In a grazing situation, it is important to understand both how plants function and their form and structure. Every plant growth response is caused by a series of internal chemical changes. Both physiological and morphological changes affect forage quantity and quality and/or plant survival. An understanding of the physiological and morphological responses of plants provides a basis for understanding how plants react to external factors including high and low temperatures, drought stress, light and grazing.

In this chapter, we present an overview of basic plant physiology and morphology. We discuss the impact of form and function of plants on grazing management. The topics discussed here are not considered in great detail. For more information, see the sources listed in the "Additional reading" section at the end of the chapter.

Photosynthesis

Green plants have the ability to trap and store energy from sunlight. Photosynthesis takes place in the chloroplasts of green plant tissue. Plants make simple sugars, or carbohydrates (CH₂O), and oxygen (O₂) using light energy from the sun, carbon dioxide (CO₂) from the air, and water (H₂O) from the soil (Figure 3.1). This reaction is responsible for all life on earth, directly by providing the energy for plant maintenance and growth and indirectly through animals eating plants to gain energy for maintenance and growth. The carbon of the carbon dioxide is converted to the carbon of the carbohydrate and is a chemical way to store the sun's energy as food. Because carbon dioxide is not very abundant (0.03 percent in the atmosphere), the success of a plant depends on its ability to collect and use CO₂.

Plant tissue is made up of complex carbohydrates synthesized from simple carbohydrates. However, energy production in a sward is a relatively inefficient process with only 2 to 6 percent of the light energy that reaches the sward from the sun being converted into useful energy for plant growth. Energy accumulation in the sward, or herbage in a pasture, is determined by how effectively light is intercepted by the leaf canopy and by the efficiency of the photosynthetic process itself. Light interception is a function of the amount of leaf in a sward and is expressed as leaf area index (LAI). Leaf area index is defined as the surface area (one side of the leaf only) of leaf blade per unit area of ground. For a grass or grass/legume pasture, virtually all of the light is intercepted when LAI reaches 4 to 6.

However, complete light interception will be achieved at a lower LAI either when the sun is low or in a sward with a high proportion of plants such as clover whose leaves are close to horizontal. In absolute terms, the amount of carbon fixed increases with increasing light intensity. A scattering of light within the canopy of a tall sward improves the photosynthetic efficiency of the sward by reducing the intensity of light on any individual leaf surface.

The structure and morphology of the sward can have other effects on photosynthetic efficiency. Young leaves have higher efficiency than older leaves. Grass leaves developed in high-intensity light have a higher efficiency than those grown in the shade. Therefore, the need to maintain a sward with a high
Wan-season plants have the potential to be more efficient in their use of water than cool-season plants at similar conditions with the C4 photosynthetic pathway. Cool-season (C3) and warm-season (C4) plants have different photosynthetic systems. Cool-season plants originated from temperate regions and have a C3 system while warm-season plants evolved under tropical conditions with the C4 photosynthetic pathway. Warm-season plants have the potential to be more efficient than cool-season plants when both are at optimum conditions because the C4 system is more efficient than the C3 system at gathering carbon dioxide.

The optimum temperature for growth is 65 to 75 degrees F for cool-season plants and 90 to 95 degrees F for warm-season plants. Warm-season plants use half as much water as cool-season plants to produce a unit of dry matter. Because warm-season plants have higher water-use efficiency and higher optimum temperature for growth, warm-season pastures are more productive during the hot, dry summer months. Conversely, cool-season pastures are more productive in the cooler, more moist spring and fall months. Warm-season plants are more efficient in their use of nitrogen and generally respond to fertilizer under humid climates.

The points outlined above explain why cool-season grasses grow in the spring and mature by late spring or early summer, then become dormant in the summer and resume growth in the autumn. Warm-season grasses begin growth in late spring, mature during late summer and become dormant by early fall.

Carbohydrates

Through photosynthesis, the green tissue of plants is able to manufacture carbohydrates. However, plants can only produce carbohydrates when there is sunlight and during the growing season. Carbohydrates are used to maintain the plant and for growth after defoliation or dormancy. Plants use carbohydrates to survive during winter and, when conditions become more suitable, to renew growth. Carbohydrates can be stored in storage organs such as stem bases, roots, rhizomes and stolons. Storage of carbohydrates in these organs is vital to the survival of the plant because carbohydrates are the only source of energy for new growth after dormancy, severe defoliation or environmental stress.

Growth has priority over storage for carbohydrate use. Carbohydrate storage increases when growth rate declines and leaf area is large. In contrast, carbohydrate storage decreases when the growth rate is fast and leaf area is small. When the plant produces more carbohydrates than are needed for growth and maintenance, the excess is moved to the storage organs. Uncontrolled defoliation can totally deplete stored carbohydrates. Plants must be allowed the opportunity to store carbohydrates for those times when they are unable to produce enough for growth.

The grass tiller

A single grass shoot is called a tiller (Figure 3.2). An individual plant is made up of many tillers, and a pasture has approximately 30 plants and 400 to 1,000 tillers per square foot. A tiller typically has three to four visible leaves, and the lowest leaf is the oldest. Moving up a tiller from the bottom, each leaf is younger than the one below, and successive leaves are on opposite sides of the tiller. Each leaf has an upper part called the blade and a lower part called the sheath. Leaf sheaths could be rolled into a structure called a pseudostem. Below the pseudostem is a true stem. The true stem has divisions called nodes. A shoot bud is found at each node, and roots also emerge near the nodes. The length of stem between the nodes is called the internode. The “growing points” of grass are found just above the node of each stem.

The tiller is essentially a single growing point encased in the sheaths of leaves that grow from it. It also has its own root system and the capacity to develop new generations of tillers from buds at the base of individual leaves. While a grass plant will have many generations of individual tillers and each tiller is self-supporting, the connection between tillers usually is not severed. This allows the transfer of nutrients between tillers, particularly following defoliation.

An individual tiller (shoot) is composed of a growing point (apical meristem), a stem, leaves, roots, nodes (joints) and dormant buds. Depending on the species, buds may be located at the base of the tiller or nodes, on the stem, and/or at the nodes on stolons or rhizomes (Figure 3.2). All these dormant, or inactive, buds have the potential to produce a new tiller.

All tillers begin as a growing point developing from a dormant bud at or below ground level. Vegetative tillers can produce an infinite number of leaves. However, once a tiller receives the message to become reproductive and elongates between the nodes (on the internode), no more leaves can be initiated. Between vegetative and reproductive tiller development, the tiller appears elongated although no seedhead is apparent. In some grasses, tillers may remain elongated (jointed) vegetative tillers.
Usually the transition phase is followed by the reproductive stage, which is evident by the emergence of the seedhead (inflorescence). Removing the reproductive tiller breaks the dormancy of the buds associated with that tiller. Following the removal of a reproductive tiller, the most rapid growth will be from a tiller bud of the defoliated tiller. The aerial tillers associated with some grasses, such as switchgrass and reed canarygrass, are the least productive of the new tillers.

Early in the growing season, all grasses have their growing points close to or at ground level, which is below the height at which an animal can physically graze. Animals, including cattle, cannot physically graze closer to the ground than 1 inch. The growing points of ryegrass, tall fescue, Kentucky bluegrass and many other grasses remain at or below ground level throughout most of the growing season. Others, such as smooth bromegrass, timothy, reed canarygrass and switchgrass, elongate the internodes and elevate the growing point relatively early in their development. At certain times of
the year, some grasses, such as smooth bromegrass and reed canarygrass, may have elongated growth without seedhead development. When a grass plant that has its growing point close to or at ground level is grazed, new leaf material can be produced from the grazed tiller (Figure 3.3). However, when the growing point has been elevated and then is removed by grazing, new leaf material must come from buds that have been dormant.

When new growth has to come from a bud, the energy required to get it started must be provided by either a residual leaf or stored carbohydrates. If all the leaf material has been removed, the only source of energy for the developing bud is that stored in the plant's storage organs. On a plant that is not severely defoliated, the developing bud can receive energy manufactured by the remaining leaf material. Then the plant's carbohydrate reserves are not depleted and do not have to be replenished. However, the plant will be harmed if it has to use its stored carbohydrates because of intense defoliation and if it does not have the chance to replenish carbohydrates because of frequent defoliation.

**Root development**

Like leaves, roots grow and die, but roots also live much longer than leaves. While a tiller may have three to four nodes with emerged leaves, it will have approximately 10 nodes with roots attached. Younger roots receive more photosynthate than older roots. Of the total photosynthesis, approximately 15 percent is allocated to the root system.

However, plants vary the proportion of photosynthate to roots and shoots on a seasonal basis. During seedhead development, allocation of photosynthate to roots is decreased. During late winter or after a summer drought, allocation to roots is temporarily increased. Following removal of the shoot, the levels of carbohydrates in the roots are low, and root growth can be suspended.

For some pasture plants such as tall fescue, leaving more herbage at grazing may allow the plant to better withstand a period of low water availability. Because removing only part of the canopy does not interfere with the continued development of the root system, the plant will have deeper roots. In a drought, a deep root system will afford some protection.

**Summary**

The leaves of plants take in carbon dioxide from the air through tiny pores. Using solar energy, the leaves recombine the carbon with oxygen and hydrogen to make sugars and carbohydrates. Minerals from the soil are combined with the sugars to make fiber, protein, plant oils and fats. The plants use the sugars, starches, proteins, oils and fats to grow and reproduce. Minerals from the soil make up approximately 5 percent of the leaves, stems and roots of plants. Carbon, hydrogen and oxygen from the air and water from the soil make up most of the remainder.

The ability of some grasses and legumes to recover quickly after defoliation makes them valuable for forage production. However, removing too many leaves reduces forage production and damages the root system of the plant. Eventually, the plants will die if subjected to repeated, severe defoliations. Root growth is closely related to the production of forage. Plants maintain maximum root vigor and growth if no more than half their leaf area is removed at each grazing. Removing more than 50 percent of the plant will impair or stop root growth. Perennial plants store food (carbohydrates) in the roots during the growing season. They use these reserves to live while dormant and to make the first new growth after dormancy or defoliation.

The growing points of grass are located just above the node of each stem. Early in the season, growing points are located at the base of the plant.
As the season progresses, the nodes of most species elongate and push upward to produce a seedhead. These tillers will produce no new leaves and are of lower quality than vegetative tillers. Some species elongate relatively early in the growing season, and removal of these tillers means that new growth must come from the base of the plant. Plants of this type require a longer interval between defoliations so that the plant’s root reserves can be replenished.

**Additional reading**


