Lesson 1: The Importance of Plants

Plants provide people with oxygen to breathe, food to eat, clothing, shelter, and landscaping beauty. This lesson discusses the importance of plants and the areas of plant science.

Benefits of Plants

Plants are essential to the survival of human beings. Plants provide biological, physical, and emotional benefits. Biological effects include the ability of the plant to convert carbon dioxide to oxygen through the process of photosynthesis. Photosynthesis also reduces carbon dioxide levels in the air. Plants are also the basis for the human food supply. People eat plants and animals that have eaten plants.

Plants provide many physical benefits. Trees provide materials that are used to build shelters. Fibers from plants, such as cotton, are used in making clothing. Plants can also supply shade, control wind, and provide cooling effects. Control of these climatic factors can aid in reducing both wind and water erosion. Energy sources such as firewood or alcohol-fuels can be made from plant materials. Plants also provide a habitat for wildlife.

Emotional benefits include the beauty of well-landscaped areas as well as the enjoyment of interesting individual plants. Many Americans receive enjoyment from gardening and growing plants. Plants also provide a way to reduce stress by the relaxing effect of gardening and tending flowers.

Plant Science Areas

Four areas of science are closely related to the study of plants. These areas study plants for different reasons.

Botany is the science of plants and consists of such areas as anatomy, ecology, physiology, and taxonomy.

Horticulture includes producing, processing, and marketing fruits, vegetables, flowers, ornamental shrubs, and trees; nursery and landscaping; and turf management.

Agronomy is the study of field crops and soil management.

Forestry is the science of managing trees for lumber, paper, and other wood products.

Economic Importance in Missouri

Based on 1998 figures, the value of plants produced in Missouri was approximately $3 billion. See Table 1.1 for a list of the leading crops and plants. This value would put Missouri plant production in the list of Fortune 500 companies (the wealthiest companies in America).

Table 1.1 - Value of Leading Missouri Crops in 1998

Crop	Approximate Value (in millions)
Soybeans	$857
Corn	$550
Hay	$533
Winter wheat	$137
Cotton	$119
Rice	$64
Grain sorghum	$46
Floriculture	$44
Tobacco	$11
Potatoes	$10
Watermelons	$6
Apples	$5
Peaches	$4
Grapes	$1
Oats	$1

A closer look at several of the major areas of floriculture in 1998 shows there were $21 million dollars (wholesale value) of bedding plants (flats) and baskets, $11 million in indoor/patio plants, and $.6 million in cut flowers produced by Missouri commercial groups.

Summary

Plants are essential for humans to breathe and eat. Plants make life more comfortable because they provide shelter, clothing, and shade. Plants also make our world more pleasant through their beauty. Botany, horticulture, agronomy, and forestry are all related plant sciences. The value of plants produced in Missouri in 1998 was approximately $3 billion, which would make the Fortune 500 list.

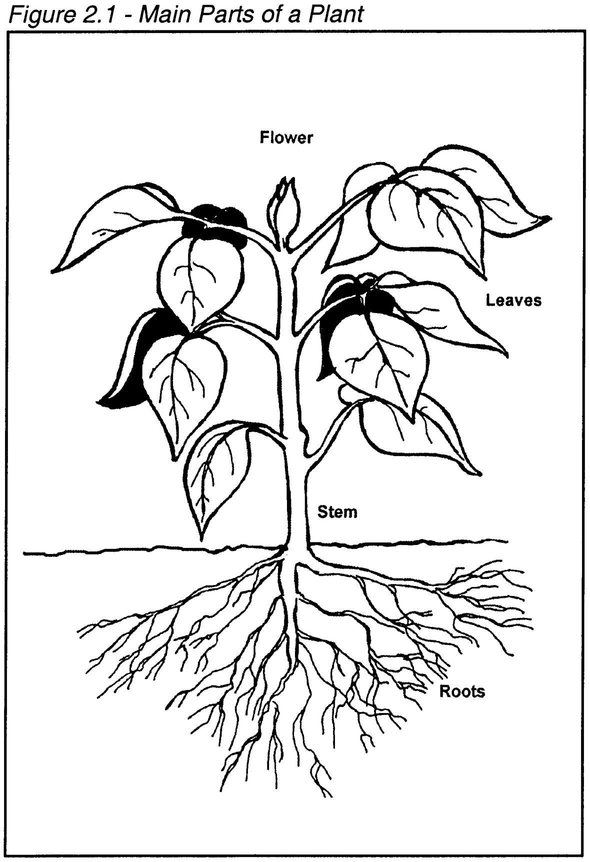
Lesson 2: Plant Parts and Processes

The major parts of plants are essential to the growth and reproduction of the plant in various ways. This lesson will discuss plant parts and their unique functions, reproduction, germination, and photosynthesis.

Main Parts of a Plant

Plants are made of four main parts: roots, stems, leaves, and flowers. See Figure 2.1. Each of the major parts is essential to the growth or reproduction of the plant.

Figure 2.1 - Main Parts of a Plant



Roots absorb water and minerals from the soil. Roots anchor the plant in the soil, allowing it to grow upright. They also act as a food storage area, like in turnips, beets, or carrots.

The stem supports the plant as a whole, but it mainly supports leaves and flowers. Stems transport water and minerals from the roots and transport manufactured food (simple sugars) to all parts of the plant. Stems can also be sites for photosynthesis and food storage.

Leaves are the location of food production for the plant. This production is through the process of photosynthesis. Respiration (release of energy and waste products) and transpiration (release of water vapor) also occur in the leaves. Leaves also can be the food storage area, like in cabbage or lettuce.

The flower is the site of sexual propagation. This is where the fruits and seeds are formed. During propagation the flower attracts insects that help transfer pollen from flower to flower. Insects can be attracted by color, pleasant fragrances, and unpleasant odors.

Plant Reproduction

Plants can be reproduced both sexually and asexually. Sexual propagation occurs within the flower, which produces fruit and seeds. It starts with the transfer of pollen from the male part of the flower to the female part. This is called pollination. Asexual propagation produces new plants from vegetative parts. New plants of some species can be produced from leaves, stems, and roots using asexual methods. Common asexual propagation methods are cuttings, grafting, division, layering, budding, and tissue culture. See Figure 2.2.

Figure 2.2 - Asexual Propagation Methods

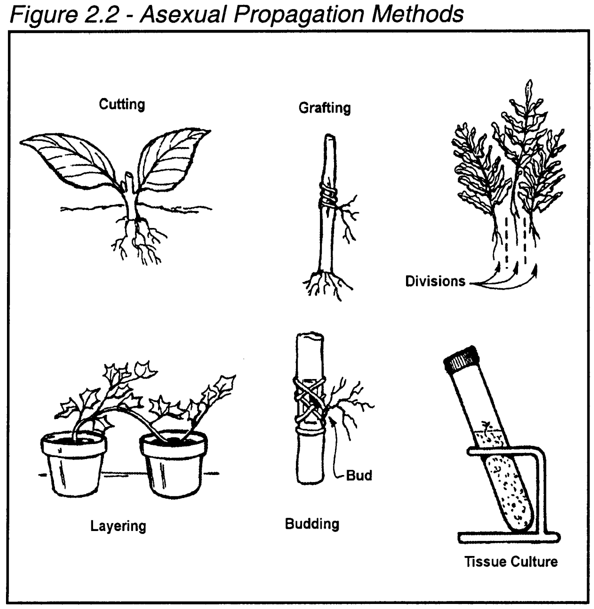
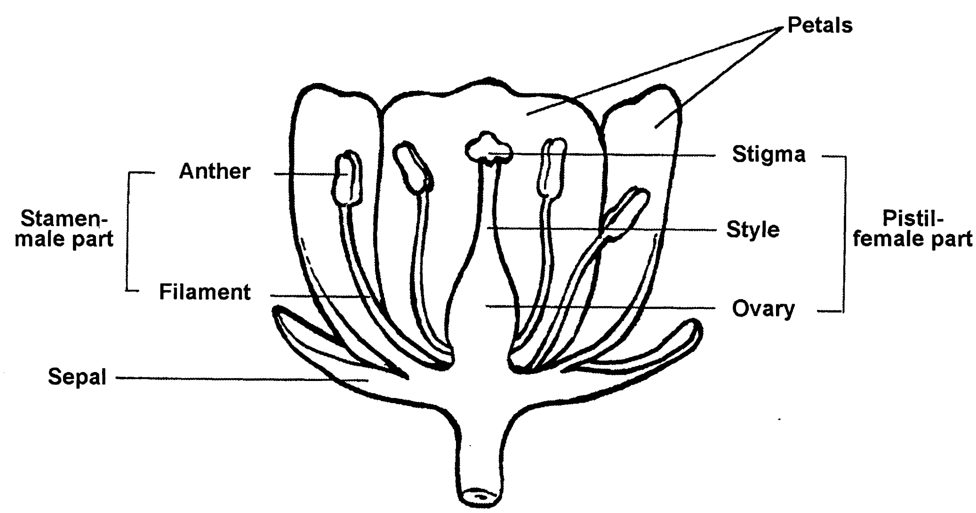


Figure 2.3 - Parts of a Complete Flower



Asexual propagation is used because (1) some plants do not produce seed or seeds are difficult to germinate, (2) it is usually a faster process than growing plants from seed, and (3) it is economical for horticultural businesses.

Parts of the Flower

Flowers are the site of sexual propagation. Flowers have four main parts: the petals, the pistil, the sepal, and the stamen. Refer to Figure 2.3.

The petals attract insects for pollination.

The pistil, which is the female structure of the flower, is the site of fruit and seed formation. The pistil is made up of the stigma, style, and the ovary.

The sepal protects the flower in the bud stage.

The stamen, which is the male structure of the flower, contains the filament and the anther. Pollen is produced in the stamen.

Pollen is transferred by a variety of methods to the pistil. This transfer of pollen is called pollination.

Seed Germination

After the seed has been produced by sexual propagation, it will germinate, or sprout, when conditions are favorable. The seed is in a dormant, or resting, stage with a supply of food and a protective seed coat until the requirements for germination are met. The following are needed for a seed to germinate: favorable temperature that varies by species, sufficient moisture, air, and the presence or absence of light (depends on the plant species). Thus germination, or sprouting of the seed, is the beginning of plant growth.

Photosynthesis

Photosynthesis is a process that occurs in green parts of the plant, mainly in the leaves and stems. Green plants contain chlorophyll, which reacts with water, carbon dioxide, and sunlight to produce oxygen and simple sugars. These sugars are the food source for the plant.

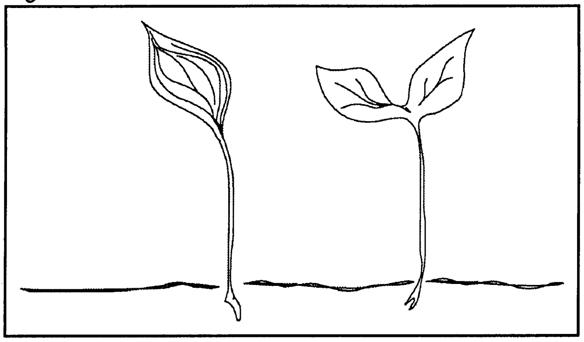
Annual, Biennial, and Perennial

Plants may be classified as annuals, biennials, or perennials based on their life cycle. Annuals complete their life cycle (grow, flower, produce seed, die) in 1 year. Biennials live for 2 years. They grow during the first year and flower, produce seed, and die during the second year. Perennials live for more than 2 years. They can grow year after year without replanting.

Monocots and Dicots

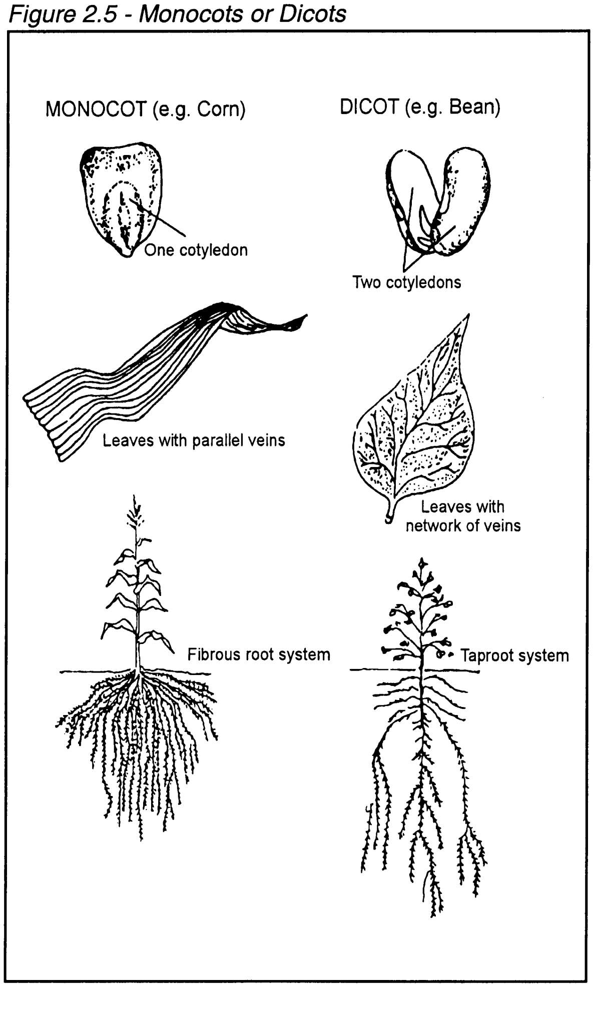
Agricultural plants can be classified as monocotyledonous plants and dicotyledonous plants. Monocotyledonous plants, frequently called monocots, have seeds with a single cotyledon (seed leaf or first leaf). Refer to Figure 2.4.

Figure 2.4 - First Leaves of Monocots and Dicots



Dicotyledonous plants, which are frequently called dicots, have seeds with two cotyledons (seed leaf or first leaves). The differences in these two major classes of plants can be clearly seen by comparing their seeds, leaves, and root systems. Figure 2.5 provides this visual comparison.

Figure 2.5 - Monocots or Dicots



Monocots have one cotyledon. The leaves have parallel veins and a fibrous root system. Corn, wheat, and lawn grass seed are several examples.

Dicots, such as soybeans and alfalfa, have two cotyledons. The leaves have a network of veins and a taproot system.

Summary

Plants have major parts that serve important functions and are important for plant survival or reproduction. Plants can be reproduced sexually by germinating seeds or asexually using vegetative plant parts. The main parts of a flower are the petals, pistil, sepal, and stamen. Germination is the sprouting of a seed when conditions are favorable. Photosynthesis occurs when the chlorophyll in the plant reacts with water, carbon dioxide, and sunlight to produce oxygen and simple sugars (food for the plant). The plant's life cycle may be completed in 1 year (annual), 2 years (biennial), or more than 2 years (perennial). Plants may be classified as monocots (single-seed leaf) or dicots (two-seed leaves).

Lesson 3: The Growing Medium

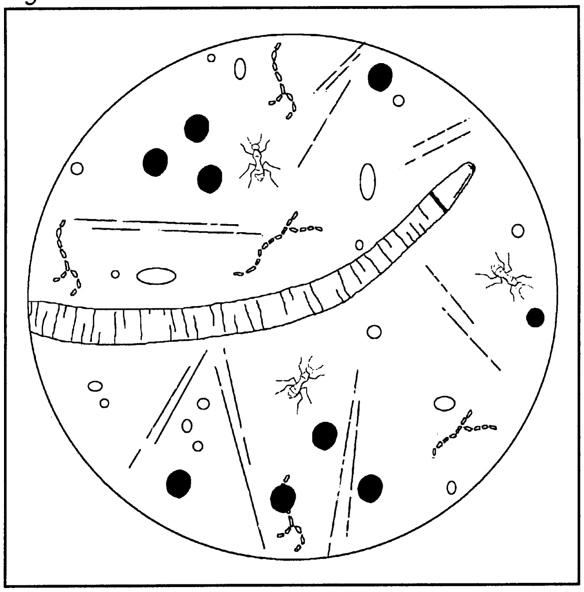
Plants require a certain environment for proper growth. Plants have an aboveground environment that affects the visible parts of a plant such as the stem, leaves, and flowers. They also have an underground environment where the roots live and grow. People who produce and grow agricultural plants must properly manage the underground environment to ensure a healthy and productive plant. This lesson focuses on the plant's underground environment.

Soil

Soil is the living and naturally occurring top layer of the earth's surface that provides food, water, air, and support for plant life. Soil is a renewable natural resource that humans depend on for food, clothing, and materials for shelter. It may be considered the basis for all life on earth.

Soil is composed of a great amount of life. Scientists agree there is more life below the surface of the earth than there is above it. In addition to the living plant roots, the life-forms are earthworms, insects, bacteria, fungi, and many other microscopic organisms. See Figure 3.1.

Figure 3.1 - A Closer Look at Soil

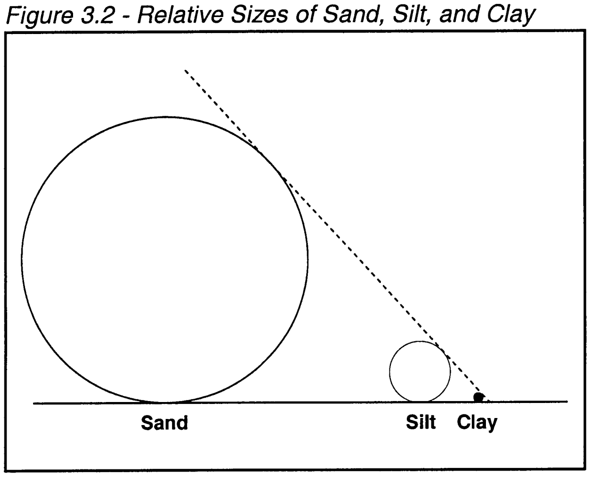


It is not accurate to refer to soil as dirt. Dirt is defined as misplaced soil. It gets on your clothing, under your fingernails, and blows into the house. Soil, on the other hand, is composed of millions of living organisms and is vital for the production of the world's food and fiber crops.

Components of Soil

An ideal soil contains 45% mineral matter, 5% organic matter, 25% water, and 25% air. Mineral matter is inorganic (from a nonliving source) and varies in size. Sand particles are the largest, feel gritty, and do not hold water effectively. Silt particles are medium-sized and have a smooth feel, like flour. The smallest mineral particles are clay, and they hold moisture much more effectively than larger particles. See Figure 3.2.

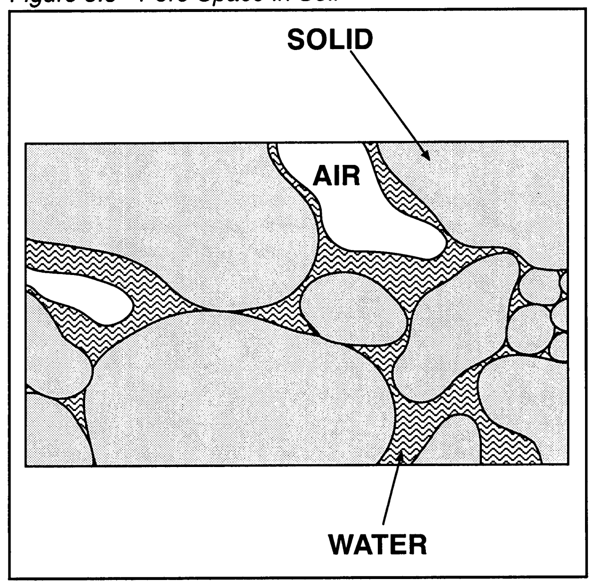
Figure 3.2 - Relative Sizes of Sand, Silt, and Clay



Organic matter originates from a living source, usually a plant or animal. This residue in the soil can be in various stages of decomposition.

Pore space is the area between soil particles. Depending on the weather and/or management practices, these small holes are filled with varying amounts of water and air. See Figure 3.3.

Figure 3.3 - Pore Space in Soil



Growing Medium

Greenhouse and nursery plants are grown in material called growing medium. Growing medium (singular) or growing media (plural) are the materials in which the roots of plants grow. An important function of a growing medium is to support, or anchor, the plant in place, even after watering.

The ideal growing medium must be able to retain sufficient moisture for good plant growth. However, the medium must also be porous enough to allow excess water to drain away from the plant roots.

Soilless Mix

Soil-based media were used in the horticultural industry for many years to grow plants. However, today almost all greenhouses and nurseries use a soilless medium to grow plants in flats, pots, and other containers.

A soilless mix is a medium that contains no soil. These mixes are commercially prepared and ready-to-use from the bag. Soilless mixes contain various combinations of the following materials.

Perlite - Perlite is gray-white material of volcanic origin. These particles are easily seen in the medium and are used to improve aeration. Perlite is also used to asexually propagate cuttings.

Vermiculite - Vermiculite is heat-treated mica (a very thin, layered mineral) that has been fired at 1400°F. It has a high moisture-holding capacity and is frequently used to asexually propagate cuttings.

Peat moss - Peat moss is partially decomposed vegetation that has been collected from marshes, bogs, or swamps. This spongy material has a high moisture-holding capacity. Most plant industry people prefer sphagnum peat moss.

Tree bark - Tree bark is used as a source of organic matter in soilless mixes. The particle size of the bark should be 1/4 inch or less in diameter. Bark of fir, pine, or cedar trees is commonly used.

There are several advantages to using a soilless medium rather than soil. Soilless mixes are lighter in weight, making them easier to handle and less expensive to ship. They are sterile and thus contain no diseased organisms, insects, or weed seeds. On the other hand, soil can harbor diseases or insects and consequently must be pasteurized by heating at 180°F for 30 minutes.

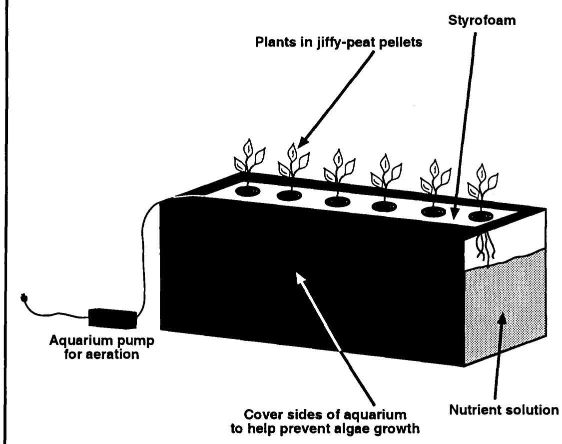
Soilless mixes drain very well. This makes it harder to overwater plants, thereby decreasing the chance of root rot diseases. In addition, soilless mixes are more uniform and do not vary in fertility or texture as much as soil.

Hydroponics

Hydroponics is a method of growing plants in water (nutrient solution) rather than soil. This technique is used to grow high-value crops in greenhouses, especially during the winter.

Some hydroponic systems use sand, gravel, rockwool, peatlite, or sawdust, rather than soil. Bare root systems mist plant roots at regular intervals with a nutrient solution, use shallow pools with plants floating on the surface, or use recirculating streams of nutrient solutions. See Figure 3.4.

Figure 3.4 - Aquarium Hydroponic System



Summary

The plant's underground environment is very important to its overall health. Nearly every product people use or consume can be traced back to the soil. The ideal soil is 45% mineral matter, 5% organic matter, 25% water, and 25% air. The growing medium is the material in which the roots of plants grow and is critical to the overall health of a plant. Today almost all greenhouses and nurseries use a soilless mix to grow plants in flats, pots, and containers. Hydroponics is a technique of growing plants in water (nutrient solution) rather than soil.

Lesson 4: Plant Care Requirements

This lesson will focus on the aboveground needs of plants and the nutrients essential for plant growth.

Plant Growth Factors

Several factors are important for plant growth: water, growing medium, nutrients, light, temperature, humidity, gases, and pest control. Water is essential to maintain the shape of plant cells and for use during photosynthesis. Water enables nutrients to be absorbed from the soil and transported throughout the plant. The manufactured food is transported to all parts of the plant by water.

The growing medium provides support for the plant. It should allow for infiltration and movement of water and air throughout the root zone. The growing medium also stores nutrients for use by plants. There are 16 essential nutrients for plant growth, which are discussed in the next section.

Plants need different levels of light intensity. Some need full sun and others need partial or full shade. Light is needed for the photosynthesis process.

Temperature is a major influence on plant survival in particular environments. Plants differ greatly in their tolerance of hot and cold temperatures. Extremes in temperature can cause slow growth, fruit or flower damage, or death of the plant. Temperature and light are related in their influence on plant growth.

Humidity, or moisture in the air, helps to reduce the drying effects on leaves. Higher humidity slows the amount of water lost from plant leaves.

Gases are important in photosynthesis. Carbon dioxide is used during the process and oxygen is produced.

Pest control is also an important consideration. One of the best ways to reduce pest problems is to keep the plant actively growing. A weakened plant is more susceptible to pests. Diseases and insects must be monitored and controlled.

Essential Nutrients

Plants need 16 essential nutrients in order to grow and develop properly. They require macronutrients in larger amounts than micronutrients. The three most essential nutrients that must be supplied to plants in the largest amounts are classified as primary macronutrients and are nitrogen (N), phosphorus (P), and potassium (K). Secondary macronutrients, needed by plants in moderate amounts, are calcium (Ca), magnesium (Mg), and sulfur (S).

Micronutrients are required by plants in small amounts, and these nutrients are boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn).

All of the above nutrients are absorbed by the plant in mineral form through the plant's root system. There are three essential nutrients, however, that are available to the plant in unlimited amounts from the atmosphere: carbon (C), hydrogen (H), and oxygen (O).

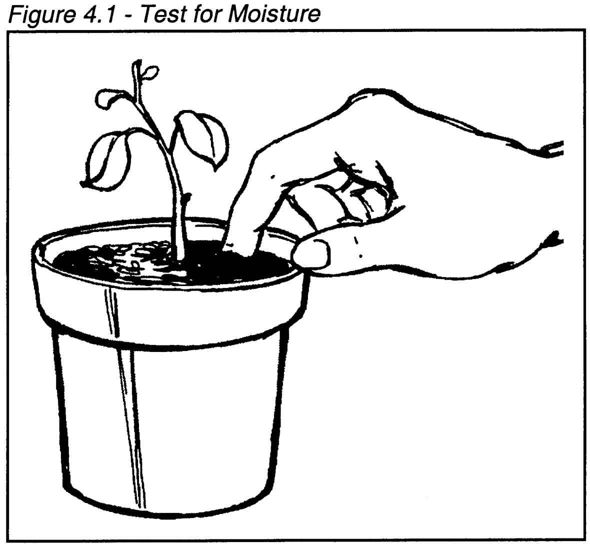
Care of Indoor Plants

For indoor plants, the watering rate will depend on the type of plant, growing medium type, temperature, light, and humidity. There are three general watering rules to follow: (1) use a well-drained growing medium, (2) water plants as needed, and (3) water thoroughly at every watering.

Select a medium that is highly porous yet retains water. Such a medium will retain sufficient water following watering to satisfy the needs of a plant for a reasonable length of time while at the same time be porous enough to supply adequate amounts of oxygen to the root system.

More plants are damaged or die from overwatering than from underwatering; therefore, care should be taken to water a plant only when it needs water. Observing the change in color of the growing medium is helpful in determining when to water. Most media turn lighter in color as they dry. Touching the medium to feel its moisture status is also a useful method of gauging when to water. Hands should be clean and no pesticides should be in the growing medium. To test for moisture, push your index finger into the medium approximately 1 inch (to the first joint). See Figure 4.1. If no medium clings to the finger when pulling it out, water the plant thoroughly. This method does not work well for plants requiring moist or dry conditions.

Figure 4.1 - Test for Moisture



In addition to watering indoor plants as needed, water thoroughly at every watering. Saturating the growing medium in a pot will make full use of the medium and its ability to store water for the plant, thus reducing the frequency of watering. The thorough watering will also leach out excess fertilizer salts that may build up and damage the root system. How can you tell if the plant has been watered thoroughly? Water should flow out the bottom of the container.

Some plants require specific humidity levels for best growth. The majority of indoor plants grow best when the temperature is approximately 70°F. Every indoor plant has varying requirements for best growth. They typically cannot tolerate extremely cold temperatures. Indoor plants require different amounts of light. Some indoor plants may not get enough light because of lack of natural light from windows. Indoor plants require good growing medium (potting mixture). Indoor plants require fertilization, according to the plants' needs. Plants should be pruned of dead or damaged leaves and branches as needed. Pruning or pinching is also done to improve the shape of plants.

Care of Outdoor Plants

Humidity is not easily controlled with outdoor plants. Many outdoor plants usually require watering only during dry periods. Smaller plants such as turf grasses, flowers, and vegetables may require more watering, depending on their specific needs. Outdoor plants are heavily influenced by the climate. This is why plants should be selected for the climate. A plant that requires the temperature to remain above 32°F will not grow well in an area where the temperature drops below freezing.

Outdoor plants vary in their need for light or shade. Plants should be selected for the level of light available. Pollution can also be a problem with outdoor plants. Trees and shurbs generally need only one fertilization per year. Turf grasses, flowers, and vegetables may need several fertilizations during the year. Prune occasionally to remove dead and damaged leaves and branches. Also, prune to maintain the plant's natural shape when it is needed.

Summary

Many factors need to be considered in caring for plants. Plants differ in their need for these factors depending on the variety and location. However, all plants require three major nutrients: nitrogen (N), phosphorus (P), and potassium (K). A key skill to be mastered in caring for plants is watering. More plants are damaged or die from overwatering than underwatering. Keeping a plant in good health will reduce the possibility of having pest problems.

Lesson 5: Technologies Used in Plant Agriculture

This lesson will focus on the current and emerging technologies in plant agriculture and the issues surrounding these technologies.

Satellite Systems Used in Plant Production

In the early 1980s, the U.S. Department of Defense started Global Positioning System (GPS), a satellite-based navigation system. Originally designed to serve as a worldwide navigational aid for the U.S. military, GPS now serves industrial, commercial, and civilian interests as well. Using 24 satellites orbiting the earth, the exact location of a tractor, combine, car, airplane, person, etc., can be determined. With the most accurate and expensive equipment, this location can be pinpointed to the nearest centimeter (.4 inch).

GPS allows a producer to improve plant management skills in many ways. Two of the more important skills are the following:

1. Use a yield monitor to measure a crop yield on-the-go and associate each yield value with a specific location on the surface of the earth.

2. Apply a variable rate of inputs (fertilizer, seed, herbicide, and insecticide) to match the field conditions.

High-tech equipment is being used in agriculture today to help producers do a better job of growing plants. Through the use of satellites and computer technology, a very detailed picture can be created about a field or plants being grown there. This is called precision farming. Precision farming is managing crop inputs such as fertilizer, seed, herbicide, and insecticide on a subfield basis. Instead of managing a large field of 90 acres, for example, the field is subdivided into subfields measuring 4 to 10 acres each.

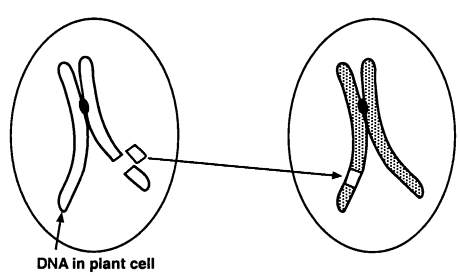
The goals of precision agriculture are (1) managing small areas within a field to reduce input amounts and costs, (2) improving the environment, and (3) increasing yields.

Genetic Engineering

Genetic engineering is modifying and enhancing the genetic components of organisms to benefit society. It is a process in which genetic material (DNA) is taken from one organism and inserted into the cells of another organism. It might also be the rearrangement of the location of genes. The resulting plant is called a genetically modified organism (GMO). This technology is being used to develop new plants with extraordinary potential for increased productivity that will help to feed the world.

In 1975, after many years of research, scientists developed enzymes that could cut DNA at precise points, thus making genetic engineering possible. See Figure 5.2. Ten years later, in 1985, genetically engineered plants resistant to insects, viruses, and bacteria were field-tested for the first time. And in 1994, the Flavr Savr tomato, the first genetically engineered whole food, was approved for sale. This tomato has a tougher skin that softens more slowly than other tomatoes. As a result, the Flavr Savr can ripen on the vine for a better taste, stay firm, and has a longer shelf life at the supermarket. Scientists accomplished this by putting a copy of the gene that causes softening of tomatoes in backwards.

Figure 5.2 - Gene Splicing



Enzymes are used to separate the DNA at a particular location on the gene.

The cut DNA is combined with DNA of another plant cell.

In recent years, corn and soybeans have been genetically modified for resistance to insects and herbicides. Figures from 1999 showed that North American producers planted about one-third of their corn acres to a GMO, primarily Bt corn, which resists the corn borer. In addition, about 55% of soybean acres had the Roundup Ready gene, which makes the soybeans resistant to herbicides.

Effects of Emerging Technologies on Plant Production

The intent of technology is to help supply the increasing world population with adequate food and clothing. The productivity of crops and plants will be increased so marginal land is not converted to crop ground and hurt by erosion. Pesticide use will be reduced as genetic traits are added to plants. According to the National Agriculture Statistics Service, written by the USDA, the overall volume of herbicide usage on U.S. soybeans fell by around 9% in 1998 compared to 1997. The increased usage of the herbicide-resistant Roundup Ready gene contributed to this decline.

Plants of the future will be developed with a much more specific purpose than today. Crops will be designed to meet specific needs. It will mean food can be produced that will be more nutritious, taste better, and be of higher quality. The nutritional value of crops for livestock and humans will be enhanced.

Scientists are using the term nutraceuticals to describe health supplements or vitamins delivered through food. Health could be improved and malnutrition alleviated in the world by supplementing needed nutrients through genetic engineering in corn, wheat, or rice. Daily diets that are low in adequate vitamins or proteins could be improved by nutraceuticals.

Farmaceuticals is another term being used today to describe the use of antibodies, medicines, or vaccines that could be inserted into plant-based products. It may one day be possible to prevent and treat a disease, such as cancer, by having a daily bowl of corn flakes.

Because these new technologies are associated with food production, they have come under close scrutiny by scientists, governmental organizations, and consumers.

Plant Technology Issues

New technology always seems to create controversy, and plant technology issues have generated considerable discussion. Some people view biotechnology as an answer to problems like world hunger and more nutritious food, but others see it as a source of environmental and ethical concerns. Most of the debate centers on two areas: genetically modified organisms (GMOs) and cloning.

The major issues can be categorized into five groups. The first category deals with the safety of consuming genetically engineered foods. Are there any negative effects from eating these foods? Is it possible that modified foods will trigger allergies? What are the long-term effects of a diet containing genetically modified foods?

The second set of issues relates to the labeling of genetically modified foods. Should these foods be labeled so that consumers have a choice? If the U.S. Food and Drug Administration has approved the genetically modified food, are different labels needed?

A third group of issues involves the safety of growing genetically modified plants in the environment. What will be the effect of these new life-forms and will the accidents be irreversible?

The fourth set of issues involves moral questions about whether genetic engineering and cloning of plants are ethical. Do scientist have the right to interfere with nature?

And finally, the last issue deals with the impact biotechnology has on the structure of agriculture. Will using biotechnology improve the profits of producers? Or will it lead to food production being controlled by a few companies? How will U.S. genetically modified products be regarded around the world?

At some future time, these issues may be resolved. Today, students are a part of this historical era of emerging plant technologies. Each can help to form public opinion on these issues.

Summary

Current and emerging technologies in plant agriculture will help to improve productivity and the environment in order to help feed and clothe the increasing world population. Humans will be supplied with more nutritious, higher quality, and better tasting food. Plant scientists continue to work on genetic engineering so medicines and vitamins can be delivered through food. The use of new technology, particularly genetic engineering, will cause debate and close scrutiny by many people and organizations. Biotechnology promises to raise food production to new levels, but concerns held by the public may slow its acceptance.

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