PHOTOSYNTHESIS

The basic reaction in green plants that converts solar energy to chemical energy is called *photosynthesis*. This reaction is directly or indirectly responsible for all life on earth. It provides the energy (carbohydrate) for *plant growth and maintenance* as well as *animal growth and maintenance.*

$$\text{Carbon Dioxide } (CO_2 + \text{Water } (H_2O) \xrightarrow[\text{green plant material}]{\text{sunlight}} \text{Carbohydrate (food)} + \text{Oxygen } (O_2)$$

The carbon of CO_2 (a gas) is converted to the carbon of the carbohydrate (a solid). The carbohydrate is a chemical way to store the sun's energy as "food." Carbon dioxide in the air, a raw material for the photosynthetic process, is not very abundant. The atmosphere has only 0.03%. The success of a plant will depend on its ability to collect and use CO_2 in the photosynthetic process. *For perennial pasture grasses to remain productive, the photosynthetic process must first feed the plant before it can provide feed for livestock.*

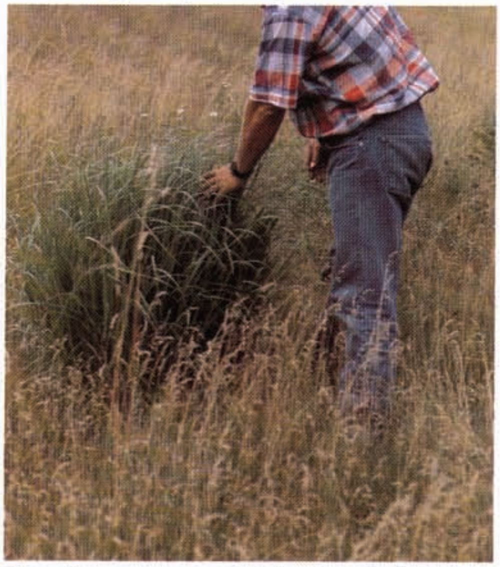
COOL - (C_3) and WARM - (C_4) SEASON GRASSES

Cool- (C_3) and warm- (C_4) season plants have different photosynthetic systems. Cool-season plants of temperate origin have a C_3 photosynthetic process and the warm-season plants which originally evolved under tropical conditions have the C_4 system. The C_4 photosynthetic system is more efficient in gathering CO_2 than the C_3 system. Consequently, warm-season plants have the potential to be more efficient than cool-season plants when both are at optimum conditions.

Optimum temperature for the growth of C_3 plants is around 65-75°F while it is 90-95 °F for C_4 (warm-season) plants. C_4 plants use less water to produce a unit of dry matter. In fact, C_4 plants may be twice as efficient in water use compared to C_3 plants. Water use efficiency and temperature optimums explain why warm-season pastures are more productive in hot, dry summer months and cool-season pastures are more productive in the cool, moist spring and fall months. Since cool-season plants start growth early in the spring, soil moisture is often depleted by early summer. Warm-season grasses which start their growth in late spring generally have a full soil moisture profile in early summer.

There is no "all-season" plant available. Producers must recognize the limitations of plant seasonality as well as take advantage of its benefits. Forage systems that incorporate both cool- and warm-season pastures provide season-long grazing in climates with a hot period during the summer.

Apparently, C_4 plants are also more efficient in nitrogen utilization. Warm-season plants can "get more out of" a given



Clump of warm-season grass (switchgrass) growing in a cool-season hay meadow (late June). Notice stage of maturity and production of switchgrass with zero nitrogen compared to cool-season tall fescue, Kentucky bluegrass and orchard grass.

**Same clump of switchgrass in October after late June haying. Notice amount of regrowth also notice that warm-season grass is over-mature and dormant while cool-season grasses are green.
These two photos dramatize the phenological difference between cool- and warm-season grasses as it relates to time of growing season as well as nitrogen and water use efficiency.**

amount of available soil nitrogen than the cool-season plants. They have more recycled nitrogen available due to increased soil microbial activity in the summer releasing nitrogen from organic matter. On the other hand, cool-season grasses have a high demand for nitrogen in the spring when there is little soil microbial activity. Consequently, nitrogen fertilization is essential to achieve satisfactory levels of production for cool-season grasses. Warm-season grasses generally respond to fertilizer under humid climates.

Comparison of productivity between smooth brome, tall fescue and switchgrass (on right) with zero nitrogen (late June).

These physiological factors help explain why cool-season grasses grow in the spring, mature by late spring or early summer, and become dormant during the hot summer months before resuming growth in the fall. Warm-season grasses mature during late summer and become dormant early in the fall.

These physiological factors have an effect on animal production. For example, the poor performance of livestock grazing tall fescue during the summer has been attributed to an endophyte fungus while the normal reduction in cool-season growth and quality during the summer has been minimized. The use of an endophyte-free, cool-season grass will only partially solve the problem of "summer slump."

Matching the seasonality of grasses with the season of livestock use is more appropriate *(Fig. 2)*.

PASTURE CALENDAR

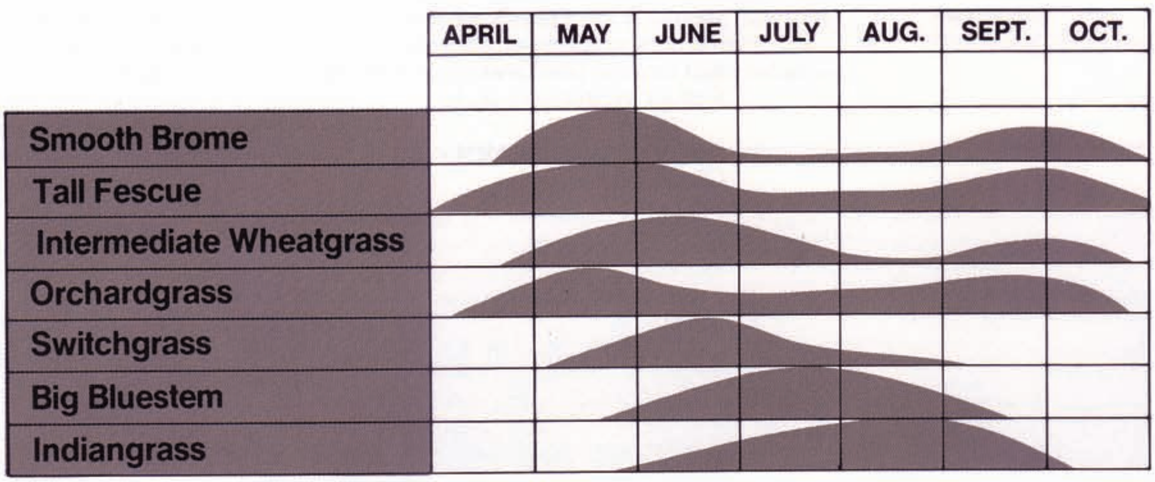


FIG. 2 Seasonal distribution of forage production.

CARBOHYDRATE MANUFACTURE, STORAGE AND UTILIZATION

Carbohydrate manufacture, storage and utilization can be thought of as a factory, warehouse and consumer outlet (Fig. 3). The factory is the green plant cell (generally leaf material) and is in production only when there is sunlight during the growing season. The raw material for the factory is CO_2, water and sunlight. The most active consumption or use of carbohydrate is during the growing season when the plant must maintain itself as well as continue growing after defoliation or dormancy.

Carbohydrates are also used (consumer outlet) during the winter. The perennial plant must survive winter and renew growth in the spring. Carbohydrate storage organs (warehouse) become extremely important since they are the only available source of energy at those times. The warehouse is also very important during the growing season when extensive defoliation or environmental stress close the factory. Carbohydrate storage organs include stem bases, roots, rhizomes and/or stolons.

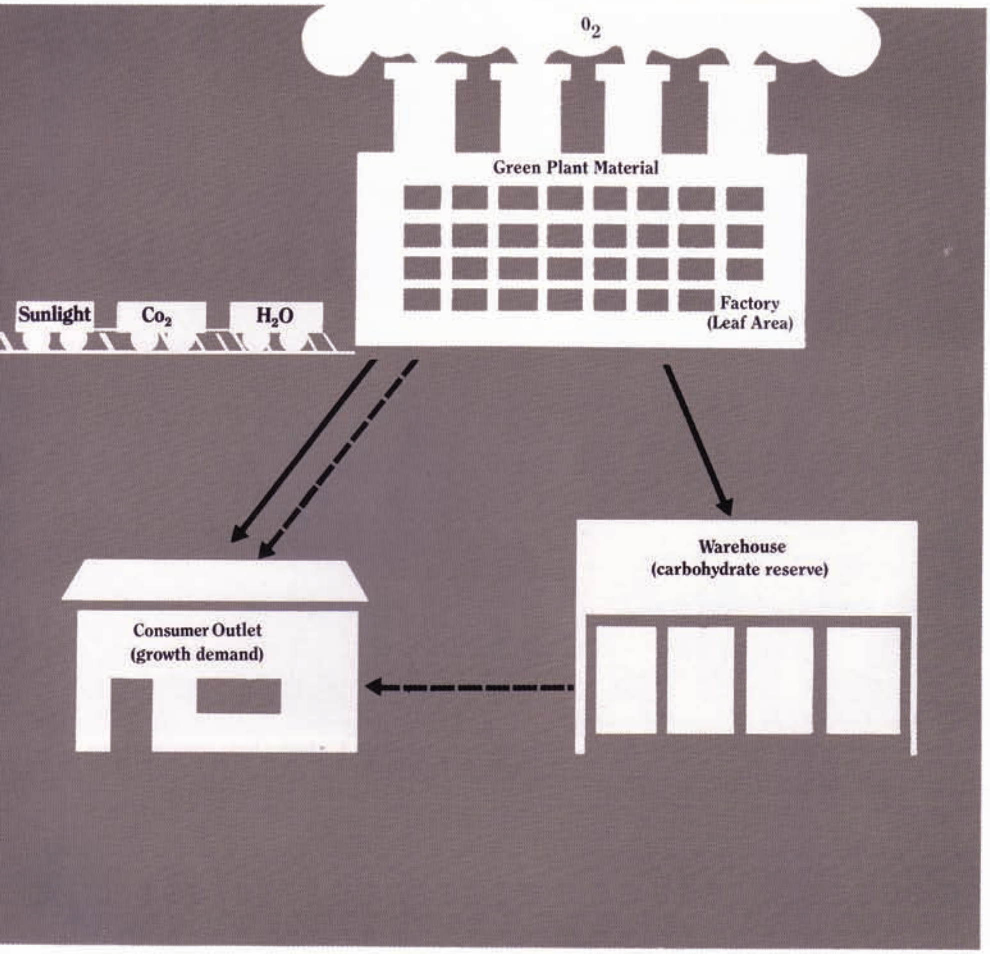
REMEMBER: The factory has only a seasonal operation during daylight hours while the warehouse and consumer outlets are open 24 hours a day, year round.

When the factory (leaf area) produces more carbohydrate than is needed for growth and maintenance, some of the production can be shipped (translocated) to the warehouse for storage. On the other hand, when factory production is insufficient to meet the demand of the consumer outlet, current factory output must be shipped directly to the outlet for growth. In addition, some stored reserves must be shipped form the warehouse to meet current demand. This situation causes no problem until the warehouse becomes nearly exhausted.

Growth has priority over storage for carbohydrate use. This is why uncontrolled grazing can totally depelete a plants stored carbohydrates. We must allow storage to occur for future use since there are occasions when plants are not able to produce enough carbohydrate to meet growth requirements, i.e., periods of non-growth (dormancy) and periods of extensive defoliation.

REMEMBER: If the factory is shut down and the warehouse is exhausted, there is no product for the consumer outlet. If there is no product being manufactured or available from storage to supply growth demands, there will be no forage for the livestock!

Carbohydrate storage *increases* when the growth rate *slows* and leaf area is *large*. Conversely, carbohydrate storage *decreases* when leaf area is *small* and growth rate is *fast*.



- Leaf area more than adequate to meet growth demand
  - Fall or when growth is slow
  - Carbohydrate reserve buildup

- Leaf area inadequate to meet growth demand
  - Spring or after severe defoliation
  - Carbohydrate reserves depeleted

FIG. 3 Carbohydrate manufacture, storage, and utilization.

PRACTICAL APPLICATIONS OF PLANT PHYSIOLOGY

Carbohydrate stored in the roots and rhizomes of perennial grasses is comparable to the carbohydrate stored in the seed of annual crops. If you plant seed low in vigor, you will have some germination but little establishment. Likewise, if you begin the growing season with a perennial plant that has been depleted of energy (low in energy) the previous year, there will be less production. *Perennial plants must have stored energy to survive the winter and to begin growth the following spring.* Likewise, a cow that begins the winter in poor condition is less likely to have a vigorous calf the following spring and successfully rebreed. Wild ruminants like the buffalo, are similar to perennial plants since their survival and reproduction is dependent on the nutrients provided by nature during the growing season. If they achieve a reasonable degree of condition prior to winter, they can maintain themselves during the winter on body nutrient stores and low quality forage.

When a plant begins growth in the spring, there is no leaf material present to manufacture energy for growth. Consequently, energy for spring green-up must be provided from stored carbohydrates. Once some leaf material is present, photosynthesis occurs and carbohydrate is manufactured. If adequate leaf area remains after defoliation, the plant can grow with little need for stored carbohydrates. However, if the plant is severely defoliated (all leaf material removed), stored carbohydrates must be used for new growth. Consequently, remaining leaf area after grazing plays an important role in growth during the grazing season and in replenishing carbohydrate reserves. *(See color plates)*

Alfalfa hay production provides a good example of the concept. The last cutting should be timed to allow adequate growth and carbohydrate storage prior to a killing frost. If the last cutting occurs too late or within 3 or 4 weeks of a killing frost, there

A.

B.

C.

D.

A. Intact indiangrass plant June 1st–Excellent growing conditions with 40 lbs. of nitrogen.

B. Plant clipped at 2″ stubble height leaving no residual or remaining leaf material.
The growing point (apical meristem has been removed from most tillers.

C. Plant clipped at 9″ stubble height (note residual leaf material). The apical meristem or growing point of most tillers has been left intact.

D. Forage harvested from 9″ clipping (note vegetative growth and lack of seedheads).

Regrowth in 6 days when clipped at 9".

Regrowth in 6 days when clipped at 2".

may be stand reduction and reduced vigor the following year. This is a direct result of the mismanagement of the carbohydrate reserves. Growth following the last cutting will use some stored carbohydrates and the plant will not have enough time to replenish its reserves prior to winter. Consequently, there may not be sufficient carbohydrate reserves left for winter survival and vigorous spring green-up. Many of our tall grasses function in a similar manner. Low growing plants like Kentucky bluegrass or white clover can maintain adequate leaf area below even a close clipping height and are relatively unaffected by close, late-season grazing. In fact, they may benefit since competition from taller plants is reduced. A plant like Kentucky bluegrass is relatively easy to manage, but very few producers would choose to plant it instead of smooth brome. Even though smooth brome cannot tolerate close continuous removal, that doesn't mean it is less productive or less desirable than Kentucky bluegrass. The choice belongs to the manager: Does he accept plants that are less susceptible to injury ("manage themselves") and are not very productive, or does he select very productive plants that require good management. *Time* and *knowledge* invested into plant management may cost very little, but pay big dividends.

Early in the growing season when growing conditions are usually most suitable, utilization of carbohydrate reserves for growth following defoliation lasts for only a short period. Not much time is required for leaf tissue to obtain a positive carbohydrate balance even under severe defoliation. Positive carbohydrate balance occurs when carbohydrate production exceeds demand for growth. Although grazing will reduce carbohydrate reserves, the impact is short-lived if defoliation is not complete and continuous. It is also necessary for environmental conditions to be adequate for the impact to be short-lived. Severe defoliation is most detrimental when growing plants are low in carbohydrate reserves and have few enlongated buds or tillers for regrowth. Severe defoliation at this time further depletes the warehouse. Depletion of carbohydrate reserves affects winter survival and spring green-up. For example, extremely close grazing of smooth brome through the fall may result in a thinned, less vigorous stand the following year. Likewise, severe defoliation of the tall warm-season grasses such as big bluestem, indiangrass and switchgrass during late summer and early fall will cause lowered production the following year.

REMEMBER: *You can afford to invest time and knowledge in productive plants*

Plant susceptibility to environmental stress depends on *plant vigor* and *growth status* (actively growing or dormant). Growth status is primarily a function of current growing conditions and time of year. Plant vigor is a function of past management as well as environmental stresses. *Generally, plants are more resistant to environmental stress during dormancy. Plants are very susceptible to environmental stress during periods of active growth.* The plant composition of a pasture can be maintained or shifted using this basic principle.

Generally, pastures are grazed during periods of active growth to optimize livestock performance. However, grazing too long or too close during this time can result in loss of stand and a shift to undesirable species. Short grazing periods that provide intervals of non-use for leaf development and carbohydrate replenishment are more desirable for the plant than continuous grazing.

REMEMBER: *Perennial grasses must have stored energy to survive the winter, to begin growth in the spring and to recover after complete defoliation. Adequate carbohydrates can best be maintained by:*

1. *Delaying initial defoliation or keep early defoliation periods short. "Don't let the cattle get ahead of the grass."*
2. *Allowing adequate leaf area to remain at the conclusion of a defoliation period.*
3. *Allowing adequate time between defoliation to permit leaf area and carbohydrate reserves to build.*
4. *Allowing adequate residual leaf area and time late in the growing season to permit carbohydrate build-up and bud development.*