TECHNOLOGIES

Lesson 1: Traditional Plant Breeding

TEACHING PROCEDURES

A. Introduction

The selection of plants based on phenotypes has been going on for thousands of years. When humans stopped roaming the land and settled in one area, plants that were useful were planted in large quantities and allowed to breed naturally. People then began to notice that some plants were more productive than others, so they saved and grew seeds from these plants, beginning the practice of selective breeding. A major advance in selective breeding occurred in 1922 with the introduction of hybrid seed corn. In the mid-1990s, the first genetically modified crops were introduced, and a new era of plant breeding began.

B. Motivation

Pioneer, DeKalb, and CIBA Seeds are well-known companies that have prospered by developing and marketing selected plant crosses. The sale of seed from these crosses, or hybrids, has yielded many billions of dollars over the last fifty years. These companies spent large sums of money in the 1920s and 1930s on plant breeding programs. In the 1990s, companies like Monsanto have invested billions of dollars in purchasing and developing gene patents and gene transfer technology. Why have companies like Monsanto made these investments?

C. Assignment

D. Supervised Study

E. Discussion

1. Review the parts of a flower, and ask students to recall the ways in which plants reproduce.

   What is natural crossbreeding?

   a) Natural crossbreeding is a reproductive process in which two plant varieties, which have different genotypes, sexually reproduce without human intervention.
   b) It allows the random mixing of genes within a species.

2. Ask students to define what selective breeding is in the livestock industry. Relate this definition to selective plant breeding.

   What is selective breeding?

   a) Selective breeding is the process of identifying plants with desirable traits and causing them to reproduce.
   b) Selective breeding can be done asexually or sexually.
   c) Plants are selectively bred mainly for two reasons.
      1) To increase the production of the useful parts of the plant
      2) To increase the ability of a plant to withstand harsh environments, disease, and plant pests

3. Compare the advantages and disadvantages of selective animal breeding to those of selective plant breeding.

What are the advantages and disadvantages of selective breeding?

a) Advantages
   1) The occurrence of desired plant traits can be increased, especially traits that can raise crop yields.
   2) The performance of a crop is more predictable since the crop of seeds is more uniform.

b) Disadvantages
   1) The occurrence of undesired traits may be increased.
   2) The genetic diversity of a crop species is reduced.
   3) Crop plant uniformity can increase insect problems.

4. Ask students why nearly every producer who plants corn uses hybrid corn. Have students speculate about what a hybrid plant variety is.

What is a hybrid?

a) A hybrid is a plant produced by crossing two inbred lines of plants that are greatly different genetically.

b) Breeders use three common methods of hybrid development.
   1) Single cross - crossing one inbred plant with another
   2) Three-way cross - crossing a single cross with another unrelated inbred plant
   3) Double cross - two single crosses are crossed

c) A hybrid displays extra growth vigor, or hybrid vigor (heterosis); however, it usually either is sterile or produces offspring that do not perform well.

F. Other Activities

Purchase Wisconsin Fast Plants and use them to show several types of selective breeding. Wisconsin Fast Plants grow and produce seed in a very short time so that several generations can be seen in a matter of a few weeks.

G. Conclusion

Since the mid-1980s, the yields of hybrid crops have not increased significantly, which has led some economic analysts to state that traditional hybrids have reached a limit in production capability. The fact that hybrid seed companies are focusing heavily on gene transfer technology for future profit potential further confirms this analysis. Some people disagree with the rationale of this new focus, but this group seems to be in the minority. Traditional plant breeding processes will undoubtedly be used in the development of new generations of crop seeds, but the real advances in yield and other desirable crop traits will most likely come from recombinant DNA technology.

H. Answers to Activity Sheet

Students will need guidance as they work through the activity sheet questions. The answers to these questions will vary, but some suggested answers are listed below.

1. How do the growth rates of a hybrid compare with the growth rates of the F_2 of a hybrid?

2. This information will vary but should reveal that F_2 generations of hybrids do not perform as well and that plant-to-plant variations are quite high.

3. Answers will vary but the given hypothesis must be measurable.

4. The experimental group should be defined as the F_2 hybrid group and should consist of a stated number of seeds. The control group is the hybrid seed group; it should also consist of a stated number of seeds.

5. Performance can be measured by the growth of the plant in millimeters per day, the change in the circumference of the stem in millimeters per week, germination rate, and nutrient uptake.

6. Examples include light, temperature, humidity, water, wind/chemical/insect stresses, etc.

7. Answers will vary.

I. Answers to the Evaluation

1. c
2. d
3. d

4. The occurrence of undesired traits may be increased, the genetic diversity of a crop plant population is reduced, and crop plant uniformity can increase insect problems.

5. To increase the production of the useful parts of the plant and to increase the ability of a plant to withstand harsh environments, disease, and plant pests

6. Natural crossbreeding is a reproductive process in which two plant varieties, which have different genotypes, sexually reproduce without human intervention.

7. A hybrid is a plant produced by crossing two inbred lines of plants that are greatly different genetically.

UNIT VI - PLANT TECHNOLOGIES Name _____

Lesson 1: Traditional Plant Breeding Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Selective breeding can be defined as the:

   a. Process of sexual reproduction of a plant in which pollen from a plant fertilizes the eggs of the same plant.
   b. Crossing of two inbred lines of plants.
   c. Process of identifying plants with desirable traits and causing them to reproduce.
   d. Reproductive process in which two plants with different genotypes reproduce sexually without human intervention.

2. Of the three common methods of producing a hybrid seed, which involves crossing two unrelated inbred plants and then breeding the result with another unrelated inbred plant?

   a. Hybrid cross
   b. Single cross
   c. Double cross
   d. Three-way cross

3. Selective breeding is:

   a. A sexual process.
   b. An asexual process.
   c. Neither a sexual nor an asexual process.
   d. A sexual or an asexual process.

Complete the following short answer questions.

4. What are two disadvantages of selective breeding?

5. Why is selective breeding done?

6. What is natural crossbreeding?

7. What is a hybrid plant?

Lesson 1: Traditional Plant Breeding Name _____

Hybrids and Their Offspring

Objective: Design an experiment that will test the idea that hybrids produce inferior offspring.

For this activity, work in groups assigned by your instructor and design and perform an experiment that will accurately test your hypothesis about the performance of hybrids (F_1) and their offspring (F_2). Use seed collected from a field of hybrid corn and seed from a bag of the same hybrid seed. Whether the offspring of hybrids is "inferior" will be measured by the growth rate of the two groups of plants from emergence to a specified height or length of time as well as the diameter of the stalk, germination rate, and rate of nutrient uptake. The questions below will help guide you through the design of the experiment. Data should be collected periodically until the experiment is completed.

1. What is the problem statement, or what information is desired?

2. List any information that can be collected about the problem. (Hint: check textbooks and the Internet, call a seed salesperson, etc.)

3. State your hypothesis.

4. Define your control and experimental groups. You must consider the size of the groups carefully.

   Experimental group:

   Control group:

5. How will the observations be measured?

6. What environmental controls will be used to ensure that the seed is the only variable in this experiment? (Hint: list the factors that affect the growth rate, and then explain how each factor will be kept the same for the control and experimental group.)

7. What will be the schedule for conducting the experiment? When will observations be made and data be collected?

UNIT VI - PLANT TECHNOLOGIES

Lesson 2: Plant Tissue Culture

Competency/Objective: Explain the process of tissue culture.

Study Questions

1. **What is plant tissue culture?**
2. **What are the advantages and disadvantages of plant tissue culture?**
3. **What equipment is needed for plant tissue culture?**
4. **What steps are involved in plant tissue culture?**
5. **What are the four stages of tissue culture growth?**
6. **How is plant tissue culturing used in genetic engineering?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.
2. Activity Sheets
   a) AS 2.1: Tissue Culturing Strawberries (Instructor)
   b) AS 2.1: Tissue Culturing Strawberries (Student)

Lesson 2: Plant Tissue Culture

TEACHING PROCEDURES

A. Review

Traditional plant breeding techniques, such as selective breeding, have increased plant quality and production. However, a method of propagation called tissue culture is providing plant breeders with new tools for crop improvement. Tissue culture has not replaced traditional breeding practices but rather has enhanced their effectiveness.

B. Motivation

Plant tissue culture was first used in the early 1970s in the propagation of orchids. The orchid seed is very difficult to sow and germinate. It is not only the smallest seed in the world, but it must be exposed to a specific fungus before it will germinate. To produce an orchid from a seed takes an average of seven years. Tissue culture became the solution to the difficulties of orchid propagation. Today, tissue culture is a commonly used and vitally important method of plant reproduction.

Purchase a miniature plant grown from tissue culture. Use this tiny plant to introduce the basic concept of tissue culture. Every plant cell has the entire genetic code and is capable of producing an entire plant.

C. Assignment

D. Supervised Study

E. Discussions

1. Ask students to define the word tissue. Explain that a tissue is a group of cells that function together for a purpose. Examples of plant tissue include the leaf, stem, root, bud, etc.

   What is plant tissue culture?

   Plant tissue culture can be defined as an asexual method of reproduction in which a piece of a parent plant is placed in a sterile artificial media where it grows into a new plant.

2. Ask students why tissue culture is done. Have students speculate about the advantages and disadvantages of using tissue culture.

   What are the advantages and disadvantages of plant tissue culture?

   a) Advantages
      1) Allows for mass propagation of clones of a desirable plant
      2) Allows the production of pathogen-free plants
      3) Conserves time through the year-round propagation of plants

4) Conserves growing space

b) Disadvantages
   1) Requires expensive, sophisticated equipment and facilities
   2) Susceptibility to contamination by microorganisms
   3) Requires skilled workers, which adds to the total cost

3. Show students a petri dish and an autoclave or pressure cooker. Ask students to describe how an autoclave works. Explain that an autoclave uses steam under pressure (approximately 15 psi) to heat items above the temperature that microorganisms can survive.

What equipment is needed for plant tissue culture?

a) Preparation
   1) Refrigerator
   2) pH meter
   3) Scale or balance
   4) Heating plate
   5) Autoclave

b) Transfer
   1) Fume or air flow hood
   2) Forceps
   3) Scalpel
   4) Test tubes or petri dishes
   5) Dissecting microscope

c) Growth
   1) Growth chamber - a room that controls exposure to heat and light

4. Ask students to list the steps of the procedure for tissue culturing.

What steps are involved in plant tissue culture?

a) Media preparation
   1) The growing media for tissue culture varies in composition with the species of plant being used.
   2) Generally the media contains plant nutrients, mineral salts with vitamins, hormones, pure water, sugar, and agar (if a semi-solid media is needed)

b) Selecting and collecting an explant to be cultured
   1) Several types of plant tissues are used for explants.
      (a) Shoot tip
      (b) Bud
      (c) Leaf with veins
      (d) Node
      (e) Bud scale
   2) Rapidly growing tissues are usually preferred for the explant.
   3) Tissue must be healthy and disease free.

c) Cleaning the explant
   1) Plant tissue is disinfected
      (a) Alcohol is used on woody plants only.

(b) For other plants, the explant is soaked in a 10 percent bleach solution for 10 minutes; plant tissue will be damaged if it is soaked too long.
(c) A drop or two of detergent is often added to the bleach solution as a wetting agent.

2) After the tissue is disinfected, it is rinsed in pure water at least three times.

d) Transferring explants to growing media
1) The explant sections are trimmed and transferred to the growing media; some tissue types are divided for growing more plants.
2) A dissecting microscope is sometimes needed for very small explant tissues.
3) This procedure must take place in a sterile environment.

5. Ask students to explain each of the four stages of tissue culture growth.

What are the four stages of tissue culture growth?

a) Initiation and establishment (four to six weeks)
1) A callus, made of rapidly dividing cells, forms and grows in response to the wounding or cutting of the plant tissue.
2) Shoots or immature stems begin to grow.

b) Proliferation or multiplication (one to three months)
1) The shoot multiplies into many shoots.
2) The new shoots can be divided to increase the number of plants produced.
3) This stage uses a slightly different growing media.

c) Pretransplant (three weeks)
1) Roots begin to grow.
2) A slightly different media is used.
3) More light is required.
4) Young plants are stressed slightly in a process called hardening off, in which young plants are exposed to conditions outside the sterile container.

d) Transplanting
1) The growing plants are put in pots and moved to a shady, humid greenhouse.
2) The plants are hardened off again and then moved to a regular greenhouse to receive full sun and less humidity.

6. Have students identify reasons that a person or company working with developing transgenic plants would want to use tissue culture.

How is plant tissue culturing used in genetic engineering?

a) Genetically modified plant tissues can be rapidly grown into plants.
b) A large number of plants can be screened for the presence of a desirable trait.

F. Other Activities

1. Demonstrate media preparation.

2. Tissue culture kits and African violet kits are available for purchase from Carolina Biological or Fisher Scientific. Follow the directions on the kits when preparing them.

3. Show the videos *Plant Tissue Culture Part 1 & 2* (VEP) and *Introduction to Plant Tissue Culture* (CEV), all of which are available from MVRC.

G. Conclusion

More than 50 plant species have been genetically modified. In almost every case, tissue culture played an important role in recovering the modified plant tissues. In 1990, more than 300 commercial plant tissue culture labs were in operation. As plant breeders continue to make use of tissue culture techniques, the use of tissue culture will likely increase.

H. Answers to Activity Sheet

I. Answers to the Evaluation

1. b
2. d
3. c
4. b
5. c
6. c
7. d

8. Plant tissue culture can be defined as an asexual method of reproduction in which a piece of a parent plant is placed in a sterile artificial media where it grows into a new plant.

9. Tissue culturing is used in genetic engineering to rapidly grow genetically modified plant tissues into plants and to screen a large number of plant tissues for the presence of a desirable trait.

10. Students may list any two of the following: refrigerator, pH meter, scale or balance, heating plate, autoclave, fume or air flow hood, forceps, scalpel, petri dishes or test tubes, dissecting microscope, or growth chamber.

UNIT VI - PLANT TECHNOLOGIES Name _____

Lesson 2: Plant Tissue Culture Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following statements is not an advantage of tissue culture?

   a. Tissue culture allows for the mass propagation of clones.
   b. Plant tissue cultures are susceptible to contamination.
   c. Plant tissue culture allows for the production of pathogen-free plants.
   d. Plant tissue culture allows for the propagation of plants year round.

2. Which of the following substances is not commonly used to make a tissue culture media?

   a. Sugar
   b. Mineral salts with vitamins
   c. Plant hormones
   d. A dilute sodium chloride solution

3. Which of the following is an important criterion to consider when selecting an explant?

   a. The explant should be selected from a young parent plant.
   b. The parent plant should be a monocot because dicot plants do not give good explants.
   c. The explant should be taken from a healthy, rapidly growing part of the parent plant.
   d. The explant is always taken from the shoot tip of the parent plant.

4. If it is not woody plant tissue, the selected explant is disinfected with:

   a. Alcohol.
   b. 10 percent bleach solution.
   c. A detergent.
   d. A very weak acid solution.

5. In which stage of plant tissue growth do the roots begin to form and grow?

   a. Initiation and establishment
   b. Proliferation or multiplication
   c. Pretransplant
   d. Transplanting

6. The stage in which the shoot begins to grow is called the:

   a. Transplanting stage.
   b. Proliferation or multiplication stage.
   c. Initiation and establishment stage.
   d. Pretransplanting stage.

7. A callus is a:

   a. Mass of dead plant cells that accumulate as the tissue culture grows.
   b. Group of cancer cells that can destroy a plant tissue culture.
   c. Group of old cells that forms when the incorrect part of the plant is selected for the explant.
   d. Group of rapidly dividing cells that is a response to the wounding of plant tissue.

Complete the following short answer questions.

8. What is plant tissue culture?

9. How is plant tissue culture used in genetic engineering?

10. What are two pieces of equipment used in tissue culture?

Lesson 2: Plant Tissue Culture Name _____

Tissue Culturing Strawberries

Objective: Perform plant tissue culture.

Materials and Equipment:

1 medium-sized stainless steel pan
1 long-handled spoon
1-2 glass test tubes with caps (25 x 100 mm)
Test tube racks
2 gallons of sterile distilled bottled water
1 glass (Pyrex) quart pitcher or old coffee pot
1 pressure cooker
2-4 eight-inch forceps
1 sharp knife or scalpel
Parafilm™ or clear tape
Rubber or latex gloves
20 ml of 1N NaOH
20 ml of 1N HCl
2 eyedroppers
1 plastic graduated cylinder
1 small bottle of household bleach
2 packages of premixed powder tissue culture medium (shoot multiplication media and pretransplant media)
1 package of agar
1 package of litmus paper (3.5-6.8) or a pH meter
2-4 medium-sized plastic containers
2-3 sterile paper towels (made by rolling them up in aluminum foil and sterilizing them in the pressure cooker)
1 72-hole seedling tray (11 x 22)
Shelves lighted by cool white fluorescent lights
1 transfer chamber (It can be made from wood or cardboard with a clear plastic sheet or plexiglass over the front and top of the chamber. Holes should be cut in the front so that both hands can be used to work inside the chamber.)
10-20 strawberry runner tips (about 1 inch long)

Procedure for Media Preparation:

1. Follow the directions on the prepackaged shoot multiplication media mix to prepare the media. About one liter of media is enough for the entire class. Make sure that a 2-liter container or larger is used when mixing the media since it can boil up and spill. Add the powder mix to the water (not the reverse). Stir the mixture.

2. Next, the pH of the mixture must be adjusted to 5.7. Measure the pH of the solution with litmus paper. If the solution has a pH higher than 5.7, add one drop of HCl and stir the

solution. If, however, the solution has a pH lower than 5.7, add one drop of NaOH and stir. This process is repeated until the pH is 5.7.

3. Thicken the mix by adding agar. Approximately 5 grams of agar are needed per liter of solution. After the agar is stirred into the solution, heat it and stir until the solution becomes clear. Transfer the hot solution to the glass pitcher and then carefully pour it into the test tubes.

4. Sterilize the medium in a pressure cooker for about 15 minutes. When sterilizing test tubes holding media, place them in a wide-mouth jar or tie them in bundles of ten so that they stand up in the pressure cooker.

Lesson 2: Plant Tissue Culture Name _____

Tissue Culturing Strawberries

Objective: Perform plant tissue culture.

Materials and Equipment:

1 medium-sized stainless steel pan
1 long-handled spoon
1-2 glass test tubes with caps (25 x 100 mm size)
Test tube racks
2 gallons of sterile distilled bottled water
1 glass (Pyrex) quart pitcher or old coffee pot
1 pressure cooker
2-4 eight-inch forceps
1 sharp knife or scalpel
Parafilm™ or clear tape
Rubber or latex gloves
20 ml of 1N NaOH
20 ml of 1N HCl
2 eyedroppers
1 plastic graduated cylinder
1 small bottle of household bleach
2 packages of premixed powder tissue culture medium (shoot multiplication media and pretransplant media)
1 package of agar
1 package of litmus paper (3.5-6.8) or a pH meter
2-4 medium-sized plastic containers
2-3 sterile paper towels (made by rolling them up in aluminum foil and sterilizing them in the pressure cooker)
1 72-hole seedling tray (11 x 22)
Shelves lighted by cool white fluorescent lights
1 transfer chamber (It can be made from wood or cardboard with a clear plastic sheet or plexiglass over the front and top of the chamber. Holes should be cut in the front so that both hands can be used to work inside the chamber.)
10-20 strawberry runner tips (about 1 inch long)

Procedure:

A. Selecting and Cleaning the Explants

1. Select a healthy-looking strawberry runner tip on which the bud has not yet opened. Cut off 1 to 1 1/2 inches of the tip and place it in a plastic bag containing a damp paper towel.

2. Fill a wide-mouth jar with 1/2 pint of sterile water. Add 2 or 3 drops of liquid dishwashing detergent. Place the runner tips in the jar, put the lid on, and vigorously

shake the jar for 1 minute. Pour out the water and rinse the runner tips 2 or 3 times with sterile water. Repeat this process, or dip the runner tips in 70 percent alcohol for only a few seconds and then rinse 2 to 3 times with sterile water.

3. In another container, add 30 ml of bleach to 270 ml of sterile water to yield a 10 percent bleach solution. Add 2 drops of the detergent and place the explant in the solution. Shake for 10 seconds every minute for ten minutes. Quickly drain the solution; add sterile water and shake the container.

B. Transferring the Explants

1. Spray and wipe down all the inside surfaces of the transfer chamber with a 10 percent bleach solution. Allow them to air dry. Place a small container of 10 percent bleach solution and another container of 1 percent bleach solution in the transfer chamber to use for sterilizing the instruments and gloved hands. Place the forceps and knife in the 10 percent bleach solution and then in the 1 percent solution. Lay the sterilized instruments on a sterile paper towel and allow them to air dry.

2. Using the forceps, unroll another paper towel on the work area inside the transfer chamber. Use the forceps to place the runner tip on the towel. Hold the tip with the forceps while picking up the knife or scalpel and cutting off 1 cm of the stem. Put the knife in the 10 percent bleach solution. Pick up a test tube of medium while holding the explant with the forceps. Remove the test tube cap with the small finger of one hand and hold it firmly in place while putting the cut explant on the medium. Cap the test tube and seal it with Parafilm™ or tape.

C. Growing the Cultures

1. Place the test tube in the planter tray or another holder on a shelf under a florescent light that is 8 to 10 inches away. Continuous light may be used, but if a timer is available, 16 hours of light is normal. Plants may remain at room temperature.

2. Check the cultures every day for signs of contamination. If any fungus or other form of contamination is present, sterilize the contaminated test tubes before discarding.

3. Transfer the explant to new medium every two weeks until it is growing well.

4. In one to two months, the explants should have many shoots and can be divided. When shoots are observed, divide the explant into two pieces about 0.5 cm in diameter. Repeat this process until enough growing plants are produced. Transfer them to a pretransplant medium that has no hormones.

5. After two to four weeks on the medium, the roots should develop. Transplant the plants to an artificial soil mix (greenhouse mix) in a seedling tray. Cover them with transparent plastic and place on a lighted shelf or in a shaded greenhouse.

6. After two or three weeks, uncover the tray daily for a length of time. Gradually increase the time it remains uncovered for a week until they are no longer being covered.

UNIT VI - PLANT TECHNOLOGIES

Lesson 3: Genetically Modified Plants

Competency/Objective: Describe current applications of biotechnology in plants.

Study Questions

1. **How are genetically altered plants developed?**
2. **How do herbicide-tolerant plants function?**
3. **How do insect-resistant plants function?**
4. **How do disease-resistant plants function?**
5. **What effect has biotechnology had on food quality and processing?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.
2. Activity Sheet
    a) AS 3.1: The Current State of Plant Biotechnology

UNIT VI - PLANT TECHNOLOGIES

Lesson 3: Genetically Modified Plants

TEACHING PROCEDURES

A. Review

Lesson 2 discussed the procedure of plant tissue culture and its use in reproducing plants. This lesson will address producing plants that have been genetically modified. Plant breeders have always searched for healthier and more productive plants. With the development of recombinant DNA technology, plant breeders have been able to select traits from sources outside the plant species with which they are working. As the vast selection of plants, animals, and microbes is examined for potentially helpful genes, researchers will continue discovering and using new genes to increase the world's crop production and decrease the cost of production.

B. Motivation

How valuable is the development of insect- or disease-resistant plants? The global cost of the current chemical control of insects and fungal diseases is $8.7 billion. However, even with the use of these chemical controls, insects and disease cause a 12 to 13 percent reduction in crop production. The chemical insecticide and crop loss costs associated with the Colorado potato beetle and the corn rootworm are over $1 billion in the United States alone. Insect damage costs for cotton exceed $645 million. Obviously, the added costs of genetically modifying a crop to be resistant to one of these pests may be easily offset by the decrease in chemical costs and the increase in yield.

C. Assignment

D. Supervised Study

E. Discussion

1. Review with students the methods of genetically modifying animal cells. Ask students to recall the differences between animal and plant cells, especially the presence of the cell wall. Explain that the cell wall of a plant requires that a forceful method of gene insertion be used.

How are genetically altered plants developed?

a) The desired gene or genes for a trait must be found, isolated, and cloned.
b) A method of genetic transfer is selected.
    1) Bacteria or virus
        (a) The desired gene and a marker gene is inserted into the bacterium or virus, and the microorganism is placed in contact with the plant cell to be modified.
        (b) The organism infects the cell and transfers the desired gene.
    2) Gene gun
        (a) The desired gene and a marker gene are inserted into a plasmid.
        (b) The plasmid is placed on the surface of very small (1 mm in diameter), heavy metal (gold) pellets.
        (c) These pellets are shot into the plant cells with the use of a small high-pressure gun.
    3) Chemicals
        (a) The cell wall is weakened or dissolved.
        (b) The desired gene is physically placed in the cell.
        (c) The plant cell is stimulated to repair the cell wall.

c) Plant cells that incorporate the desired gene into their DNA are selected (by looking for the marker gene) and grown into mature plants through the use of tissue culture.

2. Ask students to list some commonly used herbicides. How do these chemicals kill weeds? The answer lies in the fact that an important chemical process of the plant is disrupted by the herbicide.

How do herbicide-tolerant plants function?

a) Herbicides kill plants by chemically blocking a metabolic pathway.
b) Herbicide-tolerant plants have the ability to bypass the blocked portion of the metabolic pathway; this ability comes from genes that produce certain enzymes that provide a different chemical route around the blocked portion.

3. Explain to students that plants have very little natural resistance to insects and that many insects are becoming increasingly resistant to chemical insecticides. Explain the source of resistance (*Bt*) of insect-resistant plants.

How do insect-resistant plants function?

a) *Bacillus thuringiensis (Bt)* is a soil bacterium that produces a protein that, when eaten by specific insects, dissolves the wall of the gut, causing the insect to be unable to eat and eventually to die.
b) Each *Bt* strain kills a specific type of insect.
c) The genes that cause the production of the protein in specific *Bt* strains have been isolated and transferred to several crop plants, including potatoes, corn, and cotton.

4. Point out that plant diseases are commonly caused by viruses, bacteria, and fungi. Explain how disease-resistant plants combat them.

How do disease-resistant plants function?

a) Virus-resistant plants - A small portion of the DNA from the virus is inserted into the plant DNA, giving the plant an immunity to the virus.
b) Bacteria- and fungus-resistant plants - Current research in this area centers on trying to enhance the plant's natural immune response; plants resistant to bacteria and fungi are not currently available.

5. Ask students if they have heard of or tasted a FlavrSavr™ tomato. Explain that the quality and processing of foods is being advanced by biotechnology.

What effect has biotechnology had on food quality and processing?

a) Tomato
    1) The FlavrSavr™ tomato was developed by Calgene to have a vine-ripened taste and a longer shelf life.
    2) Genes were inserted into the tomato plant that cause the production of an enzyme that slows the breakdown of pectin, which keeps the tomato from getting soft and rotting.
    3) Four other companies have gained approval for similar genetically modified tomatoes.
b) Modified canola and corn plants - These plants yield a grain that is higher in oil content and has a modified oil composition in which the level of saturated and unsaturated oil has been changed to meet different uses.
c) High-starch potatoes
    1) The potatoes are higher in starch and lower in water content.

2) When chips or french fries are made, they will absorb less oil and will therefore be lower in fat.

F. Other Activities

Plant some genetically modified Roundup Ready™ soybeans from Monsanto and some soybean seeds that are the result of a hybrid cross. When the plants reach 8 to 10 inches in height, spray the plants with Roundup. Have the students record daily observations of the effects of the Roundup on both types of plants.

G. Conclusion

The development of transgenic plants by private companies has been fueled by the potential for large profits. Producers are willing to pay companies a premium for crop seed that can lower the costs of raising a crop. The potential of genetically engineered plants is only beginning to be realized.

H. Answers to the Activity Sheet

AS 3.1

Answers will vary based on available information.

I. Answers to the Evaluation

1. a
2. b
3. d
4. a

5. *Bt* or *Bacillus thuringiensis* is a soil bacterium that produces a protein that when eaten by specific insects causes the insect's gut wall to dissolve; it eventually dies. The genes in specific *Bt* strains that cause the production of the protein have been isolated and transferred to several crop plants.

6. Students may list any one of the following: the FlavrSavr™ tomato developed to have a vine-ripened taste and a longer shelf life, modified canola and corn plants that yield a grain that is higher in oil content and has a modified oil composition, and high-starch potatoes that are higher in starch and lower in water content.

7. Students should list the following steps.

   a. The desired gene must be found, isolated, and cloned.
   b. A method of genetic transfer is selected. A bacteria or virus, a gene gun, or a chemical that dissolves or weakens the cell wall is used.
   c. Plant cells that incorporate the desired gene into their DNA are selected by looking for the marker gene and grown into mature plants through the use of tissue culture.

UNIT VI - PLANT TECHNOLOGIES Name _____

Lesson 3: Genetically Modified Plants Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is not a method of transferring DNA into a plant cell?

   a. Using two electrical probes that cause the desired DNA to be forced into the targeted plant cell
   b. Chemically weakening or dissolving the cell wall and inserting the DNA
   c. Using a gene gun that fires heavy metal pellets coated with DNA
   d. Using bacteria and viruses containing the desired gene that attack the targeted cell

2. What is the name of a piece of DNA located or placed near a targeted section of DNA that helps in the identification of the targeted section?

   a. Plasmid DNA
   b. Marker gene
   c. Targeted DNA
   d. Signal gene

3. How do herbicide-tolerant soybeans tolerate the active chemical in a herbicide?

   a. The gene added to the soybeans prevents the absorption of the chemical.
   b. The gene added to the soybeans accelerates the natural immune system of the soybean plant to ward off the toxic effect of the chemical.
   c. The gene added to the soybeans chemically reacts with the substance to neutralize it.
   d. The gene added to the soybeans produces an enzyme that provides a way around the herbicide-caused metabolic pathway block.

4. The common soil bacteria, *Bacillus thuringiensis*, has played a big role in the development of:

   a. Insect-resistant plants.
   b. Disease-resistant plants.
   c. Herbicide-tolerant plants.
   d. High-starch potatoes.

Complete the following short answer questions.

5. How do insect-resistant plants function?

6. What is one example of a biotechnology product that enhances food quality and/or processing? What aspect of the product has been changed through biotechnology?

7. What are the three steps in the development of a genetically modified plant? Briefly describe each step.

   a.

   b.

   c.

Lesson 3: Genetically Modified Plants Name _____

The Current State of Plant Biotechnology

Objective: Describe the current state of plant biotechnology.

Answer the questions below. The Internet would be the best research tool, but newspapers and magazines may also be used. If additional information about plant biotechnology is found, summarize this information on the back of this activity sheet. You will be asked to share some of this information with the class.

1. List at least six companies that are involved developing products in plant biotechnology **and** one of the newest products from each company.

   a.

   b.

   c.

   d.

   e.

   f.

2. Briefly describe how one of these products was developed. (Include information on the source of the transferred gene.)

3. What genetically modified plants have been recently approved by the USDA, FDA, and EPA?

4. What do farm-related magazines have to say about the future of genetically engineered plants/crops?

UNIT VI - PLANT TECHNOLOGIES

Lesson 4: Emerging Applications of Plant Biotechnology

Competency/Objective: Identify emerging applications of biotechnology in plants.

Study Questions

1. **What are biofuels?**

2. **What are biopolymers?**

3. **What are some traits that producers desire in plants?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.

2. Activity Sheet

   a) AS 4.1: Designer Plants--The Agricultural Products of the Future

UNIT VI - PLANT TECHNOLOGIES

Lesson 4: Emerging Applications of Plant Biotechnology

TEACHING PROCEDURES

A. Review

Plants have been cultivated for centuries to provide food for both humans and animals. An increasing number of plants are now grown for industrial and medical uses as well. As discussed in Lesson 3, plants can be genetically modified to improve their usefulness for these purposes. Just as George Washington Carver discovered more than a hundred uses for peanuts, so are today's scientists discovering new uses for plants, especially modified plants. Some emerging applications of plant biotechnology will be examined in this lesson.

B. Motivation

Pass out one soybean-derived crayon, labeled "A," and one traditional crayon, labeled "B," to three or four students. Ask these students to evaluate the two crayons and determine which one is better. List their comments on the board. Ask students if any of them know any young children who play with crayons. Have they ever seen them chew on or simply eat a crayon? Tell the class that one of the crayons is safe to eat. Increase student interest by telling the class that one of the two crayons earned four college students more that $100,000 and prompted many offers of high-paying jobs. Explain that the four college students won a contest sponsored by the United Soybean Board by developing soybean-based crayons. Talk about how a problem relevant to one of those college students (his younger brother eating crayons) sparked a new use for a traditional crop plant.

Pass around a piece of soybean "marble" and explain that a fifth-grader discovered this product. She was trying to come up with a project for her school science fair. She mixed glue and newspaper in a blender and then heated it in the microwave. The mixture formed a hard, granite-like block that could be worked like wood. The formula has been changed slightly, with the glue being replaced by a product made from soy flour, and her discovery is now being marketed as a building material.

Point out that the genetic engineering of plants provides researchers the opportunity to modify a plant so that it is better suited for a particular application. Therefore, more plant-derived products like these will probably be developed, and existing products will likely be enhanced.

C. Assignment

D. Supervised Study

E. Discussion

1. Show a sample of biodiesel to the class and ask students how it is made. Ask students to list other plant-derived fuels.

What are biofuels?

a) Biofuels are combustible substances derived from organic sources. Nearly all biofuels are derived from plants.
b) Several types of biofuels exist.
    1) Alcohol-based fuels
        (a) These fuels are made by fermenting plant materials.
        (b) An example is gasohol, a fuel that is 10 percent alcohol and 90 percent gasoline.

(c) Researchers are searching for plants that they can modify to produce ethanol more economically.

2) Plant oil-based fuels, or biodiesels
   (a) These fuels are made from seeds with a high oil content.
   (b) Most are the result of the addition of methanol to the plant oil and the removal of a sticky substance called glycerin.
   (c) Soybean and rapeseed oils are most commonly used.
   (d) Scientists are looking for ways to engineer plants to produce a larger quantity of oil and to require less extensive processing.
3) Biogas fuels
   (a) Methane gas is derived from the anaerobic (oxygen-free) digestion of plant materials and/or animal waste by microorganisms.
   (b) Researchers are examining the possibility of developing plants that would produce crop residue that is more useful for methane production.

2. Ask a student to look up the definition of a polymer (a natural or synthetic substance that is formed by joining many simple molecules to form large molecules) and read it to the class. Then ask the students to speculate about the definition of a biopolymer.

What are biopolymers?

a) Biopolymers are complex chemical compounds produced by living things; biopolymers from genetically engineered plants may be useful in a variety of industries.
b) Biotechnology is being applied to develop five different types of biopolymers.
   1) Carbohydrates - Researchers are working on the development of a modified corn starch that does not break down when heated in the microwave and genetically engineered potato plants with leaves that have a high sugar content.
   2) Fatty acids - Scientists are working on modifying corn and canola oils to contain a high level of either saturated or unsaturated fatty acids depending on which is needed for a given application.
   3) Pharmaceutical proteins - These biopolymers are used for human health products.
   4) Industrial enzymes - Scientists are trying to modify plants to provide enzymes at a low price for purposes such as fermentation for brewing, processing and bleaching paper, and a feed additive to aid in digestion in livestock.
   5) Bioplastics - Scientists are attempting to develop plants with tissues that contain a higher level of the chemical components of plastic.

3. Ask students to use their imaginations and list the characteristics (other than increased yield) that they think would be valuable plant traits. Some of the traits listed are more than likely being researched as possible crop enhancements. Have students complete AS 4.1. Divide the class into groups of three or four students. Assign two or three sectors of the agricultural industry (based on the FFA proficiency award areas) to each group. Have students use any available resources, including textbooks, magazines, and the Internet. Encourage the group members to pick different questions to research and then compile all of the answers. The answers that the students come up with should be rational, but encourage them to use their imaginations as well as their resources.

What are some traits that producers desire in plants?

a) Environmentally tolerant plants
   1) Drought-tolerant plants
   2) Frost-tolerant plants
   3) Salt-tolerant plants
b) Forestry products
   1) Stronger wood
   2) Fire-resistant wood

3) Trees that grow more quickly

c) Food products with an improved taste
   1) Sweet corn and peas that stay sweet longer
   2) Naturally decaffeinated coffee

d) Fiber crops such as naturally colored and fade-resistant cotton

F. Other Activities

1. Have students search the Internet looking for emerging applications of plant biotechnology.

2. Have students compete in the Missouri Department of Agriculture New Product Contest using products created with biotechnology.

G. Conclusion

Biofuels, biopolymers, and specialized plants with traits desired by producers are three major emerging applications of plant biotechnology. As information about the vast quantity of genes available from microbes, animals, and plants increases, more and more specialty crop plants will be developed. Most of these crops will comprise only a fraction of plant agriculture, and demand will determine which crops are grown.

H. Answers to the Activity Sheet

AS 4.1

Answers will vary.

I. Answers to the Evaluation

1. c
2. d
3. e
4. b
5. a
6. a
7. d
8. Stronger wood, fire-resistant wood, and trees that grow more quickly
9. Drought-tolerant plants, frost-tolerant plants, or salt-tolerant plants

EVALUATION

Match the examples of biopolymers with their descriptions.

1. _____ These biopolymers are used in the bleaching of paper and as additives to animal feeds.
2. _____ This type of biopolymer is found in modified oils from corn or canola.
3. _____ Scientists are attempting to change the chemical components of plants to contain higher levels of substances used for these biopolymers.
4. _____ These biopolymers are used for human health products.
5. _____ This group of biopolymers consists of products like a modified corn starch that does not break down when heated in the microwave.

a. Carbohydrates
b. Pharmaceutical proteins
c. Industrial enzymes
d. Fatty acids
e. Bioplastics

Circle the letter that corresponds to the best answer.

6. Which of the following is <u>not</u> a type of biofuel for which genetically modified plants are being developed?

   a. Petroleum-based fuel
   b. Alcohol-based fuel
   c. Plant oil-based fuel
   d. Biogas fuel

7. Biopolymers are:

   a. Complex carbon compounds that are byproducts of many types of plant biotechnology research.
   b. Combustible substances derived from plants or animals.
   c. Inorganic chemicals that cause plants to mutate.
   d. Complex chemical compounds from genetically engineered plants that are useful in many industries.

Complete the following short answer questions.

8. What are three products that the forestry industry would like biotechnology researchers to develop?

9. What are three types of environmentally tolerant plants that scientists are researching?

Lesson 4: Emerging Applications of Plant Biotechnology Name _____

Designer Plants--The Agricultural Products of the Future

Objective: Describe products of plant biotechnology that could be a part of the future of agriculture.

Answer the following questions to describe a possible plant product produced through biotechnology that might be used in one of the sectors of agriculture assigned to you by your instructor. You will need to use resources like textbooks, magazines and the Internet along with your imagination to complete this assignment.

1. Which sector of agriculture were you assigned?

2. What are the problems or limitations in raising plants used in this sector? (Include anything that costs money or time to control or overcome.)

3. What traits are currently being researched that may help improve the plants used in this agricultural sector?

4. What traits could be added to a plant that would not affect its main use but would improve its secondary uses or byproducts?

5. What are some industrial proteins that could be produced with plants in this sector of agriculture?

6. What are some traits that might enhance the aesthetic appeal (desirability) of plant products in this sector?

7. What is one trait that you feel will be developed in the next ten years?

UNIT VI - PLANT TECHNOLOGIES

Lesson 5: The Impact of Plant Biotechnology

Competency/Objective: Summarize the impact of biotechnology in plant agriculture.

Study Questions

1. **What are the career opportunities in plant biotechnology?**
2. **What are some economic factors of plant biotechnology that affect producers?**
3. **What are health and safety concerns of consumers of plant biotechnology?**
4. **What are the global social impacts of plant biotechnology?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference)*. University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.
2. Activity Sheet
   a) AS 5.1: Careers in Plant Biotechnology

UNIT VI - PLANT TECHNOLOGIES

Lesson 5: The Impact of Plant Biotechnology

TEACHING PROCEDURES

A. Review

Plant biotechnology has many applications, not only for food, but for products such as biofuels and biopolymers, as discussed in the last lesson. Many of these products may be on the market soon. What will be the impact of these new products? Will they only be positive? This lesson will provide a look at the economic, health and safety, and social effects of biotechnology on the United States and the world.

B. Motivation

Ask students to imagine this headline "World Price of Sugar Drops to All-Time Low: New Sugar-Producing Tobacco Provides Bumper Crop." Discuss the global effects of this event.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to recall the career areas discussed for animal biotechnology. Relate them to plant biotechnology, pointing out those careers specific to plant biotechnology.

What are career opportunities in plant biotechnology?

a) General areas of biotechnology career opportunities
   1) Research and development
   2) Quality control
   3) Clinical research
   4) Manufacturing and production
   5) Regulatory affairs
   6) Information systems
   7) Marketing and sales
   8) Administration
b) Career opportunities specific to plant biotechnology
   1) Plant scientist
   2) Greenhouse manager
   3) Tissue culture technician

2. Ask students to list the benefits and risks of producing a genetically modified crop.

What are some economic factors of plant biotechnology that affect producers?

a) Benefits
   1) Lower input costs for crops that require less chemicals
   2) Premium price for specialized crops
b) Drawbacks
   1) Higher price of seed
   2) Higher costs associated with the special handling needed to keep crops with a modified composition separate from unmodified crops

3) Limited market for specialized crops

3. Ask students to recall the results of the survey done in Unit 2. Have students list any concerns raised by those who were surveyed.

What are health and safety concerns of consumers of plant biotechnology?

a) Questions about the healthiness of genetically modified foods arise about foods in which the composition of the plant is changed.
b) Some consumers also worry that a plant altered for an industrial purpose will wind up in the food supply.

4. Ask students to speculate about the effect on other countries if a transgenic crop is introduced in the United States. Ask students if the effect would be positive or negative.

What are the global social impacts of plant biotechnology?

a) Positive global impacts
   1) Transgenic plants, such as the sweet potato resistant to the feathery mottle virus (FMV), can greatly benefit developing countries.
   2) The development of environmentally tolerant plants could help reduce the risk of famine in some countries.
   3) The development of edible plant vaccines could make it possible for millions of poor people to receive vaccines.
b) Negative global impacts - The development of some genetically modified crops can destroy the profitability of agricultural cash crops that may be vital to a country's economy.

F. Other Activities

Have students give presentations on the possible social impacts of the introduction of a new transgenic plant.

G. Conclusion

Transgenic crops are just beginning to be planted by producers, and therefore the full impact of these new crops is not quite clear. What transgenic plants will be introduced in the next five to ten years? What will be the long-term impact of the transgenic crops already in commercial production? Will producers, consumers, and developing countries be positively or negatively affected by plant biotechnology? These questions are difficult to answer, but they must be addressed to avoid social and economic pitfalls.

H. Answers to the Activity Sheet

AS 5.1

Answers will vary.

I. Answers to the Evaluation

1. a
2. d

3. Students may list either of the following: the healthiness of genetically modified foods in which the composition of the plant is changed or that a plant altered for an industrial purpose will wind up in the food supply.

4. Reduced input costs for crops that require less chemicals and a premium price for specialized crops

5. Plant scientist, greenhouse manager, tissue culture technician

UNIT VI - PLANT TECHNOLOGIES Name _____

Lesson 5: The Impact of Plant Biotechnology Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is a positive development in plant biotechnology for developing countries?

   a. The development of transgenic plants such as the FMV-resistant sweet potato
   b. The development of corn modified for industrial purposes
   c. The development of modified potatoes with leaves that can produce a large amount of sugar
   d. The development of a modified canola oil that can replace more expensive tropical oils

2. What is a potential drawback for producers raising genetically modified crops?

   a. Some genetically modified crops can reduce input costs for producers.
   b. Most genetically modified crops require more rain to grow than unmodified crops.
   c. Producers can normally obtain a higher price for crops with a modified composition.
   d. Specialized crops produced through genetic modification may have limited markets.

Complete the following short answer questions.

3. What is one health or safety concern that some consumers have about plant biotechnology?

4. What are two economic advantages that modified crops could have for producers?

5. What are three career opportunities <u>specific</u> to the field of plant biotechnology?

Lesson 5: The Impact of Plant Biotechnology Name _____

Careers in Plant Biotechnology

Objective: Investigate a specific career opportunity in plant biotechnology.

Select a specific job title in the field of plant biotechnology. The careers listed in this lesson can be used, as well as other job titles that you might find. Compile a profile of the career by answering the following questions. Then report your findings to the class.

1. What are the responsibilities of someone with this job?

2. Where are available jobs located?

3. What is the average salary?

4. What personality traits are valuable for someone working in this job?

5. What level of education is needed to obtain this position?

6. Where can this education be obtained?

7. What is the future job market outlook like for this position?