Lesson 1: Importance of Plants

Plants and their role in the survival of humans and animals on this planet are irreplaceable. Plants provide food, shelter, clothing, and a variety of other benefits. People will always need what plants provide; however, most plants can survive without people. Research and study continue to reveal new discoveries and uses of plants. Technology continues to make possible the means by which the growing demands for food and fiber from plant sources can be met.

The Importance of Plants

Plants play an important part in the food chain. Many animals depend on plants for their survival. Since the earliest recorded history, ancient civilizations have been concerned with providing food for their people. Plants have always played a major role in providing food.

As the human population increased, hunting and gathering could no longer provide enough food. Agricultural practices that involved large scale production of food crops such as corn, wheat, oats, barley, and rice enabled farmers to provide enough food for humans and livestock.

Nonfood products can also come from plants. Fiber crops provide many needed products. Cotton, hemp, flax, jute, and sisal are all fiber crop species, with cotton being the most widely grown. Production of fiber crops provides the raw materials needed to produce products like clothing, bedding, rope and cords along with other textiles.

Most plants can survive without any assistance from humans. However, people cannot survive without plants. Aside from the production of food and fiber crops, plants provide much more. Plants and the processes involved with plant growth are beneficial to the environment.

The Environment

Plants play a major role in the environment. All forms of life need energy for growth and maintenance. Plants, algae, and some bacteria are able to take energy from the sun and convert it into food. This process is known as photosynthesis. Life forms that are unable to obtain energy through photosynthesis must eat plants or other animals that eat plants in order to get their energy.

During the process of photosynthesis, plants absorb water from the sol and carbon dioxide from the air. Water and carbon dioxide combine with energy from the sun to produce carbohydrates (food) for the plant. This process produces oxygen. Without oxygen, people cannot live. Plants provide some of the food humans eat and the oxygen they breathe.

Besides using carbon dioxide, plants act as holding organisms for carbon dioxide (carbon sinks). Carbon sinks are extremely beneficial to humans. Carbon dioxide is a natural component in the environment. A problem arises when natural carbon dioxide levels are increased by exhaust from industries and automobiles and when plants are destroyed. The removal of trees and underbrush creates an imbalance in the environment. Care must be taken when altering the balance of these natural processes.

Soil erosion is another problem that plants can reduce or prevent. Trees, bushes, and grasses help break the force of pounding rains, fast moving surface water, and damaging winds. Soil is a precious natural resource that must be conserved. Certain agricultural methods in crop production, such as leaving crop residues (corn stalks or wheat stubble) on the field, help to prevent soil erosion. These crop residues and grasses can be turned into the soil to increase the organic content and quality of the soil.

Another major role of plants in the environment is beautification. People spend millions of dollars on beautifying homes, cities, businesses, towns, interstates, restaurants, etc. Cut flowers, houseplants, indoor trees, gardens, etc., provide a more pleasing environment. Plants can change the environment. They can be used as sound barriers (block out traffic noise) or visual barriers (block off an unappealing view). Grasses can be used for recreational areas such as football and softball fields.

Plant Science

Crops and Origins

There are many food and fiber crops grown in the U.S., but very few are native to this country. Of all the food crops grown in the U.S., corn is the only crop native to North America. Corn was introduced to the Pilgrims by the Native American Indians; however, it is believed to have originated in southern Mexico.

There are many stories about how the different food crop species were introduced to the North American continent. Table 1.1 helps identify some common crop plant species grown in the U.S., the time period when they were introduced, their origin, and their uses.

Table 1.1 – Crop Origin

Crop	Introduced into the U.S.	Origin	Crop Use
Barley	Pilgrims	Abyssinia & Southeastern Asia	Food, feed
Corn	A.D. 700	Mexico	Food, feed, oil, alcohol, industry products
Wheat	Shortly after the discovery of America by Columbus	Southwestern Asia, Euphrates and Tigris Valleys	Food, feed
Oats	Shortly after the discovery of America by Columbus	Eastern Europe or Western Asia	Food, feed
Rice	1964 – South Carolina	Southeast Asia	Food, some oil, industrial use
Peanuts	Early days of Colonization	Brazil	Food, oil, feed
Potatoes	Between 1705-1749	South America	Mainly food, some feed
Sorghums	Early days of Colonization	Africa and India	Sugars, feed, industrial uses
Cotton	Actual date not known – found on the Continent when discovered by Columbus	Mexico and India	Fibers, oil from seeds, feed, food from seed
Flax	1800s	Mesopotamia, Assyria, Egypt	Oil, feed, industrial uses
Soybeans	During early colonial period	China	Food, feed, oil
Alfalfa	Introduced into what is now known as Mexico by the Spanish in the 1500s. Introduced into California in the early 1840s.	Different alfalfa plant species come from different places (e.g., Russia, India)	Forage crop for feed

Uses

Plants are used in a variety of ways. One obvious use is in the production of food and fiber crops. Researchers also use plants. Biotechnology (genetic manipulation) is used to produce genetically superior plants. Crossbreeding is also used to produce hybrid varieties of plants with specific desirable qualities. If a disease or pest-resistant plant species is needed for a certain location in the world, biotechnology or crossbreeding can be used to develop such a variety.

Plants are also used in the production of nonfood products. Examples of nonfood products include medicines, clothing, rubber, perfumes, and spices. Even though scientists continue to work on developing synthetic products, plants continue to be the primary producers. Plants are used for beautification in lawns, parks, etc.

Summary

Plants and plant products provide many things for the world. They provide food, fibers, and oxygen. Humans cannot survive without plants.

Credits

Bishop, D.D., S.R. Chapman, and L.P. Carter. *Working in Plant Science*. New York: McGraw-Hill, 1978.

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Lesson 2: Classification of Plants

Continued study and research have increased our knowledge of plants. There are over 500,000 different plant species. A method of classification is needed to help researchers identify different species. This lesson is about methods of plant classification. By classifying plants, a better understanding of the plant world can be achieved.

Classification

Since as far back as recorded history, humans have depended on plants for food and shelter. Plants have been studied, and crude methods of classification were developed. The crude means by which plants were grouped together was successful until the world population grew and became inhabited by people of many languages. A method of classification was needed that could cross cultural and language barriers.

In 1753, Carolus Linnaeus, a Swedish naturalist and botanist, established the method of classifying plants that is used today. The Linnaeus method of classifying plants divided each plant's name into two parts. The first part is for the genus (group); the second part is for the species (kind). Linnaeus was a botanist, which is a person who specializes in the study of plants. The method used by Linnaeus and botanists today is referred to as the botanical method of classification. This method classifies plants regardless of their agricultural importance. The genus and species names given to plants are usually of Latin origin.

Another method of classification is known as descriptive classification. Descriptive classification is used mostly by plant scientists, agronomists, and farmers. This method deals mainly with crop plants. This classification is descriptive of the plants use by humans rather than its botanical classification. Descriptive classification can help identify plants' cultural needs, growth patterns, limitations, and requirements for optimum production or growth.

Botanical Classification

As research and study of plants increased throughout history, the need to share discoveries became more apparent. For example, scientists working in Germany needed to share their findings with scientists in South America working on the same problem; therefore, the language barrier needed to be solved. As early as the Middle Ages, Latin was the recognized language used throughout the world by scholars and educated individuals. Latin was the basis of most European languages, including English. It was taught throughout the world regardless of a country's native tongue. Since Latin is considered an unchanging language, it is suitable for universal communication. Therefore, botanical classification uses Latin to identify the genus and species of plants.

Botanical classification places plants into discrete categories called taxa (plural for taxon). The naming of organisms is termed nomenclature, and the grouping of organisms is termed classification. These two processes belong to a specialized field known as taxonomy. Taxonomists are scientists who classify and name plants.

The botanical classification system is important because it clearly identifies plant species. Botanical classification attempts to group plants according to their similarities. In the botanical system, there are eight levels of classification for each species. The "kingdom" is the broadest category of classification. The "species" is the most specific category. Using the acronym "KDCSOFGS" May help people remember the levels of the classification system.

1. Kingdom
2. Division or phylum
3. Class
4. Subclass
5. Order
6. Family
7. Genus
8. Species

Each of the eight levels is used to classify an individual plant species. Botanical classification also helps to identify how plant species differ from other plants. Table 2.1 is an example of botanical classification.

Table 2.1 – Wheat vs. Barley Classification

	Wheat	Barley
1. Kingdom	Plantae (plant, distinct from animal)	Plantae (plant, distinct from animal)
2. Division	Spermatophyta (or seed plants)	Spermatophyta (or seed plants)
3. Class	Angiosperma (or plants with their seeds in a fruit)	Angiosperma (or plants with their seeds in a fruit)
4. Subclass	Monocotyledonae (seed with single seed leaf)	Monocotyledonae (seed with single seed leaf)
5. Order	Graminales (grass-like families)	Graminales (grass-like families)
6. Family	Graminae or Graminaceae (the grasses)	Graminae or Graminaceae (the grasses)
7. Genus	Triticum (the wheats)	Hordeum (the barleys)
8. Species	aestinum (bread wheat)	Vulgare (barley)

By comparing the two species, one can see the similarities between the two species from kingdom to family. However, the two plants differ at the genus and species levels. This system is used to correctly identify specific species, especially when there are several different species in a particular genus.

Monocots and Dicots

Agricultural plants can be divided into monocotyledonous plants and dicotyledonous plants. Monocotyledonous plants, frequently called monocots, have seeds with a single cotyledon (first leaf). See Figure 2.1.

Dicotyledonous plants, which are frequently called dicots, have seeds with two cotyledons (first leaves). The differences in these two major classes of plants can be clearly seen by comparing their seeds, root systems, stems, leaves, and flowers. Seeds of monocots contain the embryo, endosperm, and one cotyledon. See Figure 2.2.

Monocots have an embryonic root, which develops from the seed. This embryonic root dies soon after the seed germinates. The whole root system of monocots is composed of adventitious roots. Figure 2.3 shows the location of the adventitious roots of the monocots. Monocots have many roots that are all about the same size.

Figure 2.1 – First Leaves of Monocots and Dicots

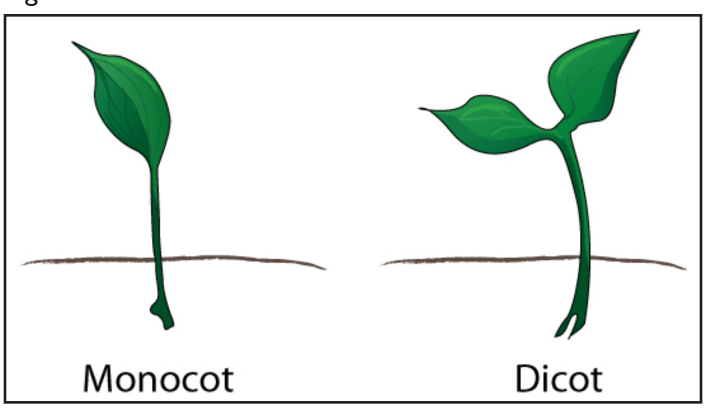


Figure 2.2 – Monocot Seed

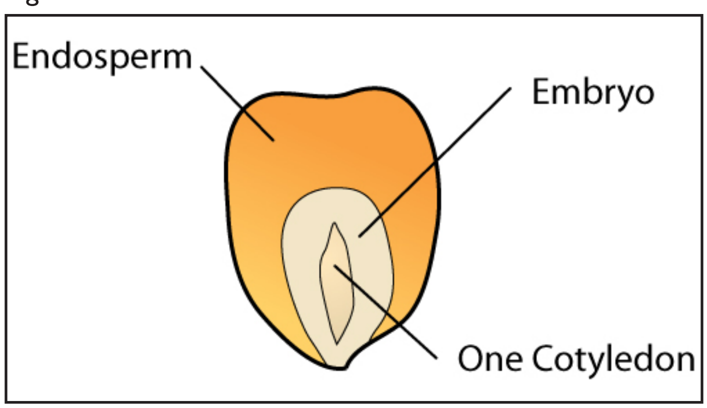


Figure 2.3 – Monocot Root System

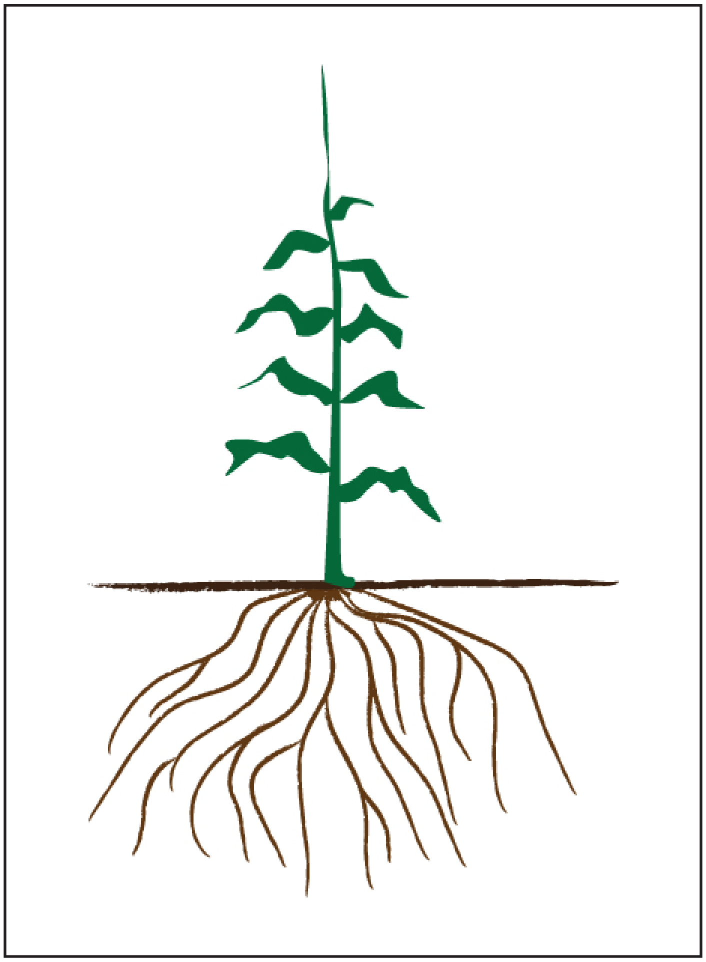
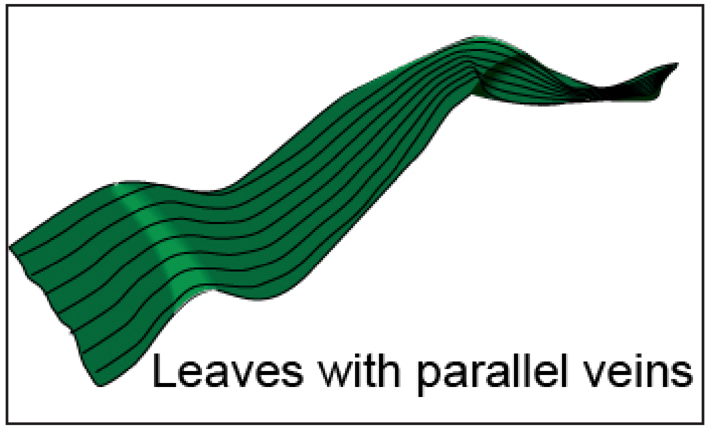


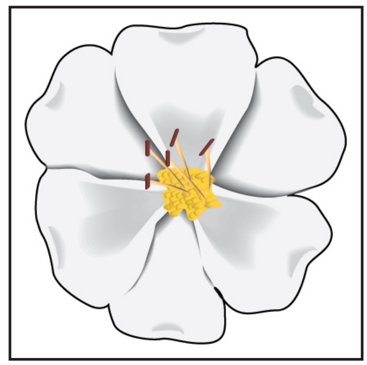
Figure 2.5 – Monocot Leaf



Monocot leaves are long and narrow with parallel veins. In the leaf's epidermis, the cells are long and run in the same direction as the leaf length. See Figure 2.5.

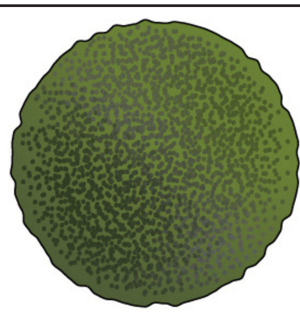
The flower of monocots contains three parts or multiples of three. See Figure 2.6.

Figure 2.6 – Monocot Flower



Monocots usually have 10 vascular bundles scattered throughout the stem. These vascular bundles contain xylem and phloem tissues, not vascular cambium tissues. See Figure 2.4.

Figure 2.4 – Monocot Stem



Seeds of dicots contain an embryo, seed coat, and two cotyledons. See Figure 2.7.

Figure 2.7 – Dicot Seed

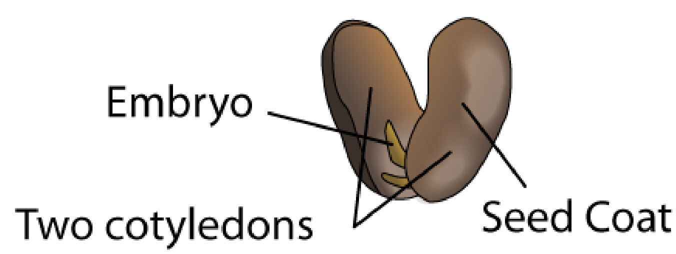


Figure 2.8 – Dicot Root System

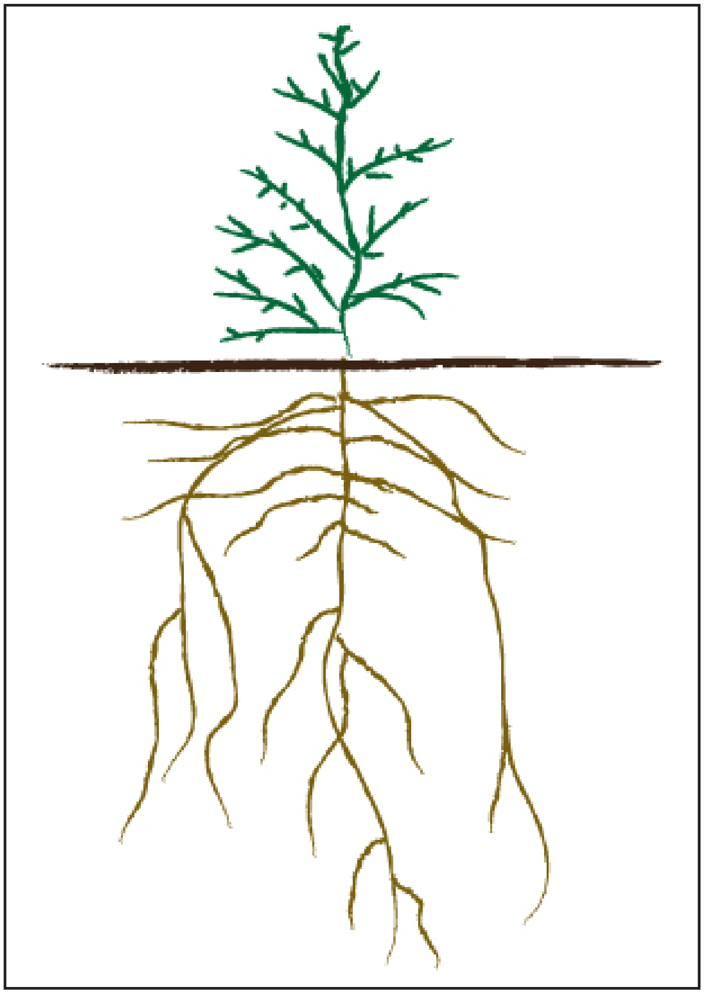


Figure 2.9 – Dicot Stem

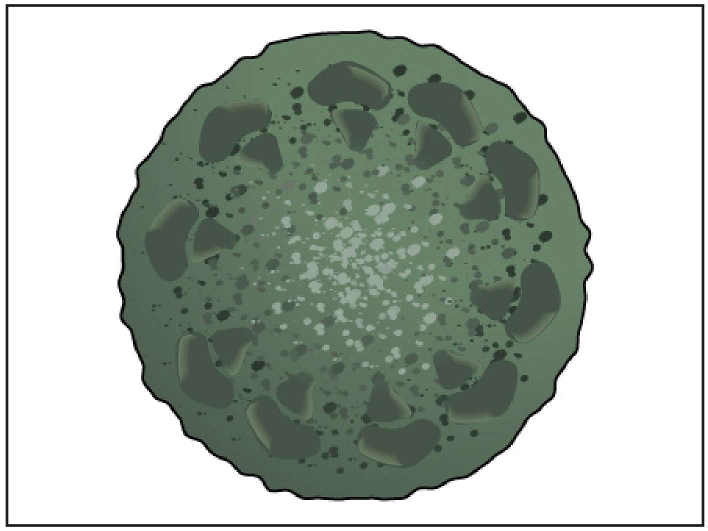


Figure 2.10 – Dicot Leaf

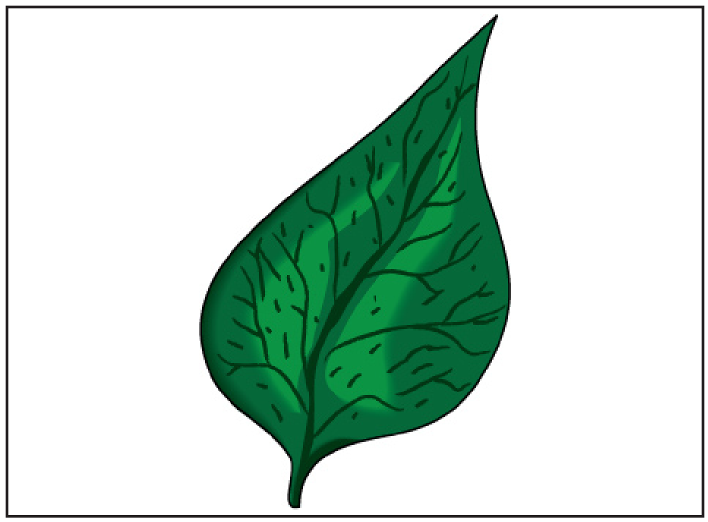
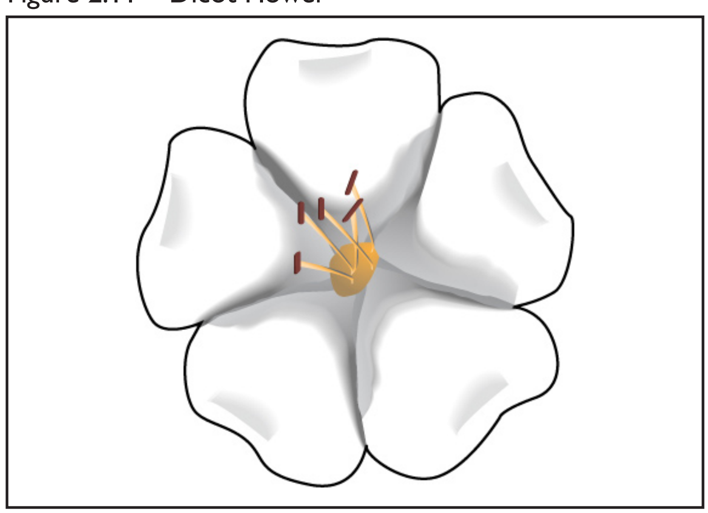


Figure 2.11 – Dicot Flower

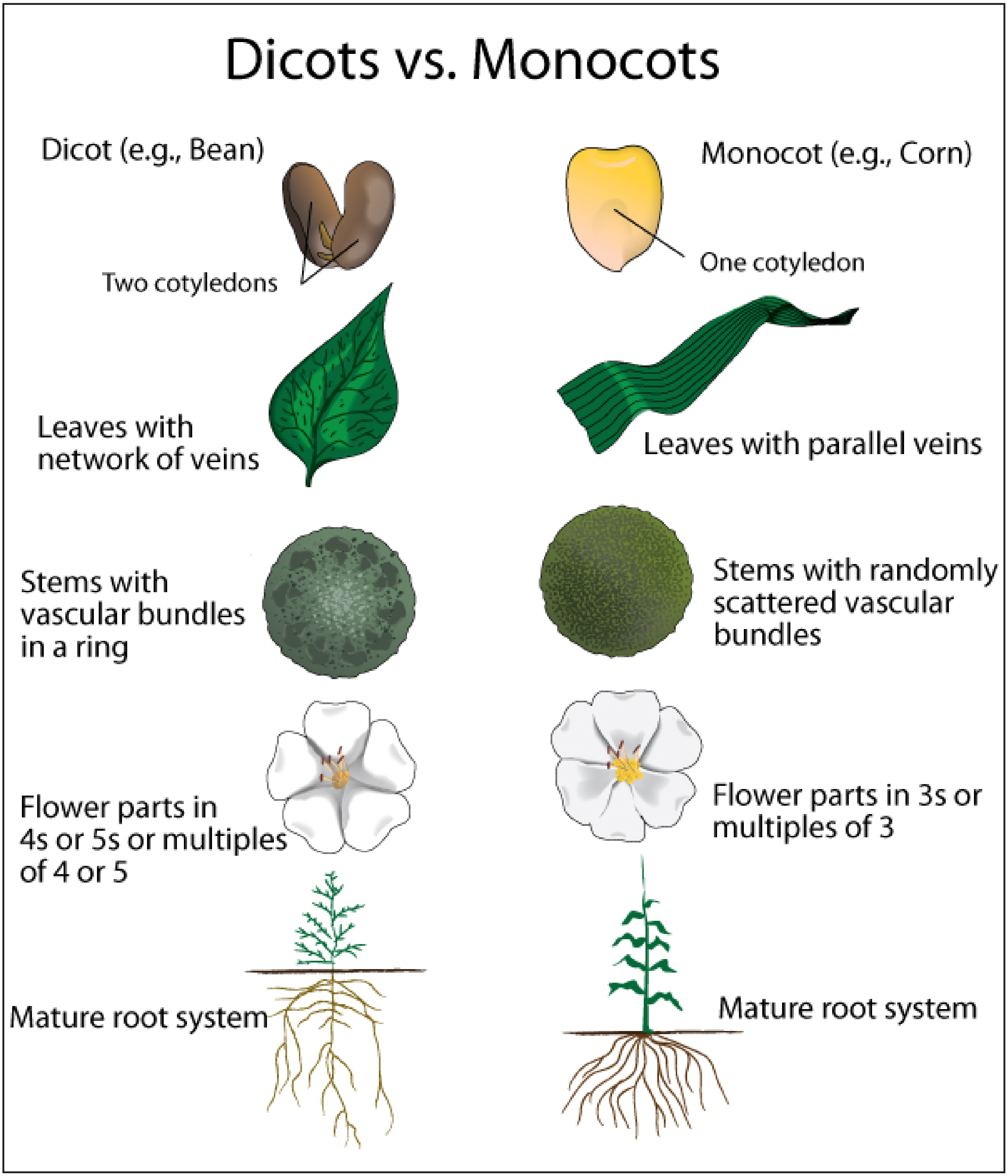


Dicots have roots with numerous root hairs that have a very short life span, often only a few days. As the plant continues to grow, new roots and root hairs grow on a continuous basis. The primary root will begin to thicken and develop secondary growth at about the same time as the stem. See Figure 2.8.

The stem of dicots contains four or five vascular bundles that form a ring around the outside of the stem. Each vascular bundle contains phloem, cambium, and xylem tissues. See Figure 2.9.

Unlike monocots, leaves of dicots have a network of veins. The veins in dicots do not run parallel with the length of the leaf. See Figure 2.10. The flower of dicots contains four or five parts or multiples of four or five. See Figure 2.11. Figure 2.12 provides a comparison of dicots and monocots.

Figure 2.12 – Dicots vs. Monocots



Legumes

Legumes (Leguminosae) are a unique family of plants in the plant kingdom. Legumes are named for the type of fruit, also called a pod, which is characteristic of plants in this family. Some examples of legumes are:

1. Soybeans
2. Peanuts
3. Beans: lentils, lima, black, black-eyed, kidney, pinto, white, scarlet runner, string, and shell
4. Peas: chick-pea and green pea

Legumes commonly used for livestock feed include:

1. Alfalfa
2. Clovers: red, white, alsike, and crimson; others less used: hop, Persian, sub, and strawberry
3. Birdsfoot trefoil
4. Vetch: common, hairy, purple, and Hungarian
5. Lespedeza: Korean, common, and perennial sericea

Legumes are also produced for their oil content. Some countries grow legume seeds primarily for their oil and use the protein as a by-product. For example, soybean oil is used in processed foods such as margarine, salad oils, and shortenings. Industrial oils from legume seeds are used in paints, varnishes, inks, and many other products.

Legumes are unique in their ability to obtain certain nutrients. All plants need nutrients for proper growth and development. The three primary nutrients needed are nitrogen, phosphorous, and potassium, all of which can be applied as fertilizers.

Some legumes have a unique capability known as symbiotic nitrogen fixation. They can take nitrogen from the air. Through a symbiotic relationship with rhizobia bacterium, legumes produce nitrogen in a form that plants can use.

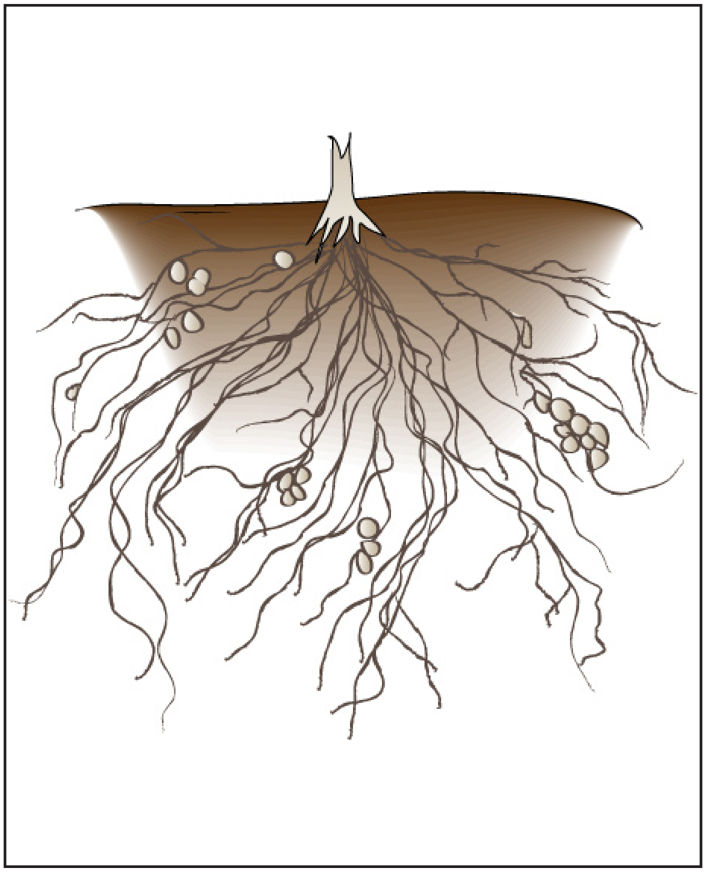
When the rhizobia bacterium enters the plant's roots, nodules form. These nodules work like small factories producing nitrogen that helps plants grow, thus reducing the need to apply commercial nitrogen fertilizers. This bacterium is not always naturally present in the soil. By placing a culture containing the bacterium on seeds before planting, it will increase the amount of nitrogen produced in the roots. Adding this bacterium to the seeds is called inoculation. See Figure 2.13.

In addition to reducing the need for nitrogen fertilizers, reducing cost, and increasing crop yields, nitrogen fixation enriches the soil. Some legumes are used as cover crops that are plowed into the soil. This increases soil nitrogen levels and benefits the next crop planted.

Life Cycles

Each plant grows in stages which, from beginning to end, are its life cycle. In descriptive classification, a plant's life cycle is important because it relates to the plant's productivity. The life cycle covers all stages of the plant's life from the seed through growth of the plant to the formation of another seed.

Figure 2.13 – Nodules on Legume Roots



Farmers and agricultural scientists study the life cycle of plants. This study increases the understanding of plants' reproductive cycles. Life cycles can be divided into three categories: annuals, biennials, and perennials. Annual plants complete their life cycles within one year or growing season. Many flowers purchased in the spring are annuals. They die off at the first frost and will not grow again the next year unless planted again.

Annuals can be subdivided into summer and winter annuals. Summer annuals are plants that are seeded in the spring and harvested in the fall. Corn is an example of a summer annual. A winter annual is a type of plant that is seeded in late summer or early fall and harvested the following summer. Winter wheat is an example of a winter annual.

Biennial plants require two years to complete their life cycles. Generally in the first year after planting, the plant produces mainly vegetative growth including leaves, stems, and roots. The second year the plant produces flowers, fruits, and seeds. At the end of the second year, the biennial dies. Sugar beets, carrots, and onions are examples of biennials.

Perennial plants live year after year. Perennials continue through their life cycle each year and produce flowers, fruits and seeds. After they produce seed, they appear to die back, but actually they go into a resting period called dormancy. This process is more noticeable in regions that have cold winter seasons. The perennial may completely stop growing for the winter. However, when spring comes, its pattern of growth begins again. During the dormant period, the perennial slows down all its natural processes. Dormancy is a means by which plants protect themselves from the colder temperatures. Many forage (animal feed) and pasture crops are perennials. Trees, shrubs, and some flowers used in landscaping are perennials also. Most lawn grass species are perennial plants.

Summary

Because plants are vital to human survival, knowledge and understanding of the plant kingdom are beneficial. Both botanical and descriptive classifications provide a means for communication. Research will continue to provide ways to meet the growing demand for food and plant products.

Credits

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Lesson 3: Plant Growth Factors

In order to discuss the process by which plants grow, a definition of plant growth is needed. Plant growth is an irreversible process during a plant's life that increases plant volume or dry weight or both. Scientists and agriculturalists are concerned with factors that affect plant growth. Understanding the factors that influence plant growth is beneficial to everyone, including consumers who purchase food at the grocery store.

Factors Affecting Plant Growth

Plant growth is affected by the environment. Factors that affect plant growth are light, water, nutrients, and temperature. Each factor affects specific processes or a combination of processes within the plant that directly relates to plant growth and development.

Light

Light is essential for plant growth. Normal plant growth requires the full range of the visible spectrum of sunlight. Plants react to light through the process of photosynthesis, phototropism, and photoperiodism.

Photosynthesis: Photosynthesis is a chemical process that takes place within plant cells. Photosynthesis changes nonliving materials into food. Through photosynthesis, water (H_2O) and carbon dioxide (CO_2) in the presence of light are converted into energy-rich organic compounds (sugars). Once these sugars (carbohydrates) are formed, they can be changed or transformed into starches. Products from the process of photosynthesis are used by the plant as food for growth and development.

Phototropism: Phototropism is a term for the reaction of plants caused by exposure to light. In the process of plant growth, organic chemical substances within the plant are involved. These chemical substances, which are known as hormones (growth regulators), can either promote or inhibit growth. In phototropism, the hormones stimulate longitudinal growth of the plant's stem.

As the hormones move throughout the plant's phloem system, they affect other growth processes such as seed germination, flower initiation, flower growth, and pollen-tube growth.

Phototropism causes the plant to bend and grow toward light. The reason for this bending action is the accumulation of hormones on the dark side of the plant. The accumulation of hormones causes the cells to become elongated. Cell elongation causes the stem to bend towards the light. Phototropism stimulates plant growth through movement of the plant.

Photoperiodism: One other plant reaction to light is photoperiodism. Photoperiodism is the growth response of plants caused by the number of light and dark hours in the day. Photoperiodism is commonly referred to as "day length." In the process of plant growth, formation of the flower is vital in the production of seed. In many plant species, flower formation depends upon day length. By understanding the plant species' photoperiodism requirements, flowering can be manipulated in controlled environments such as greenhouses. Not all plants need a specific length of daylight hours to produce flowers. However, all plants require light to complete their life cycles and continue to produce more seeds.

Water

Water is considered an essential element in plant growth. Depending on the plant, moisture content can vary from 15% to 95% of the plant's "fresh" weight, or weight of green material. When moisture is removed, the actual Weight of "dry" matter can be calculated. Water provides a means by which minerals can be taken up and transported throughout the plant. Water is involved in many chemical reactions throughout the plant. Although all plants require water, the amount of water required differs with each plant species.

Nutrients

Plants also have nutritional needs in order to grow and develop properly. The greatest percentage of the content of a herbaceous plant (a plant that lacks woody tissue) is water. Plant dry matter consists of three main elements: carbon, hydrogen, and oxygen. These three elements are made available to the plant by water, carbon dioxide, and oxygen. Plants also require 13 other essential elements for proper growth. These elements can be divided into two groups: macronutrients and micronutrients.

Plants require larger amounts of the macronutrients than micronutrients. The macronutrients include: nitrogen, phosphorous, potassium, calcium, magnesium, and sulfur. Macronutrients can be divided into primary and secondary categories. Primary macronutrients are nitrogen, phosphorous, and potassium. Secondary macronutrients are calcium, magnesium, and sulfur. To better understand the plant's need for the macronutrients, see Table 3.1, which lists the nutrients and their functions.

Micronutrients are those that plants require in small amounts (parts per million, ppm) per unit of plant dry matter. Micronutrients are: boron, manganese, copper, zinc, iron, chlorine, and molybdenum.

Methods to Obtain Nutrients

Plant growth depends on the availability of the essential nutrients. In order for nutrients to be helpful to the plant, the plant must be able to bring them up into its structure. A plant obtains nutrients by the processes of absorption and osmosis. Nutrients are then transported throughout the plant by translocation. During the transpiration process, oxygen is released into the atmosphere through the stomata in the leaves.

Absorption is the process through which plants absorb nutrients and water from the soil through its roots. Absorption is most active just above the root tip in the region of the hair roots. Once water and nutrients have been absorbed into the plant, they are then used for various needs.

Table 3.1 - Macronutrients

Primary Macronutrients	**Use of nutrient in plant**
1. Nitrogen	Needed in making proteins Increases plant green color Promotes rapid growth
2. Phosphorus	Promotes early root formation Promotes vigorous start Hastens maturity
3. Potassium	Increases vigor and disease resistance Increases strength of stalkes Increases gain size
Secondary Macronutrients	**Use of nutrient in plant**
4. Calcium	Promotes early root formation Improves general plant vigor Component of cell walls
5. Magnesium	Part of chlorophyll Aids in formation of sugars
6. Sulfur	Promotes increased root growth Helps maintain dark green color

During absorption, molecules of water and nutrients outside the plant's roots are taken up into the plant. The movement of molecules through permeable membranes is known as diffusion. As water passes through these membranes, it is referred to as osmosis. The movement of water and the flow of larger molecules is caused by pressure differences within the plant known as hydrostatic pressure.

Temperature

Temperature can influence plant growth positively or negatively. Because plants have large surface areas, it is difficult for them to regulate their own temperature. Temperatures above or below the optimum growing temperature of 68° to 95° will reduce carbon fixation within the plant. When temperatures drop, plant processes slow down. Chemical reaction rates also slow down at cooler temperatures. Gaseous exchange decreases, and diffusion and osmosis slow down because the permeability of membranes is more difficult. Colder temperatures reduce the growth rate of plants.

As temperatures rise past the optimum, plant growth is also reduced. As the temperature rises, enzymes become less stable and break down causing plant inactivity. Many processes within the plant are affected by temperatures. Consequently, plant growth is reduced as temperature rises above the optimum. The optimum growing temperature varies for each plant species.

Summary

Understanding the factors that influence plant growth is important to understanding the process of plant growth. The plant kingdom is very dependant upon the environment. The availability of light, clean water, essential nutrients, and optimum temperature all affect plant growth. Humans are equally dependent upon the plant kingdom. Caring for the environment will help to ensure the continued supply of food for the world.

Credits

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Lesson 4: Weeds, Diseases, Insects

Many areas of the world are plagued by food shortages because of pests. High percentages of crops are lost due to pest damage. Each year, billions of dollars are spent to research the causes of crop damage and possible ways to prevent crop loss due to pests. Plant growth depends on a combination of external factors and internal processes. Successful production of food and fiber crops involves more than just plowing the soil, planting the seeds, and waiting for harvest. Many factors must be managed for successful plant growth.

Plant Pests

Plant pests include all life forms that cause damage to plants. Pests can range from the smallest living organism, such as bacteria, to a deer that wanders into a field and eats or tramples a corn crop. Pets are commonly categorized into three groups: weeds, diseases, and insects.

Weeds

As was discussed in Lesson 3, plants need sunlight, water, and essential nutrients for growth and development. All plants, including weeds, require these elements. Therefore, weeds compete with crop plans for nutrient elements.

Each year American farmers lose billions of dollars because of weeds. Weeds can inhibit crop growth and lower crop quality. Weeds are vigorous in their competition for plant nutrients and often develop an immunity to other pests. Weeds often overpower crops when their seed germination rates are higher and emergence occurs before the food crop. Weeds can populate an area quickly and steal the essential nutrients before crop plants can absorb the needed nutrients.

Disease

Healthy plants are able to carry out normal physiological functions. Normal physiological functions include: cell division, development, absorption of water and essential nutrients from the soil, translocation, photosynthesis, food storage, reproduction, and overwintering.

Normal plant functions can be affected by either adverse environmental conditions or a combination of harmful factors. When normal plant functions are altered beyond some tolerance point, the plant may become diseased. The major causes of disease are environmental conditions under which plants are exposed to pathogenic living organisms (pathogens). Pathogens are organisms that transmit diseases.

Plants respond differently to various diseases. However, most diseases are harmful to plants. Injury to plant tissues and cells reduces the plant's ability to produce food through photosynthesis. The reduction of photosynthesis can stunt the growth of the plant or kill it entirely. Diseases affecting tissues and cells also affect the plant's structural strength. Weakened structural strength increases crop losses due to reduced yields and quality.

Condition for Diseases

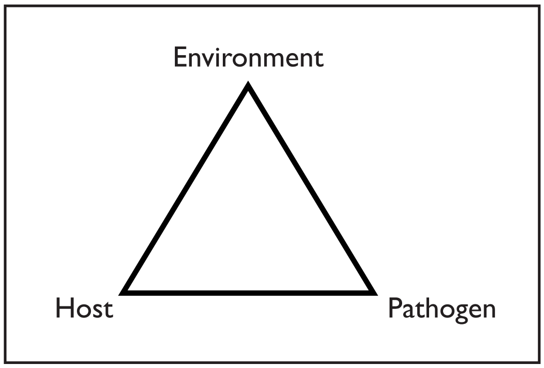
A plant can become diseased when it has been damaged or injured by environmental causes or attacked by a pathogen. In order for plant disease to develop, certain conditions must be present: a susceptible host, a virulent pathogen, and a favorable environment.

A susceptible host refers to a weakened plant that comes in contact with a pathogen. Plants that have been injured or stressed are more susceptible to infection. Plant scientists and breeders have made great progress in developing disease-resistant crop varieties. In order for the disease process to start, the combination of the plant and pathogen must be favorable. Disease-resistant crop varieties reduce the possibility of a disease starting.

The second condition is the virulent pathogen. Not only does the plant need to be a susceptible host, the pathogen must carry the disease organism. A virulent pathogen is one that is able to successfully attack a plant and inflict the disease.

The third condition necessary for the development of a disease is the environment. When the first two conditions are present, but the environment does not enhance that contact, no disease will develop. If the environment is too cold, too hot, too dry, or some other extreme, the disease may not develop at that time. These three conditions necessary for the development of a disease can best be illustrated in what is known as the disease triangle. See Figure 4.1. The absence of any one of the three factors will prevent occurrence of the disease. Disease control practices are directed toward eliminating one or more of the three factors.

Figure 4.1 – Disease Triangle



Insects

The presence of insects is a part of life. Insects need nourishment and shelter; plants provide both. Insects inflict damage to crops that cost producers and consumers billions of dollars annually. For example, the European corn borer can destroy up to 35 million dollars of the corn crop annually, and that is only one species of insect. However, not all insects are harmful to plants. Some insects actually help by destroying other harmful insects.

Insects inhibit plant growth in two ways: by causing physical damage or physiological damage. Physical damage is caused by insects attacking physical structures of the plant. For example, insects that are categorized as foliage feeders are chewing insects.

Foliage feeders are the largest group of insects. Foliage feeders chew on leaves, stems, and flowers. Some foliage feeders may bore themselves into the plant and eat the tissues inside the stem like the cutworms or army worms. Foliage feeders are found in large numbers and can do extensive damage in a short period of time.

Sap sucking insects also do physical damage to plants. Aphids and leaf hopper nymphs are species that attach themselves to plants and suck plant sap from the leaves and stems. Sucking the sap from the plant robs the plant of essential nutrients. Other physical damage caused by insects may occur on the roots, the seeds, or the fruit of plants. Attacking the physical structure often reduces plants to a weakened state and therefore more susceptible to disease.

Physiological damage refers to disruption of natural processes within the plant. Photosynthesis, respiration, and translocation of nutrients and water throughout the plant are examples of physiological processes. Physiological damage to the plant may also be caused by insects. Insects are considered vectors. A vector is a carrier. Vectors can be beneficial by carrying pollen and aiding in the pollination of plants. Vectors can also be harmful by carrying disease-causing organisms from plant to plant. Insects can also cause physiological damage to plants by depositing their eggs on or within the plant. Insect eggs can inhibit certain growth processes or even destroy the plant.

Summary

Plant growth damage from pests continues to destroy portions of the worlds food supply. Pests such as weeds, diseases and insects reduce yields and crop quality. Researchers continue to work to develop crop varieties that can resist pests and therefore reduce crop losses.

Credits

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Lesson 5: Germination

In order for a viable seed to germinate, certain environmental conditions must be met. This lesson will discuss what seeds are, how they germinate, and how emergence differs between a monocot seed and a dicot seed.

Seeds

A seed is a young embryonic (living organism in an early stage of development) plant in a dormant or resting stage. Each seed contains a supply of food and one or more seed coats. Seeds come in many sizes, shapes, and colors. Seeds can be planted to produce another plant or eaten as foods like popcorn, peanuts, or cooked beans. Regardless of the shape or color, all seeds contain three basic parts: an embryo, a food supply, and an ovary wall (seed coat).

The seed is alive even though it is in a dormant stage. Proper care of seeds during dormancy is vital. Improper storage conditions such as extreme moisture, heat, or cold may damage the seed and cause it to die. In order for a seed to germinate, it must be a viable (capable of living or growing) seed.

Germination

A seed must germinate in order for the young plant to begin to grow and develop. Germination of a viable seed occurs when a seed has been exposed to certain environmental conditions that stimulate the process. Favorable temperature, sufficient moisture, and air (specifically oxygen) are three environmental conditions necessary for germination. However, due to differences in plants, the degree to which these environmental conditions are required will vary. Some ornamental bedding plants require light to begin the germination process. However, light will inhibit germination of most agronomic crops.

Seed germination involves several steps. The first step in germination is absorption of water by the seed. Seeds will generally absorb 35% to 100% of their weight in water. Absorption of water causes the seed coat to swell. When penetration of water and swelling of the seed occurs, the seed's proteins are activated.

The second step of activating the seed's proteins involves the activation of the seed's enzyme system. Increased enzyme activity in the seed stimulates the growth of the embryo. The embryo's rapid growth requires more moisture and oxygen.

Emergence of the root structure from the seed is the third step. The new root anchors the seed in the soil and absorbs moisture for continued growth.

The fourth step in the germination process is the emergence of the shoot from the seed. Because the seed has a limited supply of food, the plant must soon begin producing its own food. The shoot of the embryo will push its way up through the soil into the sunlight.

Once the shoot has emerged from the soil, the last step can take place. The last step is the formation of leaves and the production of food through photosynthesis. The plant begins to grow and develop after the process of germination has been completed.

Monocot Seeds

Monocot and dicot seeds require three environmental conditions for germination. However, when comparing seeds of monocots and dicots, the parts and functions are different.

The monocot seed consists of a seed coat, endosperm, and embryo. The embryo contains the cotyledon, epicotyl, hypocotyl, and radicle. See Figure 5.1 for parts.

Each part of a monocot seed has a unique purpose. The seed coat is the tissue surrounding the embryo, which protects the inner parts. The endosperm is a source of starch or energy (food) for the miniature plant until germination is complete. After germination, the plant produces its own food through photosynthesis.

The embryo is a miniature plant within the seed structure. The embryo contains the cotyledon (scutelum), which breaks down the starch in the endosperm to provide food for the embryo. The epicotyl is the shoot above the cotyledon. This part grows above the ground. The hypocotyl is the part of

Figure 5.1 – Monocot Seed (Corn)

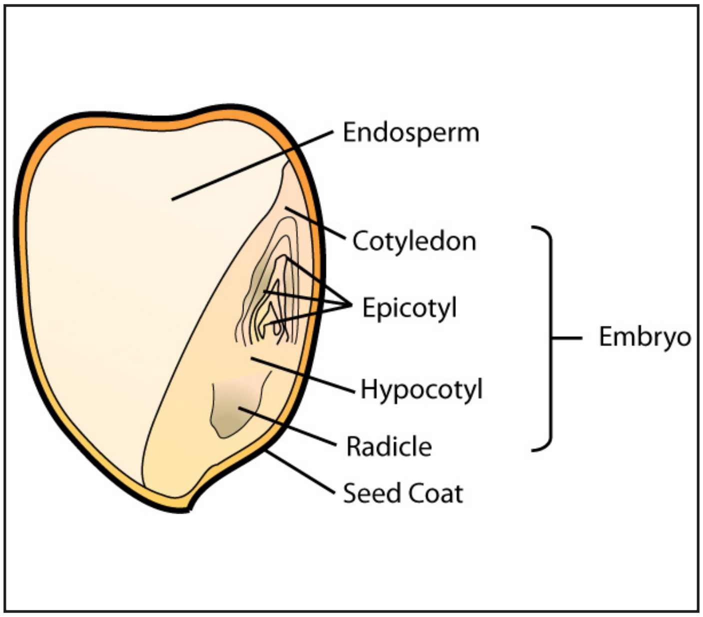
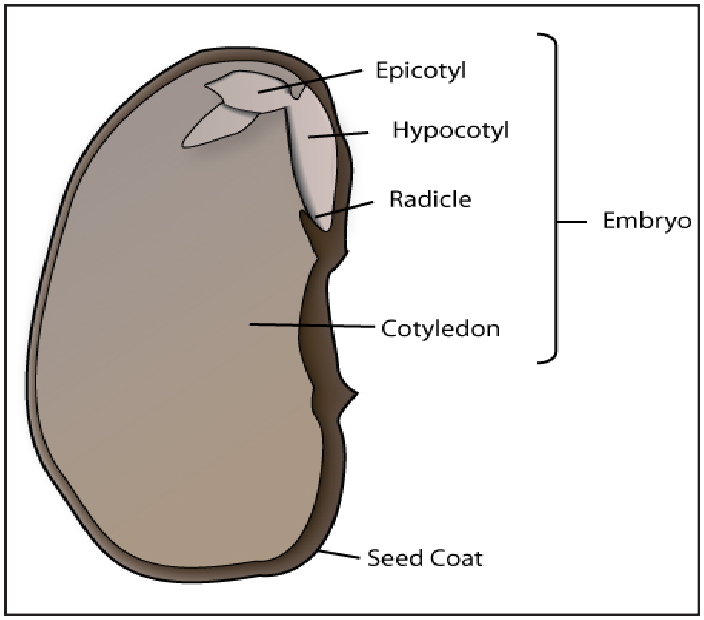


Figure 5.2 – Dicot Seed (Bean)



the stem below the cotyledon. The radicle develops into the primary root of the plant. The radicle absorbs water during germination. The radicle dies after other permanent roots have formed.

Dicot Seeds

Figure 5.2 is an example of a dicot seed. The parts of the dicot seed consist of the seed coat and the embryo. The embryo contains two cotyledons, the epicotyl, the radicle, and the hypocotyl. The purpose of the seed coat is to protect the embryo during the dormant stage. The two cotyledons store food during dormancy. The epicotyl forms into the first true leaves, shoot, and everything above the cotyledons. The hypocotyl is the first true stem between the root and first node of the stem. As the hypocotyl straightens upright, it pulls the cotyledons up out of the ground. The radicle forms the root system.

Germination and Emergence

During the germination process, tender parts of the young plant emerge from the soil. Emergence of the young plant is vital to begin photosynthesis. The emergence process of the young monocot plant is quite different than that of the dicot plant.

Germination and emergence of a monocot seed starts with the swelling of the seed due to absorption of water. Moisture stimulates enzyme activity and the seed coat ruptures. The radicle is the first part of the miniature plant to emerge from the seed. During the next step, the epicotyl grows out of the seed and starts pushing its way up through the soil towards the sunlight.

After the epicotyl emerges, new leaves form and food production begins through photosynthesis. A new root system forms above the first internode just beneath the soil surface. The temporary root system ceases to function and dies.

The process of germination and epigeal emergence, which occurs in most dicot seeds, also begins with the seed swelling and rupturing due to the absorption of water. The hypocotyl is the first part to grow out of the seed. The hypocotyl begins to elongate and forms an arch that breaks the soil surface. Once the hypocotyl reaches light, elongation ceases, The hypocotyl then straightens up and pulls the cotyledons out of the soil. Once the cotyledons have been exposed to light, they turn green and begin to manufacture food. When new leaves develop, the cotyledons dry up and fall off. The radicle extends downward into the soil to form roots during germination.

Figure 5.3 – Germination and Emergence of a Monocot Seed (Corn)

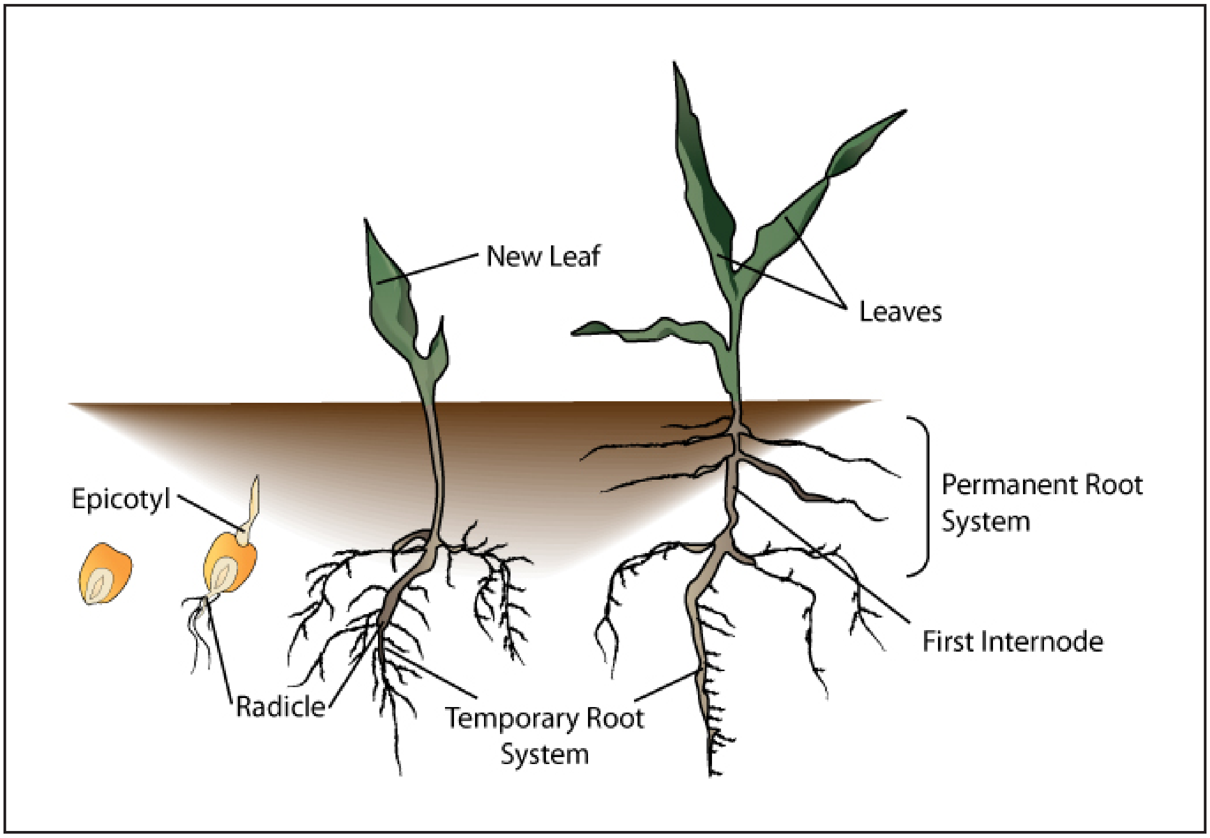
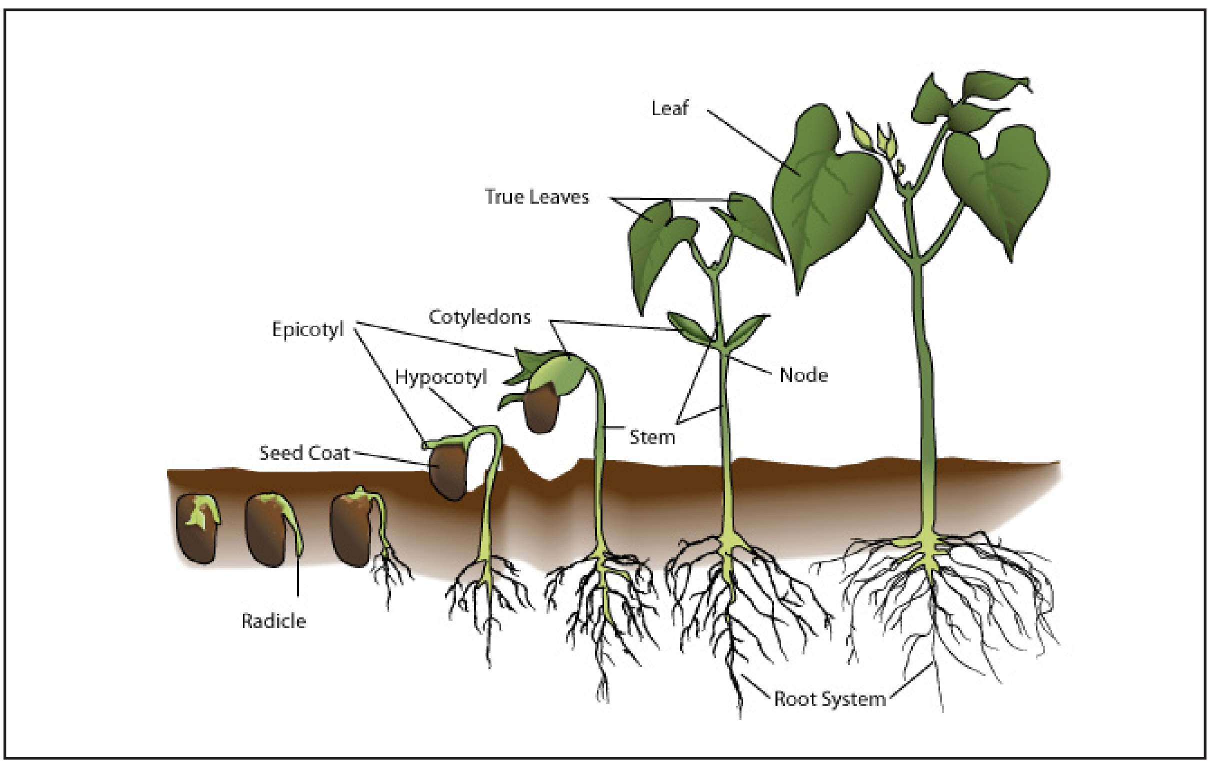


Figure 5.4 – Germination and Emergence of a Dicot Seed (Bean)



Plant Science

Summary

Seeds are the beginning of a plant's life cycle. Seeds are also an important food source throughout the world. Knowing the parts and functions of seeds, and the factors that affect germination and emergence are important to develop an understanding of how plants grow. In both monocot and dicot seeds, each part of the seed performs functions that are vital in the process of germination.

Credits

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Lesson 6: Photosynthesis and Respiration

Basic Plant Processes

There are five basic processes that plants depend on for growth. In order to grow plants properly, it is important to understand how these processes affect plant growth. These processes include: photosynthesis, respiration, water absorption, translocation, and transpiration.

Movement of Nutrients and Water

The movement of water and nutrients in a plant involves three processes: transpiration, translocation, and absorption.

Transpiration is the loss of water by evaporation through the leaf surface. Although it occurs primarily through the leaf surface, it also occurs from the stems and petals. Transpiration occurs when the plant's stomata open to take in carbon dioxide, needed for photosynthesis. Transpiration is greatly influenced by environmental factors such as light, temperature, humidity, and wind. As more water is lost to transpiration, more water must be absorbed by the plant.

Translocation is the movement of water and organic compounds within the plant. The vascular system consists of canals of xylem and phloem tissues through which translocation occurs. Water and dissolved minerals are primarily translocated upward from the roots through the xylem tissues. This is due to tension in the xylem tissue caused by the continuous water column. This tension, produced by transpiration, is transmitted to the absorbing cells in the roots, triggering them to absorb more water. Organic compounds (sugars and starches) are translocated through the phloem tissues from areas of high concentration to areas of low concentration. Primarily it is from the leaves to the rest of the plant, including the root system.

Water and dissolved minerals are absorbed by plant root hairs. Absorption of water and dissolved minerals from the soil into plant root cells is by the process of osmosis. Osmosis is a type of diffusion. Diffusion is the movement of molecules from an area of higher concentration to an area of lower concentration. Osmosis is the diffusion of water through a differentially permeable membrane. For example, the membrane surrounding plant cells will allow some molecules and materials—depending on their chemical properties and size—to pass through easily and quickly. Other materials are allowed to pass through very slowly. Still other materials are blocked from entering.

Plant Food Production – Photosynthesis

Photosynthesis is the process through which green plants convert carbon dioxide and water in the presence of light into simple sugar (food). The formula is illustrated in Figure 6.1.

Figure 6.1 – Photosynthesis Formula

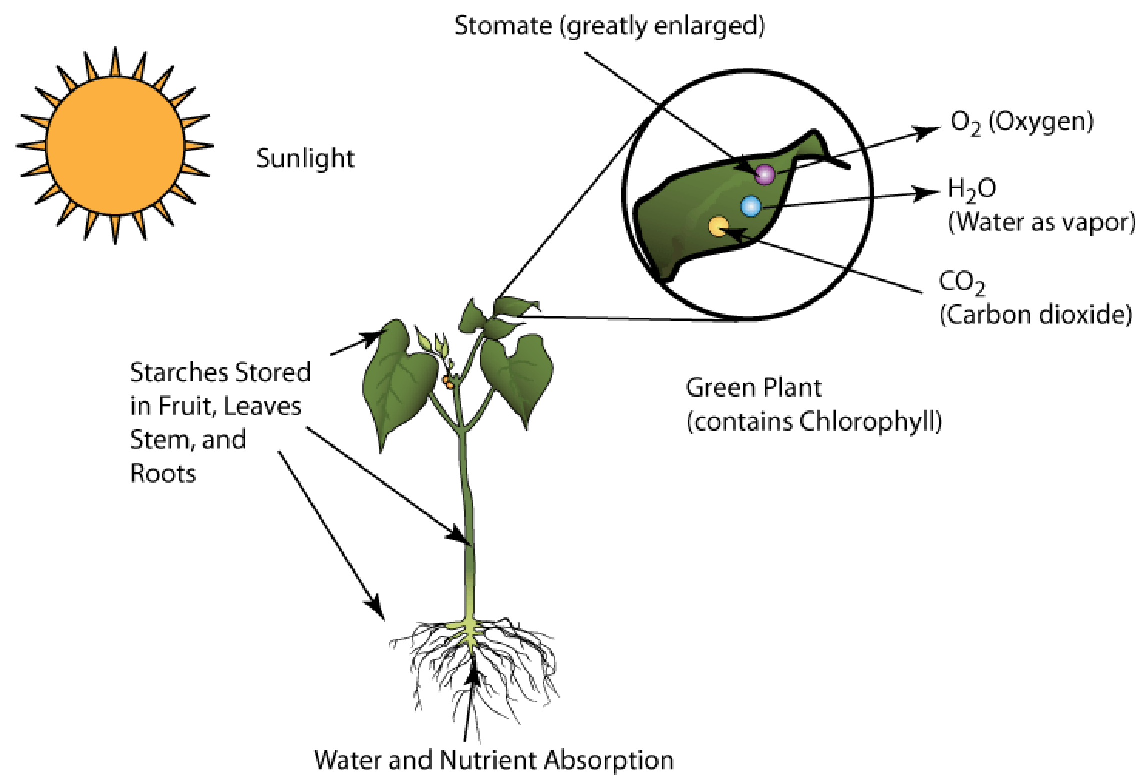
$$\underset{\text{(carbon dioxide)}}{6\,CO_2} + \underset{\text{(water)}}{6\,H_2O} \xrightarrow[\text{light energy}]{\text{chlorophyll}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6\,O_2}$$

Carbon dioxide enters the plant through stomata, primarily located on leaves. Water is absorbed through root hairs and moves to the leaves through the xylem tissues. Light strikes the chlorophyll, which is present in the cells of the leaf and stem. Light energy is absorbed, enabling a chemical reaction to take place between carbon dioxide and the hydrogen in water. Glucose, the most common carbohydrate and a simple sugar, is produced and transported by the phloem tissues to other parts of the plant. Oxygen is released as a by-product through the stomata. Water vapor is also released when the stomata open. See Figure 6.2.

Plants produce their own food through the process of photosynthesis. Plants use photosynthetically manufactured food for energy to perform the various processes necessary for plant growth. Plants also store food in the form of carbohydrates to be used by the plant when needed.

Respiration involves the breakdown of glucose. This process releases energy for plant growth, absorption, translocation, and many other processes occurring within the plant. Glucose molecules are combined and stored in the form of complex starch molecules in plant cells. Nearly all respiration occurs in the presence of oxygen (aerobic respiration). However, some cellular respiration may occur

Figure 6.2 – Photosynthesis Process



for a short time without oxygen (anaerobic respiration). The formula for aerobic respiration is illustrated in Figure 6.3.

Figure 6.3 – Respiration Formula

$C_6H_{12}O_6$	+	6 O_2	$\longrightarrow$	6 CO_2	+	6 H_2O	+	energy
(glucose)		(oxygen)		(carbon dioxide)		(water)		

Respiration enables the plant cell to release energy, which is used in energy-requiring chemical reactions within the cell. In addition, respiration releases carbon dioxide (CO_2) and water (H_2O) into the atmosphere. Respiration is a continuous process occurring throughout the day, for as long as the plant lives.

Figure 6.4 compares photosynthesis and respiration. Note that photosynthesis changes light energy from the sun into chemical energy. The chemical energy is stored in the form of glucose molecules. Respiration reverses the process by changing the chemical energy from the breakdown of glucose molecules into other forms of energy needed by plants.

Air Quality

The role of plants in improving air quality is vital. All forms of life need oxygen to survive. Plants produce oxygen as a by-product of photosynthesis. Excessive emissions from automobiles and industry damage plant life and lessen the production of oxygen by plants. Pollutants entering the atmosphere, the soil, and the water interrupt some plant processes. For plants to continue to grow and produce oxygen, humans need to keep the environment clean.

Summary

Five processes affect plant quality and longevity. Through the process of photosynthesis, a green plant manufactures its own food (simple sugar or glucose). The process

Figure 6.4 – Photosynthesis vs. Respiration

	PHOTOSYNTHESIS	RESPIRATION
Energy relationships (stored or released)	Stored	Released
Raw Materials	CO_2 and H_2O	Glucose and O_2
Function	To convert sun energy into chemical energy	To release energy from glucose for cellular metabolism
End products	O_2 and glucose	CO_2, H_2O, and energy

of respiration breaks down glucose to release energy needed within plant cells. Water and dissolved mineral nutrients enter roots through the process of absorption. Translocation is the movement of water, dissolved minerals, glucose, and other organic compounds within the plant. Transpiration is the process of water loss from the plant primarily through stomata located on leaves. Plants play a vital role in improving air quality through the production of oxygen.

Credits

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Lesson 7: Reproduction – Sexual and Asexual

Plant Reproduction

The controlled reproduction of plants is called plant propagation. These are two kinds of plant propagation: sexual and asexual. Sexual plant propagation uses seeds for producing new plants. Asexual plant propagation is the reproduction of plants using a vegetative part of the plant.

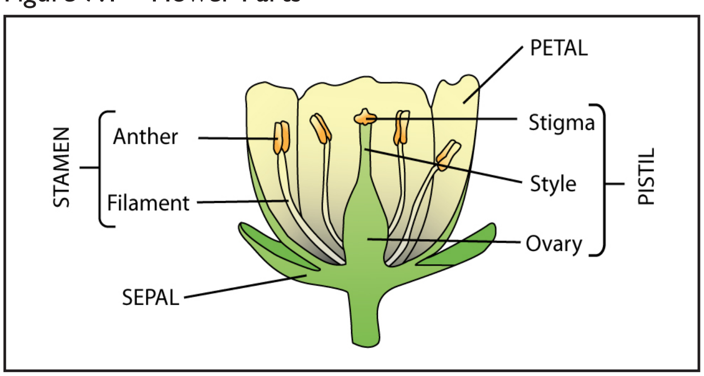
The Flower

Flowers contain the reproductive parts of plants involved in sexual reproduction. Flowers can have either male floral structures, female floral structures, or both. On some plant species, both male and female flowers can be found on the same plant. Plant flowers with male and female parts on the same plant are known as monoecious plants. Corn is an example of a monoecious plant with tassels (male flower) on top and silks on each ear (female flower). Dioecious plants have male and female flower parts on separate plants. Date palms and asparagus are examples of dioecious plants.

There are four parts of a flower: sepals, petals, stamens, and pistils. Sepals and petals are the vegetative parts of the flower. The stamens and pistils are the reproductive parts of the flower. Figure 7.1 illustrates the four parts of the flower as well as the parts that make up each stamen and pistil.

Sepals: When the flower bud is closed, an outer, scale-like covering is formed by the sepals. All of the sepals together are called the calyx. The function of the sepals is to protect the petals, stamens, and pistils when the flower is in the bud stage.

Figure 7.1 – Flower Parts



Petals: The petals are usually brightly colored to attract pollinators (usually insects). All of the petals together are called the corolla. The petals protect the stamens and pistils in the bud stage.

Stamens: The stamen is the male reproductive part of the flower. Each stamen consists of two parts: the anther and the filament. The anther produces pollen grains, and the filament supports the anther.

Pistil: The pistil is the female reproductive part of the flower. The pistil consists of the ovary, stigma, and style. The ovary is the enlarged portion at the base of the pistil. The function of the ovary is to produce ovules. Ovules that are fertilized become seeds. The stigma receives and holds the pollen grains. The style connects the stigma with the ovary. Pollen grains travel through the style to reach the ovary. The style supports the stigma.

Complete and Incomplete Flowers

A complete flower has all four main parts: sepals, petals, stamens, and pistils. An incomplete flower is missing one or more of the main parts of a flower.

Pollination and Fertilization

Pollination is the transfer of pollen from the anther of the stamen to the stigma of the pistil. The process of pollen transfer is the first step in pollination. Pollination can happen by either self-pollination or cross-pollination. In self-pollination, pollen is transferred from the anther to the stigma of the same flower or to other flowers on the same plant. Examples of plants that self-pollinate are oats, barley, wheat, and soybeans. In cross-pollination, pollen is transferred from the anther of one plant to the stigma of another plant. Examples of plants that cross-pollinate are alfalfa, red clover, and rye.

Fertilization is the union of male and female cells to form the first embryonic cell and the first endosperm cell. Fertilization is the final step in sexual reproduction. There are four steps in fertilization:

1. Pollen sticks to the moist stigma, which provides favorable conditions for pollen germination.
2. As the pollen germinates, a long structure known as the pollen tube grows downward through the style into the ovary, contacting the egg cell.
3. As the pollen tube breaks open, one sperm cell unites with one egg cell, resulting in production of the zygote, or fertilized egg. This is the beginning of the embryo.
4. A second sperm cell unites with to other nuclei (polar nuclei), forming the endosperm.

Conditions for Pollination and Fertilization

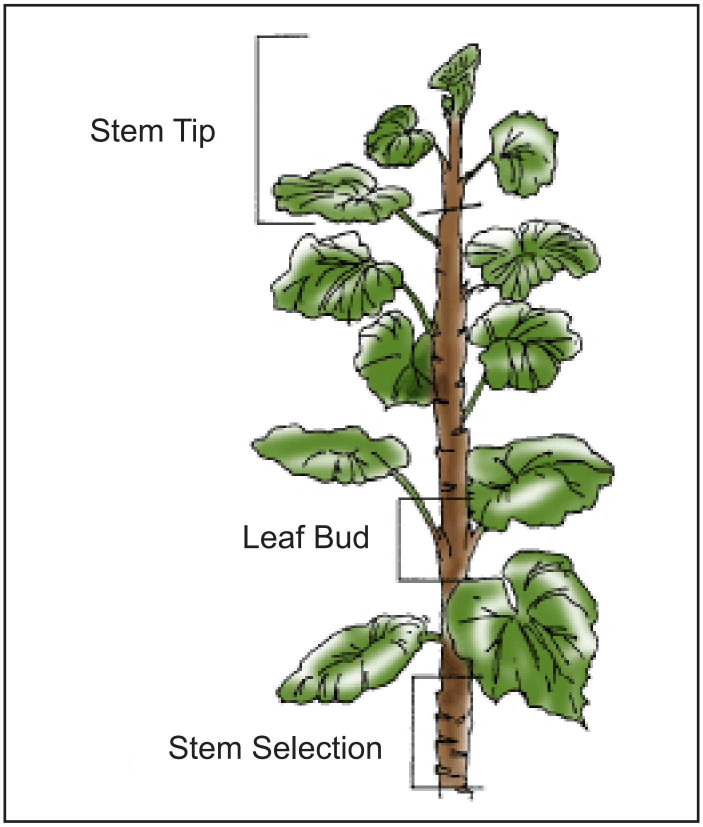
Pollination and fertilization occur when the plant reaches the proper stage in its life cycle and when the conditions are right. In self-pollination, the pollen must fall from the anther of the flower to the stigma of the same flower or another flower on the same plant. Gravity aids in self pollination; however, favorable weather conditions are helpful. Weather conditions can either help or hinder pollination and fertilization. Favorable weather conditions with air movement (wind) can assist the transportation of pollen. Pollinators such as insects aid in the pollination process when they travel from flower to flower, seeking nectar. Favorable weather conditions and insects are crucial in cross-pollination, since the pollen must be transferred between plants.

Asexual Propagation

Asexual propagation of plants involves using plant parts to produce another plant. The plant parts used in asexual propagation are stems, leaves, and roots. Methods most commonly used in asexual plant propagation are cuttings, division, layering, budding, grafting, and tissue culture.

Cuttings: Cuttings are plant pieces that are "cut" from the parent plant and rooted to form new plants. Cuttings may be taken from stems, leaves, and roots. There are four types of cuttings: stem tip, leaf, leaf and bud, and stem section. Figure 7.2 illustrates the location of stem tip, leaf bud, and stem section cuttings on a typical plant. Figure 7.3 shows a stem cutting. Figure 7.4 shows examples of leaf cuttings. Figure 7.5 is an example of a leaf and bud cutting.

Figure 7.2 – Cutting Locations



Division: Division is a way to propagate plants by separating clumps of plants into smaller groups. Each small group would have roots, stems, and leaves or the potential to develop these parts. Division is the easiest way to propagate plants that produce offsets, basal shoots, or a multiple crown. See Figure 7.6.

Figure 7.3 – Stem Cutting

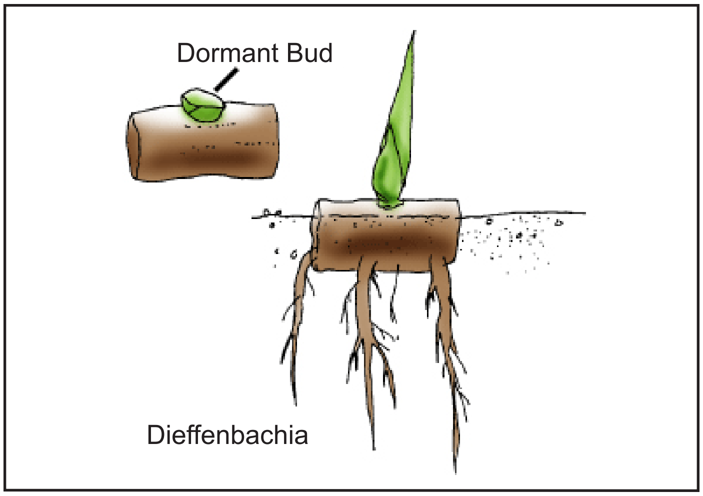
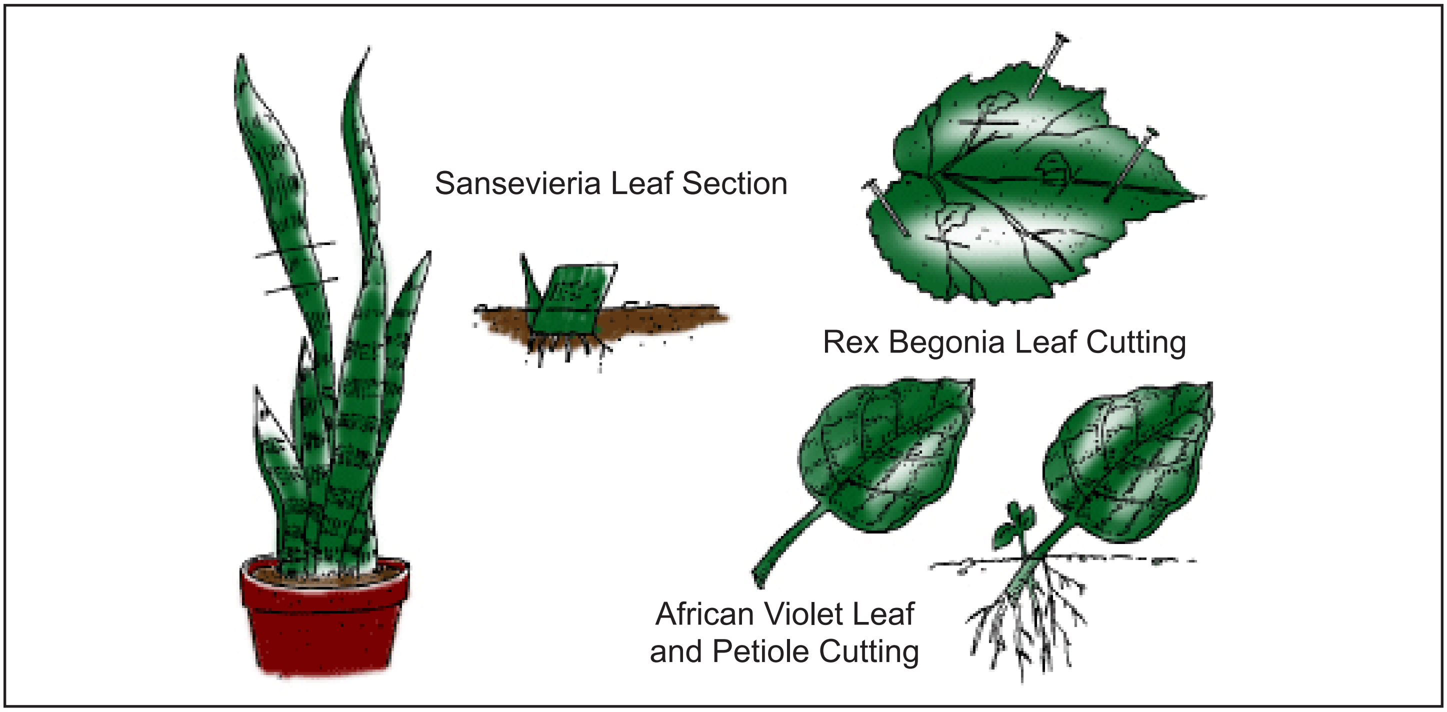
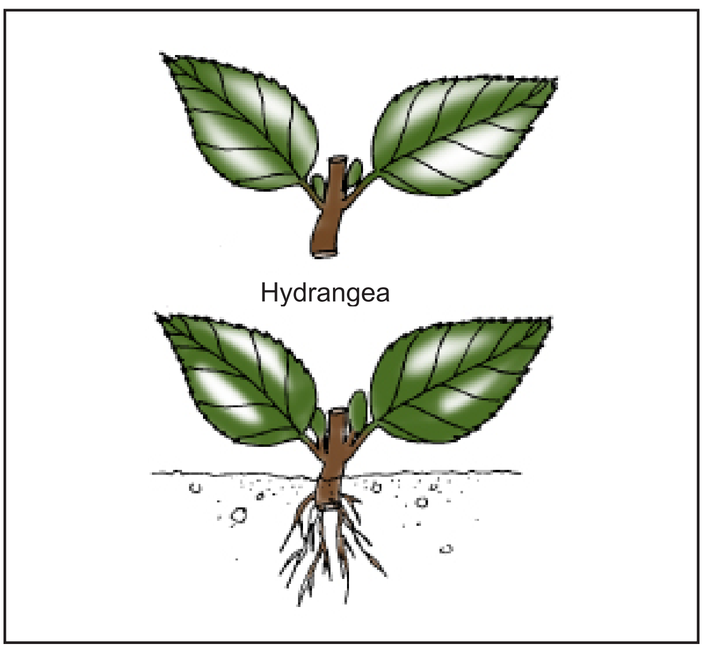


Figure 7.4 – Leaf Cuttings



Layering: Layering is a method of rooting a new plant while the stem is still attached to the parent plant. Types of layering include simple, tip, compound, mound, trench, and air. Simple and air layering are the most frequent types of layering used in greenhouses. Figure 7.7 illustrates simple layering. Figure 7.8 illustrates air layering.

Figure 7.5 – Leaf and Bud Cutting



Grafting: Grafting is a method of propagating plants by inserting buds, twigs, or shoots from one plant onto the stem of another plant. Grafting is used mainly to produce fruit trees.

Budding: Budding is a special form of grafting that uses a single bud, which is inserted into the bark of another variety. Budding is used on fruit trees, nut trees, and rose plants.

Figure 7.6 – Division

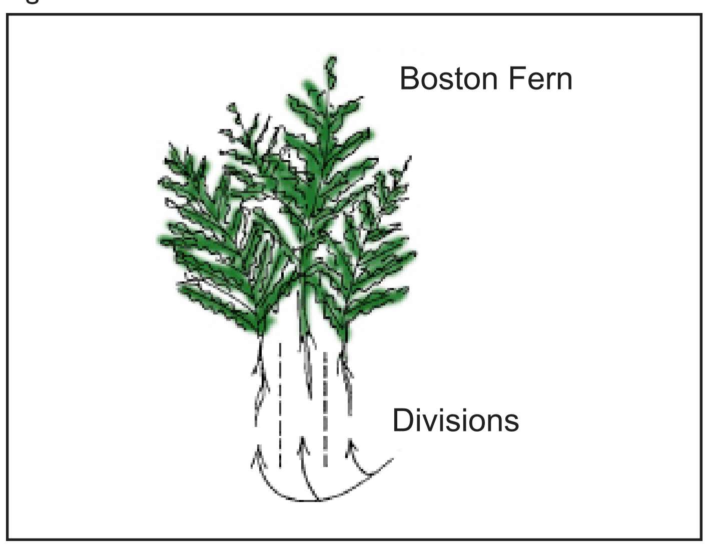


Figure 7.7 – Simple Layering

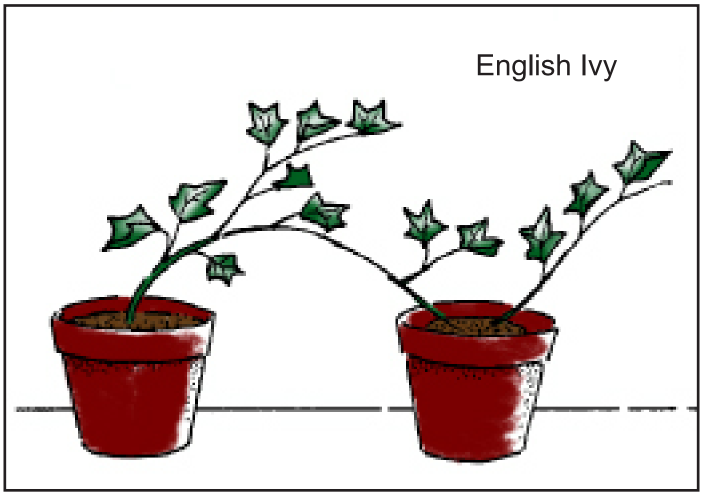
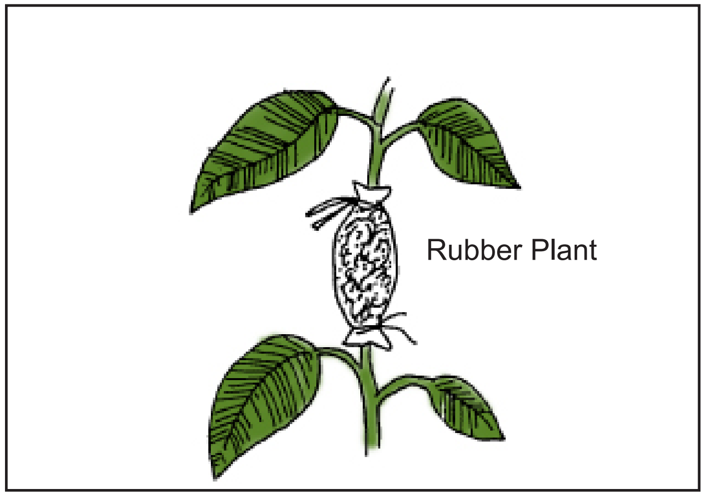


Figure 7.8 – Air Layering



Tissue Culture: Tissue culture is a relatively new propagation technique in which a single cell or a small piece of plant tissue called the explant is taken from the meristematic tissue to produce a new plant. The explant is placed in a germ-free growing medium in a closed, sterile container. Plant vitamins and hormones are used to control root and shoot growth. When the plants are large enough to be handled, they are transplanted into individual pots and placed in a greenhouse.

Summary

There are two kinds of plant propagation: sexual and asexual. Sexual plant propagation involves each stage of the plant's life cycle: pollination, fertilization, the formation of seed, and germination of the seed to produce another plant. Asexual plant propagation involves the use of plant parts to produce another plant. The methods of asexual plant propagation are cuttings, division, layering, grafting, budding, and tissue culture.

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Lesson 8: Plant Genetics

Many factors contribute to the high production levels of quality food crops in the U.S. One very important factor is the application of knowledge gained through research in plant genetics. In this lesson, plant genetics, genetic engineering, and their effects on plant production will be discussed.

Inheritance

Inheritance is a term used in plant genetics that refers to the transmission of genes from one generation to the next. The genetic makeup of a plant determines the expression of traits (e.g., yield potential, flower color, and leaf structure). Many plant characteristics are transmitted from one generation to another. Genes are the smallest unit of inheritance, which transmit genetic information between generations.

Environmental factors will ultimately determine the extent to which the genetic potential of a plant is expressed. However, the genetic makeup of each plant dictates the potential for the expression of each plant characteristic.

Researchers have begun to manipulate the genetic makeup of plants. Desirable traits are retained, while undesirable traits are eliminated. Genetic manipulation involves the transfer of genetic material from one generation of plants to the next.

DNA and Genes

Chromosomes are located within the nucleus of each plant cell. Chromosomes consist of a sequence of DNA (deoxyribonucleic acid). Within the DNA chain, there are specific function-controlling segments called genes. Genes are the parts of a chromosome that determine individual plant characteristics. The overall function and importance of DNA is that it serves as a coding mechanism for heredity. DNA also contains information to control the synthesis of enzymes that control the basic metabolic processes of all cells.

Genetic Engineering

In 1866, an Austrian monk by the name of Gregor Mendel published a scientific paper reporting the results of his experiments. Mendel had been researching plant genetics and how specific characteristics are passed from generation to generation. Since Mendel's time, much work has been done in the area of plant genetics.

During the process of pollination, plants either self-pollinate or cross-pollinate to reproduce. This process involves sexual fusion of male and female cells. (Refer to Lesson 7 for more information on sexual reproduction). Humans can intervene in this process of pollination by controlling and directing the cross-pollination of specific plants. Genetic engineering is quite different from controlling the pollination process. Genetic engineering is the process of transferring genes from one organism to another. This process can develop new plants known as somatic hybrids.

Biotechnology Benefits Crop Production

The term biotechnology is often used in a discussion of genetics or genetic engineering. Biotechnology is the use of technology in the study and research of living beings and life processes. Researchers use biotechnology in the study of plants for many reasons. Using biotechnology in plant production, researchers can genetically manipulate the production of crop plants. This manipulation has led to increased production levels to meet the growing demand for food. Genetic engineering can reduce the amount of time required to change the genetic makeup of a plant species. These new plants are known as somatic hybrids.

Genetic engineering can also increase beneficial characteristics of plants. Insects and diseases can decrease plant growth and food production. Introducing disease-resistant traits into plants through genetic engineering can enable plants to produce under adverse conditions.

Ethics

Genetics is basic to all living organisms. Therefore, the genetic engineering techniques used on lower life forms are theoretically applicable to higher life forms. Ethical considerations are important factors to consider when making decisions about genetic engineering. Genetic manipulation changes the makeup of a living organism from an occurrence in nature to a product of science. Consideration of the motives for the research, safety during the research, and application of the findings must be part of the decision making process. Social and consumer acceptability, environmental impact, and the costs versus the benefits of genetic engineering should also be considered. Genetic engineering has become a controversial issue in scientific research. However, there is usually less public concern with genetic engineering in the plant kingdom than in the animal kingdom.

With a continually growing world population, the need for food confronts everyone daily. Plant scientists, geneticists, and agriculturalists work to address specific food shortage problems. Not all countries are able to produce adequate amounts of food crops, yet the need for food for their citizens is very real. Working with genetic engineering, modified plants can be developed to grow and produce in harsh environments. Genetic research with plants is conducted to find more efficient ways to produce quality food crops.

Summary

Plant genetics is a highly technical area of science. Research on the inheritance of specific traits, DNA, genes, and genetic engineering of desirable traits continues to address the growing need for food through plant production. As plant geneticists work toward improving plants, ethical considerations must be an integral part of that process.

Credits

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