## *Lesson 1: Plant Physiology*

Plants are often characterized by their structure and the various functions of their many parts. To produce crops effectively, producers must be able to identify the different types of seeds and plants. One of the best ways to learn about these differences is by comparing the parts and functions of seeds and plants.

### Monocot and Dicot Crops

Agricultural crops can be classified by their many variations in seed and plant structure. One common classification is by the number of cotyledons, or first leaves, located in the seed. Monocotyledonous plants, frequently called monocots, have only one cotyledon in each seed. Dicotyledonous plants, or dicots, have two cotyledons and can bring forth a new plant bearing two seed leaves. Additionally, monocots are usually thought of as "simple" plants in contrast with the more "complex" dicots. The simple structured crops in the grass family are always referred to as monocots. Monocot crops produced in the state include corn, grain sorghum, wheat, grass hays, and rice. The most productive Missouri dicots include soybeans, cotton, alfalfa, and clover.

### Parts and Functions of a Monocot Seed

Monocot seeds have a simple composition with three main parts: (1) the seed coat, (2) embryo, and (3) endosperm. (See Figure 1.1.) The embryo contains the single cotyledon, epicotyl, hypocotyl, and radicle. All seeds will also have a seed scar, a break in the seat coat, where it was attached to the plant. In corn, the seed scar is called the tip cap, and it was once attached to the cob. In the monocot crops of grain sorghum, wheat, grass hay, and rice, the seed is located in or attached to the inflorescence, or head of the plant.

The outer covering on a seed is called the seed coat and serves as a protector. It resists water and insects and maintains the seed's viability, or ability to grow. The names of the seed parts, such as the seed coat, may vary depending on the crop. For example, in corn the seed coat is known as the pericap; in wheat it is referred to as the bran.

The embryo of a monocot seed is a miniature plant that sprouts within the seed. It contains all the essential genetic information, enzymes, vitamins, and minerals for the seed to grow into a new plant. Each part of the embryo plays a role in the creation of the plant. The cotyledon, known as the scutellum in corn seeds, breaks down the starch in the endosperm, absorbs it, and moves it to the embryo. The epicotyl will develop into the first shoot with a leaf or leaves that emerge from the seed upon germination. It is located above the cotyledon. The hypocotyl, found below the cotyledon and connected to the radicle, is the first true stem of the plant. As the hypocotyl lengthens, the cotyledon and epicotyl emerge from the seed during germination. The radicle develops into the

*Figure 1.1 - Parts of a Monocot Seed (Corn)*

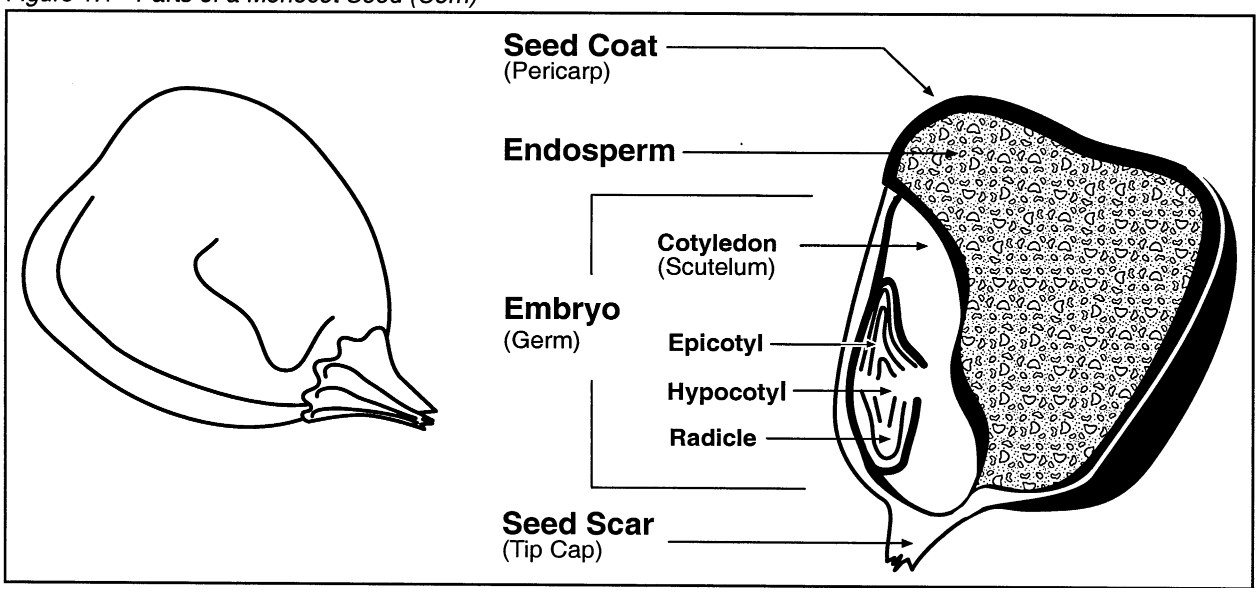
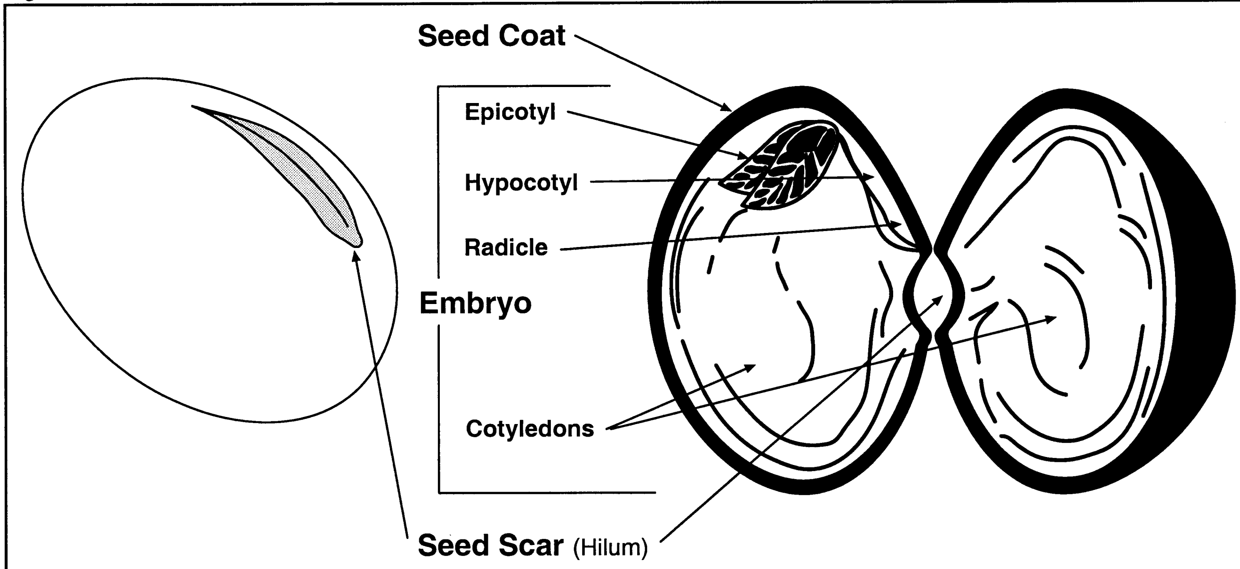


*Figure 1.2 - Parts of a Dicot Seed (Soybean)*




primary root, absorbing water and nutrients for the seed and dying later when permanent roots are formed. It is located below the hypocotyl. When monocot seeds such as wheat are processed as a food source, the embryo is called germ, which is ground separately or with the endosperm in whole wheat products.

The endosperm, found only in the monocot seedlings, serves as the energy source (starch) for the germinating seed. It comprises more than 75% of the entire seed. For example, in corn the endosperm is about 82% of a seed's dry weight. When seeds are used as a feed source for livestock or food source for humans, the endosperm provides carbohydrates, protein, iron, B-complex vitamins, and other essential nutrients.

## Parts and Functions of a Dicot Seed

The parts of a dicot seed are basically the same as monocots, but they have a more complex structure. A dicot seed consists of the seed coat, embryo, and seed scar, or hilum. The seed coat serves the same protective function as in the monocot seed. Likewise, the embryo has similar parts with an epicotyl, hypocotyl, and radicle; however, a dicot embryo contains two cotyledons as shown in Figure 1.2. Each serves as a new part on a growing seedling.

The epicotyl serves as the growing end of the plant's main stem. It is attached to the hypocotyl on one end and has tiny, undeveloped leaves (embryonic leaves) on the other end. The hypocotyl becomes the main stem of the plant. Its main function is to lift the cotyledons out of the soil so the new seed leaves can emerge. The radicle stays below the soil surface to become the new primary root. Cotyledons protect the epicotyl and provide food for the sprouting plant. They are usually fleshy in form and high in protein and oil.

## Parts and Functions of a Monocot Plant

Regardless of the classification, plant parts are essential because each has a specific function to aid in the growth, maintenance, or reproduction of the plant. The primary parts of a monocot plant include the inflorescence, leaf blade, node, internode, leaf sheath, tiller, and roots. (See Figure 1.3.)

Recognized as the floral portion of the plant, the main function of the inflorescence in the monocot is reproduction. Leaf blades are essential for plant life as the manufacturer of food by photosynthesis. Respiration, transpiration, and food storage all take place in the leaf blade. The leaf remains connected to the stem by the node. The internodes, or stem sections between the nodes, support the plant and transport and store nutrients. The base of the leaf that wraps around the stem is the leaf sheath. Its function is to provide support and stabilization to the stem and protect the leaf axil, or base. At the bottom of a monocot plant is the growth of a secondary stem called the tiller. The tiller is a new shoot from the primary plant that

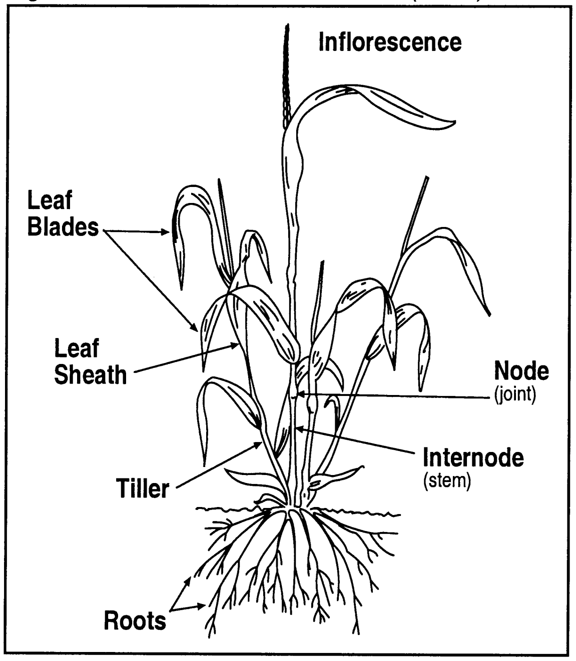


*Figure 1.3 - Parts of a Monocot Plant (Grain)*

can grow and reproduce by itself. Tillers are one example of how monocots multiply, specifically in rice and wheat. Roots provide support, food storage, and nutrient absorption.

## Parts and Functions of a Dicot Plant

Dicots consist of similar functioning parts including the terminal bud, leaf, petiole, node, internode, axillary bud, hypocotyl, branch or lateral roots, primary (or taproot), and root hairs as shown in Figure 1.4.

The terminal bud in the dicot plant refers to the growth point in the plant. Apical meristem tissues are located in the terminal bud and increase the length of the plant. The leaf serves the same function in the dicot as it does in the monocot. Leaves manufacture food through photosynthesis, conduct respiration and transpiration, and sometimes store food. The stalk of the leaf, called the petiole, attaches the leaf to the plant stem. The petioles provide support for the leaves and transport nutrients. The node is the attachment site of the petiole to the stem giving support to the petioles. The internodes, stem sections between the nodes, provide support to the aboveground plant. They also transport and store nutrients. An axillary bud,which will produce a new leaf or stem, is located along the side of the stem. The hypocotyl function identified in the dicot seed remains the same. The hypocotyl is responsible for lifting a new plant out of the soil after germination and serves as the stem base for the plant. Branch, or lateral, roots are those roots branching off the taproot, or primary root, to provide additional support and increase nutrient absorption. The taproot serves as the main anchor site and stores tremendous amounts of nutrients for the plant. Root hairs are common on both branch and taproots. The hairs increase the overall absorption area for the plant.

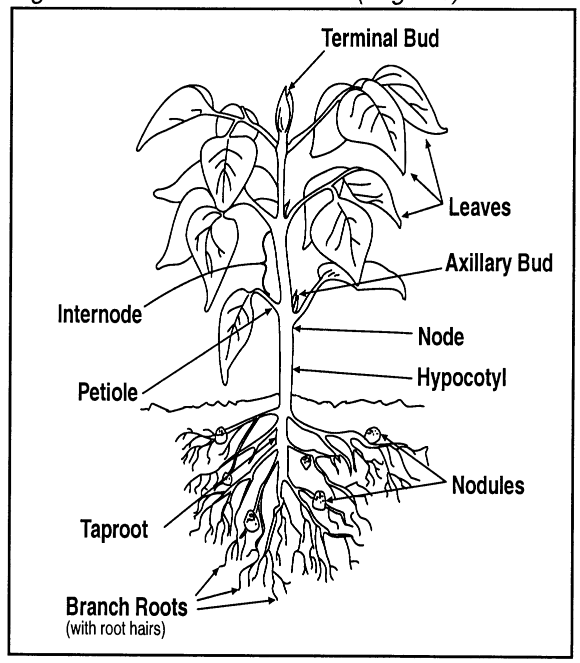


*Figure 1.4 - Parts of Dicot Plant (Legume)*

## Summary

To produce crops effectively, producers must be able to identify the different types of seeds and plants. One way agricultural crops are classified is by the number of cotyledons, or first leaves, located in the seed. Monocots have one leaf and dicots have two leaves. Monocot and dicot seeds have the same basic parts, but the functions of each part differ; the dicots are more complex. Part names may also vary by crop.

Regardless of a plant's classification, every part of a plant is essential to its survival, growth, or reproduction. Monocot and dicot plants have some similar parts with similar functions such as leaves, nodes, internodes, and roots. Although the roots and leaves are structured differently in a monocot and dicot, they are important to the survival of a plant, assisting in support and photosynthesis, respectively.

## Credits

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## *Lesson 2: Plant Growth and Nutrient Needs*

Understanding the various stages of crop growth and development enables producers to exercise better management by allowing inputs to be used at the proper growth stage. Likewise, understanding the life cycle of plants allows producers to plan continuous or future production of the same or compatible crops. Soil is a storage facility holding minerals, chemicals, water, and air for plants to use. The nutrients soil provides play a key role in successful crop production.

### Plant Growth Stages

Crops have four major growth stages between planting and harvesting: (1) germination, (2) vegetative, (3) reproductive, and (4) maturity. (See Figures 2.1 and 2.2.) The germination stage occurs when the embryo within the plant seed sprouts and begins its development into a plant. During the vegetative stage, the plant grows by stem extension and leaf multiplication. The reproductive stage occurs next and includes the production of flowers and seed formation, the most critical time in the life of most crops. If anything interferes with the plant's functions during this period, crop yields may suffer. The maturity stage starts once the plant has reproduced and the grain has ripened. The plant goes through a dry-down process when the leaves and stems lose their green pigment and turn yellow to brown. In some crops, such as soybeans, defoliation occurs when leaves dry up and fall from the plant stems. Chemical defoliation is used in cotton production to speed up the maturity stage. When the plant completes the ripening process and has reached the ideal dry weight or moisture content, harvesting occurs.

Growth stages may vary from crop to crop with different names for each of the main stages. In wheat, for example, the vegetative stage is broken into two stages: tillering and stem extension. Also, the reproductive stage of wheat is called the heading stage, as shown in Figure 2.3.

### Plant Life Cycles

All plant growth stages combine to form a life cycle. The seed from a mature plant germinates into a plant that grows to maturity; the seed is harvested or returns to the ground when the plant dies. Therefore, a plant's life cycle is classified by the length of time required for the plant to complete its growth stages. For most production crops, the life cycle can be less than 1 year or as many as 3 years. Life cycles for plants are grouped into three general classifications based on how long it takes to complete their growth stage: annuals (spring and winter), biennials, and perennials.

*Figure 2.1 - Growth Stages of Corn*

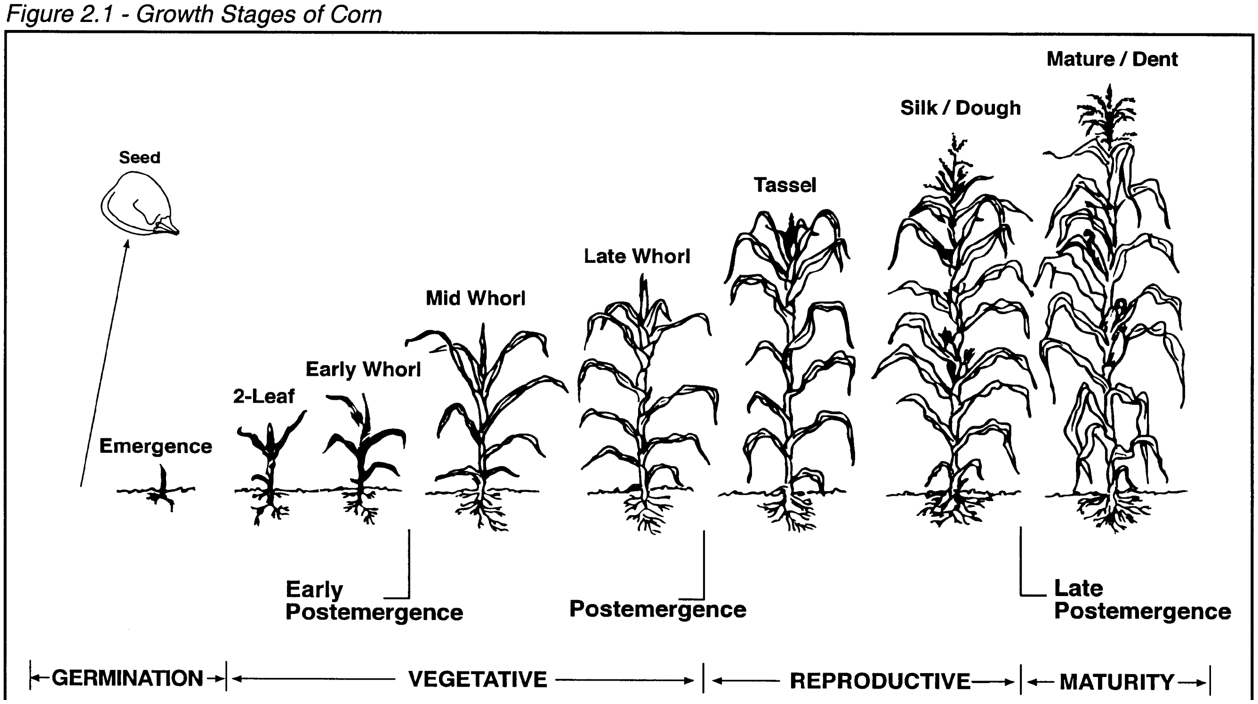


*Figure 2.2 - Growth Stages of Soybeans*

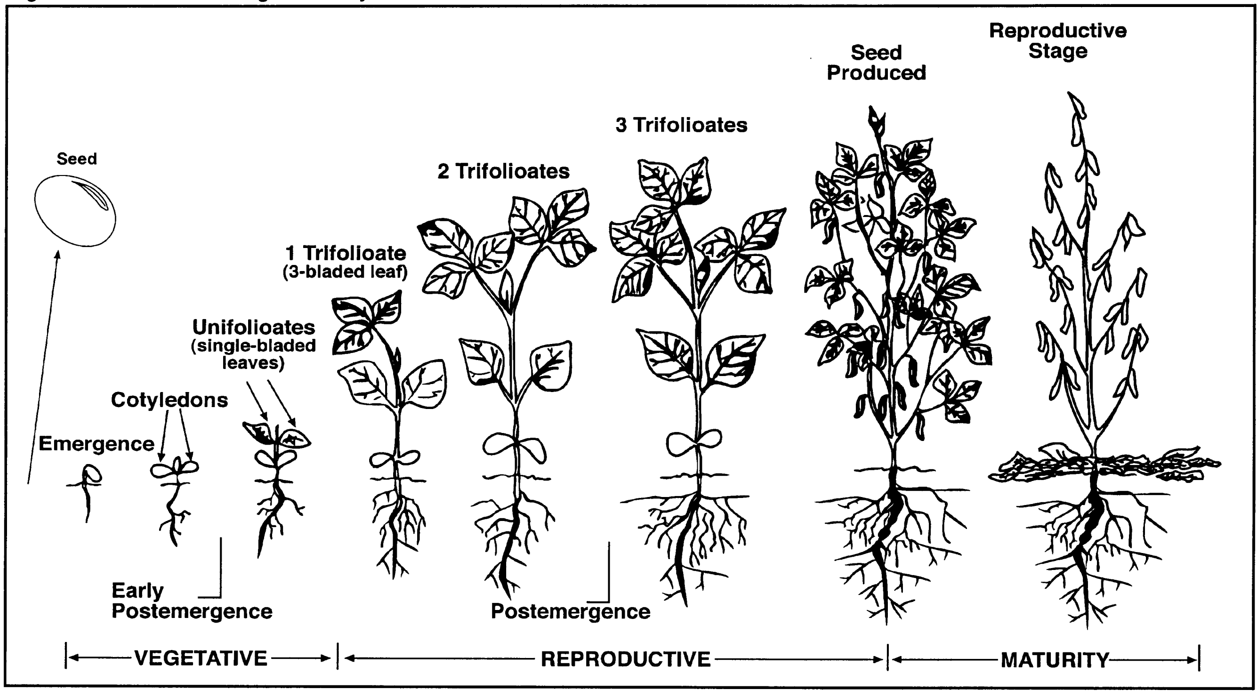
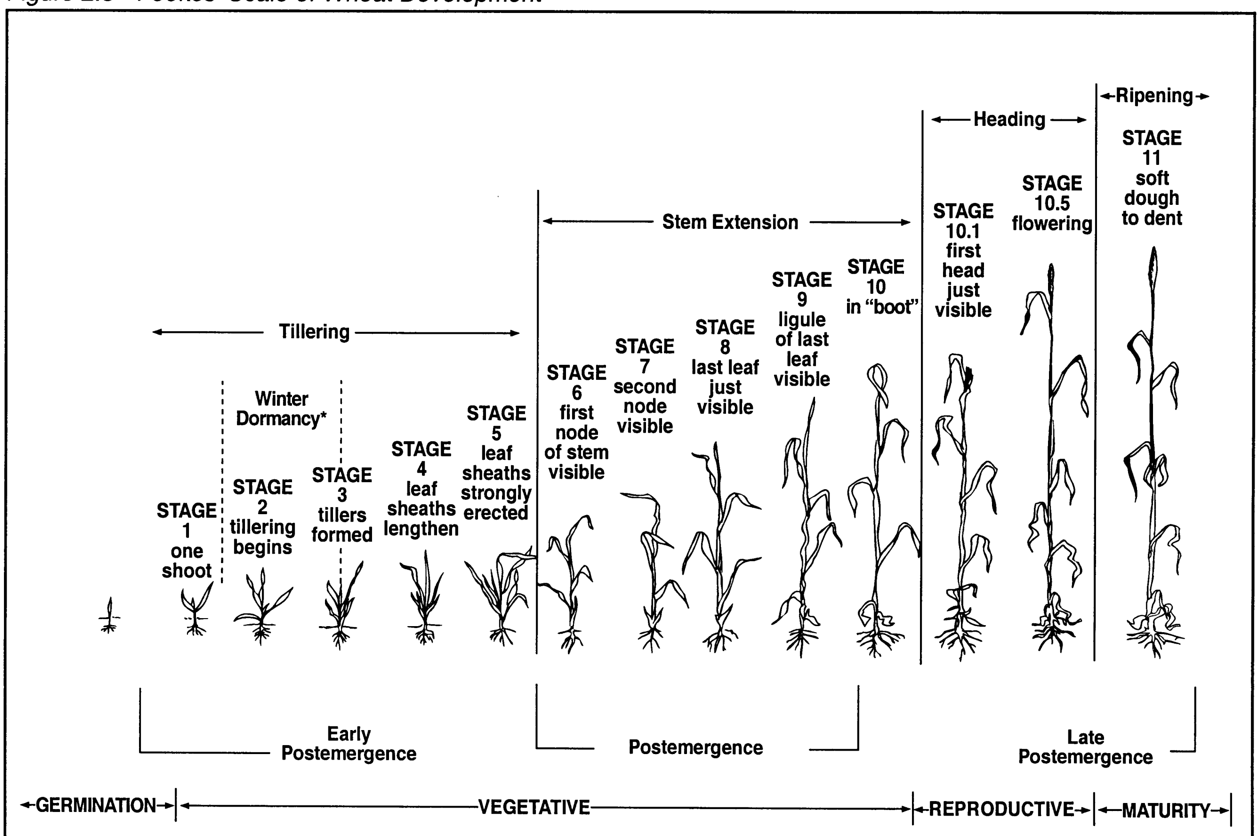



*Figure 2.3 - Feekes' Scale of Wheat Development*




*** Usual dormancy occurrence within this range, depending on weather.**

Annuals are crops planted and harvested during a 1-year period or less. Refer to Figure 2.4. Annuals are subdivided into two groups depending on the time of year the crop is planted. Summer annuals are planted in the spring or summer and harvested in the fall of the same year. These crops include corn, grain sorghum, soybeans, and rice. Winter annuals are typically referred to as crops planted in the fall and harvested the following summer. Examples of winter annuals include winter wheat, winter oats, winter barley, and winter rye.

Biennials are crops that complete their life cycle during the second year after planting. Very few biennials are field crops with the exception of sweet clover, the most prominent biennial produced in the state. Biennials generally do not flower in the first year and are more common in vegetable crop seed productions.

Perennial crops or plants remain alive 3 or more years after planting. (Refer to Figure 2.4.) Forage crops, for example, include many species that live longer than 5 years. Fescue, alfalfa, and lespedeza are all perennial crops grown in Missouri. Perennial stands are maintained by the plant's ability to reseed or spread by vegetative reproduction. Life expectancy for these plants can be limited by weed pressure, disease, grazing intensity, and/or competitive species.

## Essential Plant Nutrients

Plants cannot grow and develop without essential nutrition. Seventeen essential plant nutrients are needed for optimum plant growth and development. These essential plant nutrients are broken down into nine macronutrients (major) and eight micronutrients (minor) as shown in Table 2.1.

### *Macronutrients*

Of the nine essential macronutrients, the three most basic elements found in all life-forms are carbon (C), hydrogen (H), and oxygen (O). These basic elements are all supplied by air and water. Plants also require additional macronutrients

*Figure 2.4 - Life Cycles of Annual and Perennial Crops*

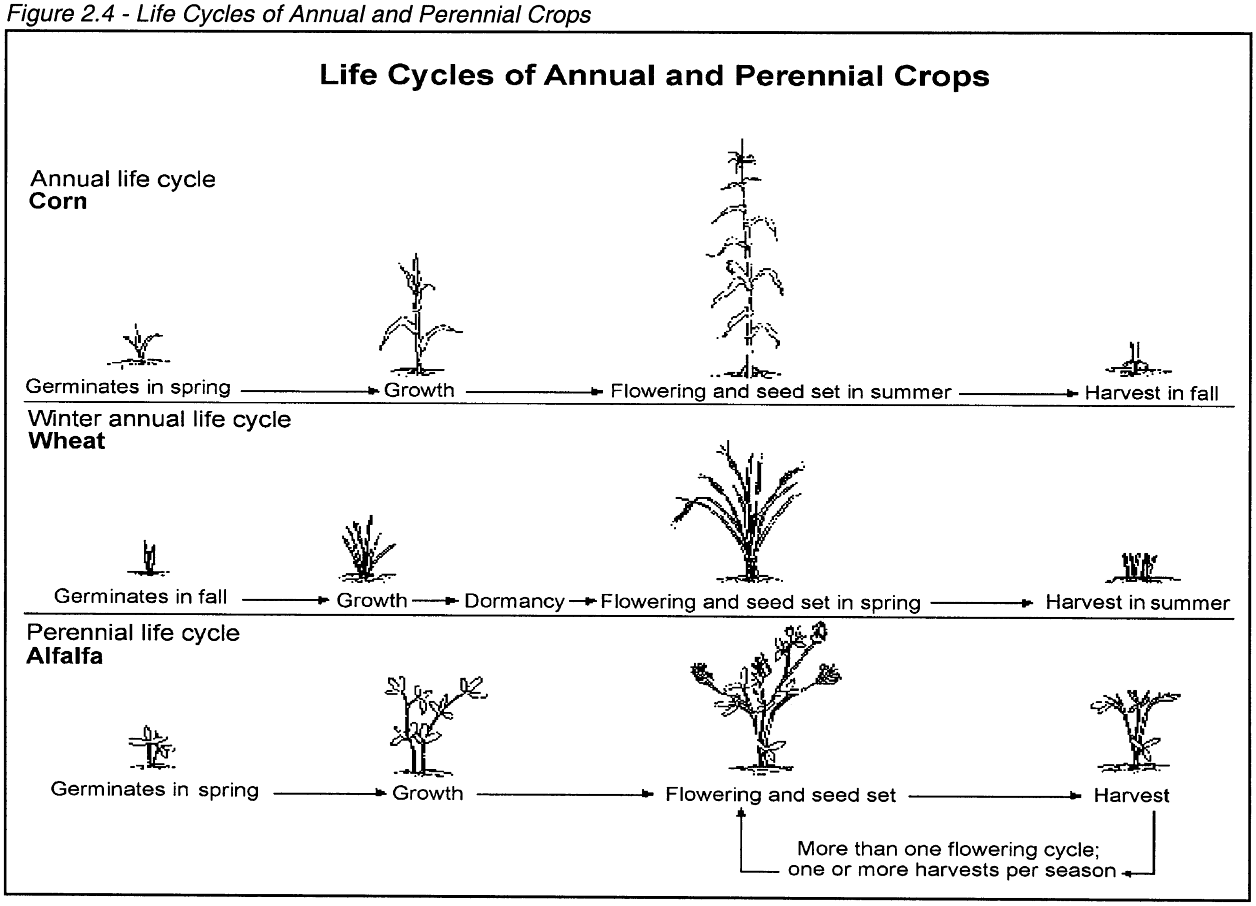


*Table 2.1 - Seventeen Essential Elements for Most Plants*

| ***Macronutrients (9)*** | | | |
|---|---|---|---|
| **Element** | **Symbol** | **Comments** | **Source** |
| Carbon<br>Hydrogen<br>Oxygen | C<br>H<br>O | Carbon, hydrogen, and oxygen are obtained by plants from carbon dioxide and water found in the air and soil. They are called mineral elements. | Water and air |
| Nitrogen<br>Phosphorus<br>Potassium | N<br>P<br>K | These three nutrients are needed in greater amounts by plants. They are called the major or macronutrients. | Organic matter (primarily)<br>Mineral solids and organic matter |
| Calcium<br>Magnesium<br>Sulfur | Ca<br>Mg<br>S | These three nutrients are needed by plants in lesser amounts than macronutrients. They are called secondary nutrients. | Mineral solids |
| ***Micronutrients (8)*** | | | |
| **Element** | **Symbol** | **Comments** | **Source** |
| Boron<br>Chlorine<br>Cobalt<br>Copper<br>Iron<br>Manganese<br>Molybdenum<br>Zinc | B<br>Cl<br>Cu<br>Co<br>Fe<br>Mg<br>Mo<br>Zn | These nutrients are needed in smaller amounts by plants. They are called the minor, or micronutrients. | Naturally in soil; can be added or increased with fertilizers |

found in soil solids. Of these, three are classified as primary macronutrients, nitrogen (N), phosphorus (P), and potassium (K) because they are needed in greater amounts by plants. The secondary macronutrients of calcium (Ca), magnesium (Mg), and sulfur (S) are also available in mineral soils but are needed in lesser amounts by plants.

Nitrogen is a major component of the atmosphere. About 78% of the atmosphere is made up of nitrogen gas ($N_2$). Nitrogen is also found in the soil. Organic matter releases N into the soil through the activity of microbes, or microscopic organisms. Nitrogen is one of the most critical elements for plant growth. Plants use two forms of nitrogen: ammonium ($NH_4^+$) and nitrate ($N_3O^-$). Both ammonium and nitrate leach from the soil through percolating water (water moving downward through soil). Nitrogen is equally important in the breakdown of decaying plants by microbes to form humus, the brownish-black organic material in soil. If microbes run out of nitrogen, they stop working. This is noticeable when plant matter in the soil has not decomposed (broken down) after 1 year. Nitrogen cycles through various forms as it moves from the soil microbes and back to the soil. This is referred to as the nitrogen cycle and is illustrated in Figure 2.5.

Abundant nitrogen results in a dark green, lush growth. The pale green color of nitrogen-deficient plants results from a shortage of chlorophyll. This nitrogen deficiency is caused by inadequate soil moisture even though adequate amounts of nitrogen may have been supplied through fertilizer applications. Nitrogen deficiencies are most noticeable during long dry periods. Therefore, nitrogen should be applied deeply into the soil so that roots can get adequate supplies during dry periods.

All phosphorus (P) comes originally from rock. Phosphorus in the soil forms complex, negatively charged particles with oxygen (O). This makes the solubility (ability to be broken down by water) of phosphorous low and results in it being less available, often causing phosphorus deficiencies in plants. The availability of phosphorus to plants is very complex and is related to the soil pH level (acidic or alkalinity level), soil moisture, nitrogen in the soil, and other chemical properties. One positive factor about the low solubility of phosphorus is that unlike nitrogen, it is not leached from the soil.

Phosphorus in soil comes in two forms, organic and inorganic. The organic form is held tightly and is not readily available to plants. It is broken down by microorganisms into forms of phosphorus ($H_2PO_4$ and $HPO_4$) that can be used by plants. The breakdown of phosphorus is most efficient when soils are warm and well aerated (filled with air). (The amount of available phosphorus in the soil depends usually on the soil pH, the types of fertilizers added, and how they are applied.) Phosphorus is found in the seed and growing parts of plants where it supplies energy for root development and maturation of the crop. Cool temperatures reduce the availability of phosphorus. Applications to correct phosphorus deficiencies should be based on a soil test. Plants with deficiencies will be slow to mature. Purple spots and streaks will appear in the leaf tissues, which are the result of slow conversion of sugar to starches and cellulose. Phosphorus is second only to nitrogen in fertilizer usage.

Potassium (K) is the third element in all complete fertilizers. Plants use potassium in the K+ ion form with most of the potassium being found in the upper 7-inch layer of topsoil. Because only a small percentage of potassium in the soil is available to plants and they absorb large amounts of potassium, the potassium level can be depleted quickly, especially when growing high foliage-producing crops.

Potassium assists in the uptake of nutrients and in enzyme systems, affecting metabolism and photosynthesis. It is important in the formation of carbohydrates and helps to regulate the opening and closing of stomata in the leaves, which are the openings, or slits, that allow for breathing and water transportation. It also assists root cells in absorbing water. Potassium is important for strong roots in corn, which is important during harvest when plants need to remain standing to cut or combine. If the soil is too wet and aeration is inadequate, potassium cannot be absorbed by plant roots.

Potassium deficiencies can be detected in plants as the edges of older leaves and areas between the veins turn yellow, then brown. Small brown spots develop while the veins are still green.

Three secondary macronutrients, calcium (Ca), magnesium (Mg), and sulfur (S), are also essential for plant growth. Generally, soils are not as deficient in secondary macronutrients as they are in primary nutrients.

Calcium (Ca) usually makes up more than 80% of the total bases present in the soil. The amount of exchangeable calcium is critical in changing soil pH, as is the availability of other elements. Calcium can be supplied to the soil through agricultural limestone that is high in calcium carbonate ($CaCO_3$). Calcium is essential for the plant to build cell walls and grow new roots and leaves. Calcium deficiencies are not visible by definite coloration changes as in other nutrient deficiencies. Deficiencies result mostly in low production, even in soils adequately supplied with the other major nutrients.

Magnesium (Mg) makes up about 15% of the bases in the soil and can be supplied through dolomitic limestone high in magnesium carbonate ($MgCO_3$). Magnesium is vital to the photosynthesis process. Most of the magnesium in plants is in chlorophyll or in seed. Like calcium, magnesium deficiencies are not visible through definite coloration changes in plants but result in low crop production.

Sulfur (S) is absorbed by plants as sulfate ($SO_4$) or from the air as sulfur dioxide ($SO_2$). It is also available through organic matter. Sulfur is a vital part of all plant proteins and some hormones. Plants use about as much sulfur as phosphorus. Sulfur can be applied as ferrous sulfate or aluminum sulfate (alum). It can be added to reduce high pH levels. Sulfur deficiencies slow protein production and formation of amino acids. It resembles nitrogen deficiencies in that leaves turn yellow during dry periods.

### *Micronutrients*

Micronutrients are needed in smaller amounts by plants than macronutrients. Therefore, micronutrients are sometimes called the minor, or trace, elements. They include iron (Fe), zinc (Zn), chlorine (Cl), molybdenum (Mo), manganese (Mg), copper (Cu), boron (B), and cobalt (Co).

In the past, adequate levels of micronutrients were maintained in the soil because crop yields were lower and crop residue returned many needed micronutrients to the soil and fertilizers were not accurately applied. Current production practices have heavy applications of highly specific fertilizers, and higher-yielding crops have quickly depleted micronutrients in many soils. Even though plants require small amounts of these nutrients, a deficiency can have a devastating effect on plant growth,

Some micronutrients function as part of enzyme molecules or aid in the enzyme function. Others assist in plant metabolism. Some micronutrients, such as copper (Cu) and iron (Fe), aid in the formation of chlorophyll. The amount of micronutrients needed is usually a few pounds per acre; therefore, they are generally included in complete fertilizer mixes. It is important that micronutrients are mixed thoroughly so that the small amount needed is applied evenly over a field. Overdoses can be toxic to plants, killing them or making them unfit for human consumption.

### Management Practices Associated with Growth Stages

There are several management practices that need to be considered during the growth of the plant. These include nutrient management, repopulation or replanting, moisture management through irrigation, and the management of pests.

Prior to the growing season, it is recommended that the producer test the soil to determine nutrient content. Nutrients that are not available for the plant population to reach a certain level of production will need to be supplied for the plant. Some of the nutrients may need to be applied prior to planting. The use of lime would be an example. Lime would be used in an acidic soil to adjust the pH level for specific plants.

Some of the plant's nutrients are supplied through starter fertilizers. These are nutrients that are placed in the ground with the seed. The nutrients are placed in a specific location to the seed, usually 1 to 2 inches to the side, ready for root growth.

Some crops are fertilized after emergence. This may be done as side dressing or foliar fertilization. Side dressing applies the fertilizer on the soil surface close enough to the plant so cultivating or watering will carry the fertilizer to the plant's roots. Foliar fertilization feeds the plants through their foliage and is considered a supplemental method to feeding the plants through the root system. Foliar fertilization is not a practical method of applying large amounts of nutrients. Applications are expensive and if large amounts of a nutrient are needed, severe burning of the crop is likely to occur, resulting in reduced plant growth.

The amount and nutrients included in the fertilization process will vary greatly depending on the specific crop, the amount of nutrients already available in the soil, the amount of soil moisture, and the method of application.

Sometimes replanting decisions must be made. The failure to achieve desired plant populations may be caused by insect infestation, frost, hail, flooding, or poor seedbed condition. The first rule to observe is to not make a hasty decision. The cause of the problem must first be determined. Sometimes plants that are damaged by weather (hail, flooding) can make a comeback and develop leaf growth. When deciding whether to replant, growers should consider the following:

1. What was the original planting date and what is the desired plant stand?
2. What is the earliest possible replanting date that may be used?
3. Would the cost of the seed and pest control measures be economically justified?

Moisture is usually supplied in adequate amounts to the plants by rainfall. A small amount is needed to complete plant germination. As the plant develops during the growth phase, its moisture requirement greatly increases until after the grain or seed head matures. If additional moisture is needed, it may be supplied by some type of irrigation method. The ability to irrigate may be determined by the topography of the land, the availability of a water source, and the capital required to initiate the process. These determinations must be considered by the producer.

One final management practice that needs to be considered during plant growth stages is pest management. Pest management may be divided into three categories: weed management, disease management, and insect control.

Some soils and field locations lend themselves to more weed infestation problems. Once established, the producer must rely on mechanical, cultural, biological, or chemical methods for control. Mechanical methods include hand pulling, hoeing, burning, mowing, or smothering with plastic mulch. Cultural methods include crop rotation, crop competition, and using weed-free crop seed. Biological control involves the use of natural enemies for weeds. For example, some beetles are natural enemies for certain weeds. Chemical control (use of herbicides) must be done by always following the label directions. Intelligent use of herbicides requires positive identification of the weed and recognizing their stage of growth. Chemicals may be applied as a broadcast treatment, in a band, as a spot treatment, or as a direct spray.

Plant diseases may affect the crop at any stage of growth. Every plant has some potential for a disease problem. These diseases may be caused by biotic (living) or abiotic (nonliving) agents. Living agents include fungi, bacteria, viruses, nematodes, and parasitic plants. Nonliving agents include weather, water or temperature stress, or a combination of these factors. Diseases may be attacked at the seed level with inoculants or during early growth stages with chemical, cultural, or biological control.

Insect damage and control may take place at every stage of the plant's growth. Insects may attack the seed or the vegetation of the plant during growth. Insect control may be divided into four groups: physical, cultural, biological, and chemical. Physical control may involve the direct removal of the insect by means of controlling light or changing temperatures to drive them away. It could also involve using sticky bands or traps to keep insects out of a field. Cultural control involves using crop rotations, tilling the soil, using resistant varieties, and removing plant vegetation that may act as a host or shelter to insects. Biological control is the use of other insects or pathogens to control a certain insect. Examples would include beetles that eat the larvae of aphids, parasitic wasps that attack other insects, and assassin bugs. Chemical controls employs the use of liquids, gases, powders, or granules to control insects. These chemicals may control the insects after they ingest the material, or it may come in contact with the outside of the insect.

## Summary

Crops have four major growth stages between planting and harvesting, although the cycles may differ slightly between crops. Plants are classified by the length of their life cycles, which is the time required for a crop to complete its growth stages. Plants require 17 nutrients to achieve optimum plant growth and development. The nutrients are classified into two groups: macronutrients (Basic: carbon, hydrogen, and oxygen; Primary: nitrogen, phosphorus, and potassium; and Secondary: calcium, magnesium, and sulfur) and micronutrients (iron, zinc, chlorine, molybdenum, manganese, copper, boron, and cobalt). Management practices during certain growth stages of the plants would include nutrient management, population management through replanting, controlling moisture through irrigation, and the management of pests such as weeds, diseases, and insects.

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