Grass Growth & Regrowth for Improved Management

In addition to differences in life cycle, grasses differ in their growth habit and response to climatic variables such as day length and temperature. Grasses may be referred to as sod-forming or bunchgrasses (based on their form of tillering), short or tall grasses (referring to both potential height and water requirements), jointing or non-jointing (with respect to their regrowth characteristics), and cool-season or warm-season (with respect to their optimal season of growth). This section describes each of these categories and the management required for optimal utilization.

Sod-forming grasses are characterized by their capacity to produce either rhizomes or stolons, each being a modified stem, which extends laterally enabling the grass to develop a firm sod. Rhizomes are underground stems, varying widely in length, often extending 12 inches or more before the tip breaks through the soil crust to form a new shoot. Stolons remain largely at the soil surface with new shoots and roots arising from nodes.

Both rhizomes and stolons arise from adventitious buds in crown tissue. However, adventitious buds may also give rise to a new shoot with virtually no lateral spreading. In either case, the new growth breaks through the surrounding leaf sheath to form an independent branch of the mother stem. This type of branching is called extravaginal growth.

Since their growth is often horizontal, their growing points are often low to the ground and avoid removal by defoliation. Sod-forming grasses will fill in spots and form a tight web of plants.

Most grass species classified as bunchgrasses do not produce well developed rhizomes or stolons and therefore have a tufted growth habit as opposed to dense sod. The adventitious buds of bunchgrasses are found on the basal nodes in crown tissue and produce new tillers which remain within the surrounding leaf sheath of the mother stem. This type of branching is called intravaginal and the plants maintain an erect growth habit. This feature results in a bunch or tussock type of growth with minimal lateral spreading as occurs with rhizomes and/or stolons. The upward growth means that their growing points are often susceptible to removal by defoliation.

Grasses which reproduce vegetatively from adventitious buds on corms represent still another class. Corms are thickened, bulbous internodes which form in crown tissue, serving as storage organs. New tillers arise from nodes in the corms.

The following list designates the sod-forming or bunchgrass growth habit of the common forage grasses.

Sod-forming grasses with extensive rhizomes: smooth bromegrass (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), quackgrass (*Agropyron repens*), prairie cordgrass (*Spartina pectinata*), foxtail muhly (*Muhlenbergia andina*), Johnson grass (*Sorghum halepense*), and redtop (*Agrostis alba*).

Sod-forming grasses with extensive stolons: bermudagrass (*Cynodon dactylon*), bentgrasses (*Agrostis* spp.), and buffalograss (*Buchloe dactyloides*).

Sod-forming grasses with short rhizomes: tall fescue (*Festuca arundinaceae*), sideoats grama (*Bouteloua curtipendula*), big bluestem (*Andropogon gerardii*), and Indiangrass (*Sorghastrum nutans*).

Bunchgrasses - chiefly intravaginal branching: perennial ryegrass (*Lolium perenne*), orchardgrass (*Dactylis glomerata*), and little bluestem (*Schizachyrium scoparium*).

Bunchgrasses - reproducing vegetatively via corms: timothy (*Phleum pratense*) and tall oatgrass (*Arrhenatherum elatius* var. *bulbosum*).

Although animals eat all year round, there is no "all season" plant to use as forage. Knowing that some plants are C_3 (cool season, temperate) and some plants are referred to as C_4 (warm season, tropical) is a basic key to having quality forage all year long. But understanding the physiology (internal chemical changes) of both can even further improve the management of forages.

The science:
C_3 and C_4 plants both use the process of photosynthesis to convert light energy and atmospheric CO_2 into plant food energy (carbohydrates).

Sunlight Carbon dioxide (CO_2) + water (H_2O) -> carbohydrate (food) + oxygen (O_2) green plant material

C_3 and C_4 plants differ in the leaf anatomies and enzymes used to carry out photosynthesis. These differences are important with respect to their optimal growing conditions, N and water-use efficiency, forage quality, and seasonal production profile.

C_3 plants (cool season)

The science:
C_3 plants are called temperate or cool-season plants. They reduce (fix) CO_2 directly by the enzyme ribulose bisphosphate carboxylase (RUBPcase) in the chloroplast. The reaction between CO_2 and ribulose bisphosphate, a phosphorylated 5-carbon sugar, forms two molecules of a 3-carbon acid. This 3-carbon acid is called 3-phosphoglyceric acid and explains why the plants using this chemical reaction are called C_3 plants. The 3-phosphoglyceric acid molecules move out of the chloroplast to the cytoplasm and are used to make hexose, sucrose, and other compounds. The enzyme ribulose bisphosphate carboxylase also triggers a reaction where oxygen splits ribulose bisphosphate into a 2-carbon acid and a 3-phosphoglyceric acid. The 2-carbon acid is respired to carbon dioxide via photorespiration and basically lost to plant function. As much as 15-40% of the light energy taken into the C_3 plants is lost via photorespiration which rises with increasing temperatures.

Thus, C_3 plants fix CO_2 more efficiently in cooler environments.

The ramifications:
C_3 plants have an optimum temperature range of 65-75 degrees F. Growth begins when the soil temperature is 40-45 degrees F. C_3 plants become less efficient as the temperature increases, but they provide a higher percentage of crude protein than C_4 plants. Cool temperatures of

early spring also effect the activity of soil organisms which release nitrogen from organic reserves. Thus, C_3 plants respond to nitrogen fertilizer during this season. Cool-season grasses are productive in the spring and fall because of the cooler temperatures during the day and night, shorter photoperiods, and higher soil moisture. During the summer, growth is reduced and dormancy is induced by high temperatures and low precipitation. However, in fall, when temperatures drop and moisture is more available, growth resumes.

There is evidence that summer dormancy is associated with mismanagement of seed heads. Timely removal of seed heads, at the late-jointing to early boot stages, triggers growth of the second cycle of tillers before the onset of hot, dry weather. It may be possible to increase summer productivity in this manner.

There is some evidence indicating that conditions necessary for floral induction in C_3 plants are different from C_4 plants. Cool-season grasses may require short days and/or low temperatures in the fall or early spring (a vernalization period) before the seedhead develops from the meristem (growing point). There also seems to be a need for the tiller (shoot, new plant) to reach a certain size before vernalization can commence. Timothy does not require this vernalization but requires long days to flower.

C3 plants can be annual or perennial. Annual C_3 plants include wheat, rye, and oats. Perennial C_3 plants include orchardgrass, fescues, and perennial ryegrass. The degradation of C_3 grasses in the rumen of an animal is often faster than C_4 grasses because of the thin cell walls and leaf tissue and are therefore often of higher forage quality.

C_4 plants (warm season)

The science:
C_4 plants are often called tropical or warm season plants. They reduce carbon dioxide captured during photosynthesis to useable components by first converting carbon dioxide to oxaloacetate, a 4-carbon acid. This is the reason these plants are referred to as C_4 plants. Photosynthesis then continues in much the same way as in C_3 plants. This type of photosynthesis is highly efficient and little fixed CO_2 is lost through photorespiration.

The ramifications:
C_4 plants are more efficient at gathering carbon dioxide and utilizing nitrogen from the atmosphere and recycled N in the soil. They also use less water to make dry matter. They grow best at 90-95 degrees F. They begin to grow when the soil temperature is 60-65 degrees F. Forage of C_4 species is generally lower in protein than C_3 plants but the protein is more efficiently used by animals. This efficiency may result because C_3 plants contain a lot of non-protein nitrogen (NPN), very labile (changeable) in form, which pass into the gut or is absorbed directly into the portal vein leading to the liver and not incorporated into microbial proteins by rumen microflora. It is well established that NPN levels may exceed the liver's capacity to filter it out, thus it enters the systemic blood and causes ammonia intoxication.

Warm-season grasses are specifically triggered by day length so latitudes should be considered in selecting warm-season grass species. They are most productive during the warmer summer months. Often, cool-season and warm-season species are used in combinations to provide forage throughout much of the year. With ample soil moisture, warm season grasses may respond to nitrogen fertilizer but because irrigation is often expensive, supplemental nitrogen is seldom applied.

C_4 plants can be annual or perennial. Annual C_4 plants include corn, Sudangrass, and pearl millet. Perennial C_4 plants include big bluestem, Indiangrass, bermudagrass, switchgrass, and old world bluestems.

Practical Applications

In recent years, warm-season grasses have been recommended for seeding retired cropland. Efforts are also underway to improve rangelands by introducing species that have disappeared due to over grazing. To ensure persistence, pastures can be established using cool-season and warm-season grasses. Cool-season grasses could be utilized for fall, winter, and spring grazing and the warm-season grasses would flourish in the summer. In spring, the warm-season grasses should be protected until they can better withstand defoliation. To determine when that is, monitor the root system for the production of new tillers.

Warm-season grasses reach their peak of production about a month later than cool-season grasses. Although warm-season grasses produce less yield, their virtue is to provide superior midsummer grazing when cool-season grasses are semi-dormant. Both types can be stockpiled during late summer and fall to provide maintenance energy for livestock during the winter months.

Warm-season (C_4) grasses normally contain less protein than is found in cool-season (C_3) grasses. This might be expected because warm-season grasses are seldom fertilized with supplemental nitrogen. However, to achieve yield goals with cool-season grasses, they are often fertilized with some form of nitrogen. This increases the protein content of the grass, as nitrogen accounts for 16 percent of the protein molecule. Nitrogen that is not incorporated into proteins is temporarily stored in various forms: free amino acids, nitrates, amides, and amines, broadly classed as non-protein nitrogen (NPN). In chemical analyses of feedstuffs, these forms of nitrogen are commonly considered as being as nutritious as true proteins. This may not hold true if the NPN level is too high.

The protein in C_4 grasses is used more efficiently by ruminant livestock. A higher percentage of the protein in C_4 grasses is retained in the carcass and less is voided via the kidneys as urea. Cattle reach a higher degree of finish on C_4 range grasses than on more lush C_3 grasses. Why is this?

Research suggests that reduced efficiency in protein utilization in C_3 grasses might be due to excessive levels of NPN. These NPN substances are rapidly deaminated (an amino group is removed) by enzymes (chiefly urease) present in the rumen microflora. The ammonium (NH_4) released from deamination can cause stress similar to the type which often occurs when feeding excessive amounts of urea to livestock.

There is evidence that livestock may suffer illnesses from lush pastures because the rapid release of ammonium N from the labile nitrogenous substances in grasses.

High levels of soil nitrogen lead to rapid uptake of this element by plant roots. Some of it may be stored as NPN. If rumen microflora fail to incorporate the liberated ammonium N into microbial protein (this being the normal function of rumen bacteria), a significant portion may be absorbed through the rumen wall into the portal vein leading to the liver. Additionally, in a worst case scenario, some of the nitrogen-rich material may pass into the cecum where it is degraded by bacteria rather than by the enzyme urease. This is known as intestinal putrefaction (proteins rot or putrefy, whereas carbohydrates ferment). The ammonium N released via putrefaction is absorbed directly into the portal blood system leading to the liver. The liver is challenged to convert the nitrogen in the portal blood system to urea so that will enter the general blood stream which nourishes the brain, kidneys, muscles, and other organs.

- If the liver malfunctions, or its capacity to filter the ammonium nitrogen is exceeded, this toxic ammonium eventually reaches the brain via the general circulation and causes various forms of livestock disorders, broadly classed as ammonia intoxication.
- The above interpretation suggests that cool-season grasses should not be heavily fertilized with nitrogen (>50 lb. of actual N per acre per month). Nitrogen should be applied in split applications. As an extra precaution to maintain low levels of NPN in cool-season grasses, maintain ample levels of phosphorus and potassium in the soil. Potassium serves a catalytic function in protein synthesis thereby lowering the level of NPN and phosphorus is important in energy metabolism (ATP).
- What about pasture supplements? Energy-rich supplements can be offered as additional insurance against NPN stress. For example, when urea is added to livestock rations, it is essential to supply grain or molasses to stimulate growth of rumen microflora, thereby creating a demand for the ammonium nitrogen released in the rumen. Additionally, livestock relish a mineral supplement which contains clay. The cation exchange properties (buffering capacity) of clay minerals promotes the absorption (and possible fixation) of ammonium ions.

Forage vs. Turf Grasses

Although grasses used for forage are not fundamentally different from those used for turf, their purposes are, so their management is different. Many species could be effectively used for both if management and purposes are well matched. Grasses used for forage are intended to provide good quantities of high-quality feed for livestock and wildlife while turf grasses provide utilities such as soil stabilization or air filtering and cooling, decoration, and recreation. Turf grasses are used for golf courses, sporting areas, lawns, and roadways.

Forage managers want abundant, high quality feed which assumes encouraging the vertical growth of grasses, mostly the leaves. Turf managers want to encourage horizontal growth and control vertical growth. Both can be possible when the growth and regrowth of grasses is understood.

Turf managers want to create a dense, fine textured, uniform, and smooth look. Grasses that are rhizomatous and stoloniferous are key players in thick turfs. They want grasses that are uprightly rigid, with good elasticity and resiliency to improve footing stability and ball roll.

Desired forage grasses are leafy, palatable, and digestible. Persistence of both turf and forage grasses is desirable, as is a healthy stand.

Though the purposes may be different, both turf and forage grasses are often mismanaged. Both require proper selection, establishment, fertilization, pest control, and cultivation although with different goals in mind. Turf grasses are often irrigated and mowed, while pastures may not require as much intensive management.

Management Implications

Turf grasses are usually low growing and often stoloniferous (bentgrass, bermudagrass), or rhizomatous (bluegrass), or are seeded at such high rates that the individual plants form a firm sod (as with ryegrasses). With frequent, precise, and consistent mowing systems, the grass shoot adjusts by maintaining short sheaths so that the collar zone of the leaf is safeguarded, and the essentially complete lack of culm development serves to preserve the shoot apex of flowering shoots. Thus, the above ground meristem is largely preserved and can function to provide prompt competitive regrowth.

Grasses chosen for turf have an abundance of vegetative shoots (as opposed to flowering shoots) and there is little concern about the seedheads in shoots that are induced to flower. Shoots of turf grasses that have been induced to flower will produce a seedhead no matter the frequency of mowing or stubble height. But, culm internodes in these shoots elongate minimally and the shoot apex remains below the cutting height until the peduncle pushes the seedhead up to a vulnerable position.

If forage grasses were managed with the same finesse, there would be some positive outcomes. Forage grasses have a tendency to grow tall, and infrequent defoliation provides the opportunity for the grass to reach a stage of development that renders it sensitive to severe defoliation (growing points are sacrificed, or collar zones of elongated sheaths are destroyed so there is no mechanism to ensure continued blade development). This is basically the secret of wise turf management.

Grasses used for forage have a strong tendency to produce flowering stalks. Consequently, the "early-jointing" stage represents a hazard under intensive close grazing. Additionally, the longer rest interval between defoliations may allow the grass to reach a developmental stage when it is sensitive to mismanagement. To mimic the turf grass management which usually means mowing once a week with a 7-day rest interval, it would require 8 paddocks to accommodate 1 day of grazing with 7 days for rest. The livestock would need to work overtime trying to get enough energy for production from 7 days recovery growth.

During the past decade intensive grazing systems have been developed which essentially mimic turf grass management. Their goal is to maintain strong plant growth, so grazing or mowing is used to help the plant remain strong. Forage managers that view grazing only from the livestock's viewpoint would gain much by balancing the needs of the plants with those of the animals.

With turf grasses, it is easy to mow a 3-inch growth back to 1 1/2 inches and thus "take half and leave half." However, with grazing systems it is difficult to adjust the stocking rate to ensure that this goal is achieved. More than likely, a 12" canopy will not be grazed back to 6" in order to preserve essential meristemic regrowth systems. The temptation to maximize consumption is too great.

Turf grasses are carefully watered because their root system is shallow. Irrigation is scheduled to prevent foliar diseases. Forage grasses are often not cared for in such a careful manner.

Consider these points before grazing or clipping in balancing grass health, yield, and quality:

- The developmental phase of the plant.
- Both the defoliation frequency and height.
- The effects of canopy and irrigation.

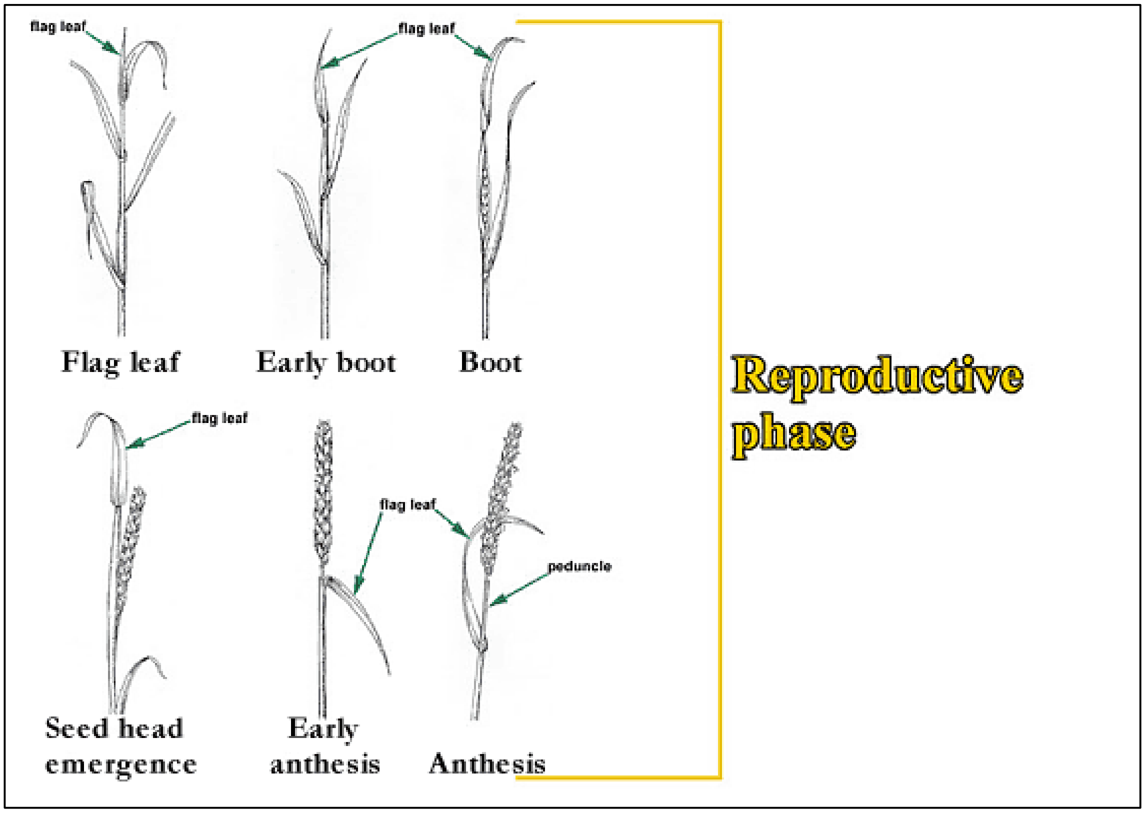
Rationale for Creating This Distinction

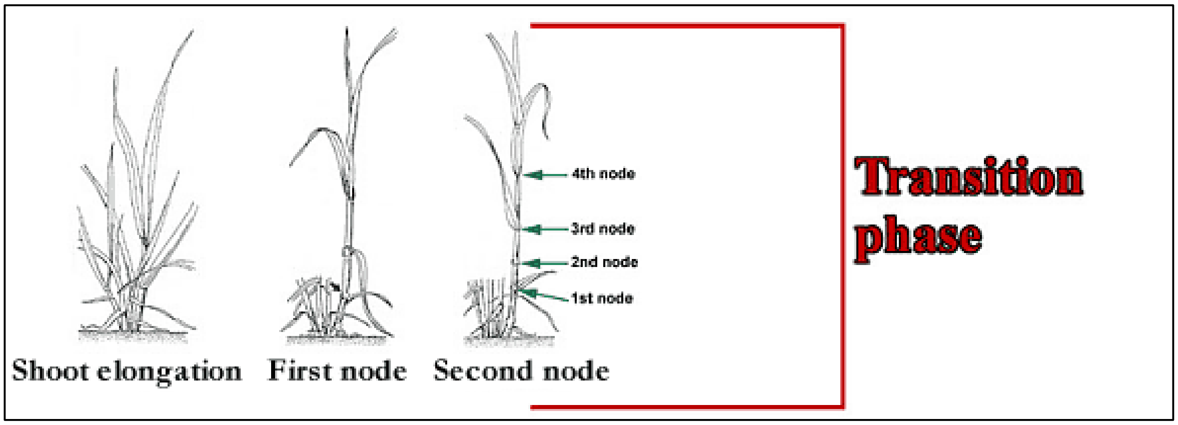
Grasses are defined as herbaceous, monocotyledons with **jointed,** flowering culms. Some texts further classify grasses as being jointed or non-jointed with respect to how they regrow. Grasses that produce jointed culms again in regrowth are called jointed grasses. Grasses that regrow without elevating a flowering culm are called non-jointed.

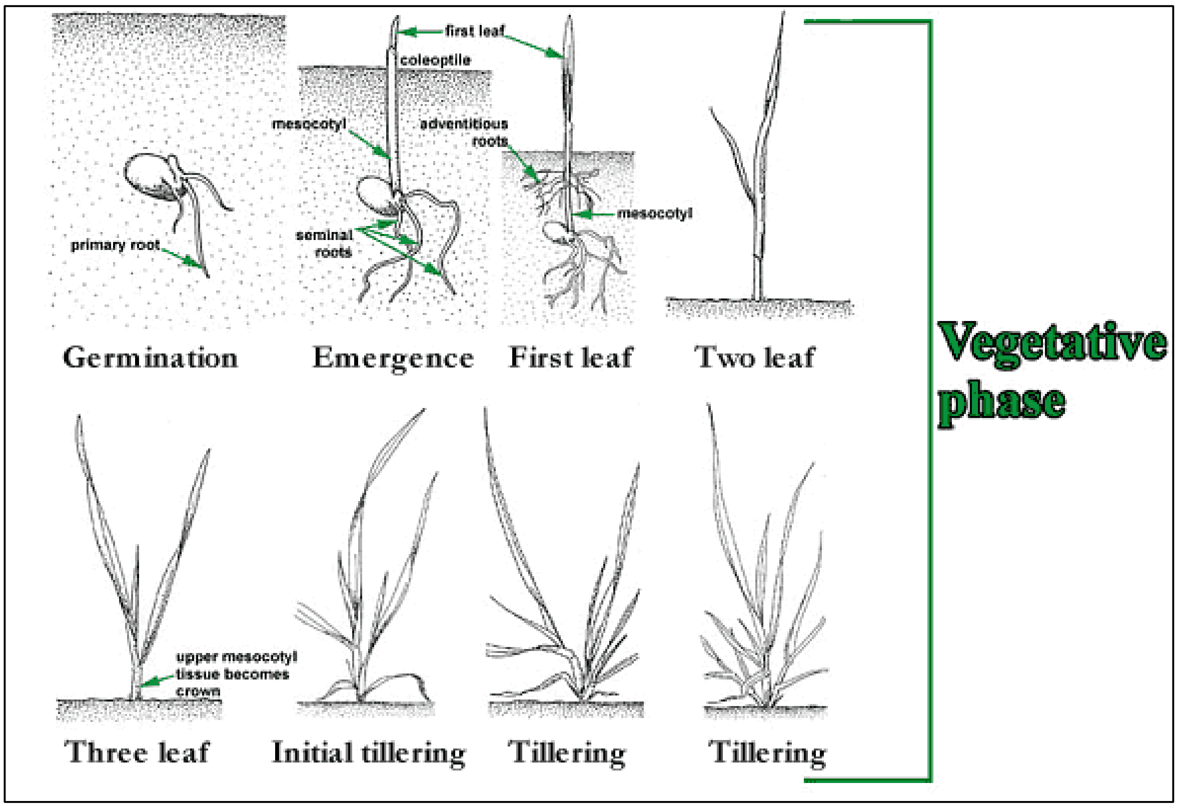
Understanding this distinction in regrowth habit is important in developing successful management practices because jointed grasses are more easily damaged. They elevate their apical meristems several times in a year. Damage occurs from untimely removal of the apical meristem. Defoliation is untimely when regrowth mechanisms are immature. Some grass seed mixtures contain one or more of each type (jointed and non-jointed) making management of such mixtures complicated.

All Grasses

The flowering stems of all grasses pass through a gradient of developmental phases commencing with vegetative shoots and ending with seed production (see "Grass Development Phases" section for a description of growth stages).

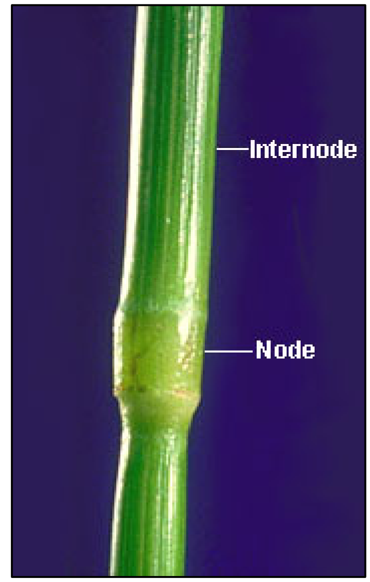






During vegetative growth leaves are pushed upward but after becoming induced to flower, the shoot produces a central stem called a culm. The culm consists of nodes separated by internodes. Each node with its associated internode represents a stem segment, commonly called a joint.

Thus, the term "jointing" refers to the commencement of internode elongation, a process which creates a main stem (culm) and also elevates the meristematic growing point to a vulnerable defoliation height. Destruction (decapitation) of this elevated meristem forces regrowth from adventitious buds in crown tissue. Early decapitation results in delayed regrowth because buds are immature.



Although this is a highly critical management issue, it is only practically important for grasses that have a high proportion of floral tillers. Some grasses produce many non-flowering (sterile) tillers which remain culmless and the apical meristem remains low.

Phrased differently, with proper environmental conditions, many grass species are prolific seed producers. A high percentage of the shoots will contain a jointed culm which will support a seedhead in the first cycle. In contrast, other grass species are less prolific and produce many non-flowering, culmless, vegetative shoots even though environmental conditions would support floral induction. Various species have different seed production capacities.

Grasses with many flowering shoots should be carefully managed during the early-jointing stage of development. Early-jointing implies that the internodes of the developing culm have commenced elongation thereby raising the meristematic tissue to a vulnerable height. If the grass is producing mainly flowering shoots and they are removed then there is not a good regrowth mechanism.

In less-prolific species, those with fewer flowering culms but more vegetative (sterile) shoots, the vegetative shoots provide for rapid competitive regrowth even when early-spring growth is mowed low or intensively grazed during the early-jointing stage of culm development. This is why grasses like Kentucky bluegrass and bentgrasses are good candidates for turf, landscaping, and intensive grazing. Rapid recovery after mowing is due to well-established vegetative shoots that did not commence elongation and therefore have a growing point nestled low in the shoot. Without thoughtful management, this type of grass has a decidedly competitive advantage which can be good or bad depending on the purpose and goals of the manager.

Though these grasses may tolerate intensive grazing because their apical meristems are low in the many vegetative (sterile) tillers, there is a risk for poor management in dry conditions or after long rest intervals. Dry conditions and long rests may cause intercalary meristems (at the base of the leaf blade) to become elevated and vulnerable. This elevation means that defoliation may be removing the leaf bases. Once that meristem is removed a leaf cannot be regenerated there. Excessive leaf blade removal disrupts photosynthesis and transpiration which leads to a thinning of the stand and the opportunity for invasion by undesired species.

If very intensive defoliation destroys the apical and intercalary meristems, no subsequent growth from that tissue is possible. Regrowth eventually can occur from new shoots arising from basal buds in the crown zone. If those buds are not yet well developed, recovery is delayed and companion species and weeds may flourish during the delay. To reduce this threat, avoid shoot decapitation until basal buds have produced new shoot sprouts which will produce a second growth (aftermath) for mid-summer production.

Grasses with Culmed Vegetative Shoots (AKA "Jointed" Grasses)

There are grass species that produce many flowering shoots, while others produce some flowering shoots and many vegetative shoots. There are also those that have shoots that produce a culm but fail to become induced to flower. This results in a vegetative shoot with an elevated meristem. Such shoots are intolerant of defoliation because the growing point is raised and, if adventitious buds in crown tissue are not developed sufficiently to serve as a regrowth mechanism, regrowth is greatly delayed.

Jointed Grass Examples are: smooth bromegrass, wheatgrasses, quackgrass, timothy, reed canarygrass, and annual ryegrass. Culmed (jointed) vegetative shoots, whether found in the initial spring growth or in the aftermath, develop chiefly (if not entirely) in grasses which produce new tillers extravaginally, via basal crown buds, rhizomes or stolons.

In sharp contrast, intravaginal tillers, characteristic of bunch grasses, produce a jointed culm only if they become induced to flower. With some exceptions, floral induction of aftermath shoots of intravaginal types is rare due to improper climatic conditions. The shoot primordium (growing point containing the apical and intercalary meristems) of such shoots remains at or near the soil surface. This feature provides a degree of grazing tolerance, however, with deferment of defoliation, mid-summer hay harvesting, sheath elongation becomes a factor governing recovery. If most of the leaf blades are severed beneath the collar (through the sheath) there will be no blade renewal and the grass may suffer.

Grasses with Culmed Aftermath Shoots

Aftermath is a term assigned to the recovery growth following the removal of grass seedheads. It is known that the initiation and early development of aftermath shoots is temporarily suppressed by hormones associated with floral development. The suppression is called "apical dominance" because the apical meristem is dominating the growth processes by producing seed. With cool-season grasses that are prolific seed producers, destruction of seedheads by intensive grazing or clipping at the "boot stage" of development is wise because it disrupts apical dominance, allowing growth energy to be redirected to aftermath growth from buds at the plant base.

The practice of removing seedheads during the boot stage is particularly helpful with grasses such as orchardgrass and smooth bromegrass because the aftermath shoots of these grasses are not nourished by the mother root system. To enhance midsummer production, aftermath shoots must regenerate roots before the advent of hot arid conditions of midsummer. So, preventing any delay is wise. Dry weather limits root growth which limits shoot growth.

Aftermath shoots of grasses such as timothy, bromegrass, reed canarygrass, and quackgrass produce culms. Culm development commences approximately 4-6 weeks after initial recovery growth. Intensive defoliation at this time is ill-advised because the shoot growing point may be destroyed at a time when basal buds are not yet ready to produce new shoots. Summer dormancy or death may be the result of this mismanagement.

Percentage of floral tillers

These grasses have a high percentage of floral tillers and have "jointed" aftermath shoots (culmed vegetative shoots):

- Annual ryegrass
- Big bluestem
- Indiangrass
- Perennial ryegrass
- Reed canarygrass
- Smooth bromegrass
- Switchgrass
- Timothy
- These grasses have a medium percentage of floral tillers:
- Little bluestem
- Orchardgrass
- Sideoats grama
- Tall fescue

These grasses have a low percentage of floral tillers and are not "jointed" in their regrowth:

- Bentgrass
- Blue grama
- Buffalograss
- Kentucky bluegrass

Management Implications

Grasses pass progressively through the developmental phases (vegetative, transition, reproductive), but regrowth after seedheads have been removed can happen in two ways: 1) regrowth can progress through the same phases as initial growth (culmed aftermath), or 2) regrowth can remain vegetative, that is, growth without elongation and preparation for reproduction (culmless aftermath).

Most species do not produce seedheads in aftermath shoots (they have culmless aftermath). Certain species do produce a culm that remains vegetative, producing an indeterminate number of leaves. Research has not determined a complete listing of species with this growth habit but smooth bromegrass, timothy, reed canarygrass, and quackgrass are examples of such growth. They are sometimes called jointed grasses but "culmed aftermath grass species" is a more accurate term. This type of growth habit will influence midsummer growth and stand persistence unless management considers the location of the growing point when the shoots develop a culm.

Given adequate moisture and fertility, culm development commences after approximately 5 weeks of recovery. Thus, with 3-4 weeks of regrowth, the growing point is below the normal grazing height. After 5-6 weeks recovery, close examination reveals that culm development has commenced. Basal internode elongation has elevated the meristematic growing point to a vulnerable height. In this situation intensive defoliation may cause nearly complete loss of stands in sensitive species, particularly if basal buds have not yet initiated new tillers necessary for regrowth.

Determining whether a grass species is culmed or culmless in growth after initial growth is important in defoliation management. This is because the growing point of the culm could be elevated and removed. But consider another potential problem. If the rest interval between defoliations is too long and growth from the leaf sheaths progresses too far, then the meristematic tissue of the leaf blade in the collar region is raised to a vulnerable height. If the leaf blade is severed beneath the meristematic zone of the collar there can be no more leaf generation of that leaf. If a leaf blade is severed above the collar area, the leaf blade can continue to grow. If several leaves on a shoot are severed below the collar regions then photosynthesis is greatly hampered since it takes place in the blades. Transpiration is also reduced, reducing water movement upward from the root zone. This could lead to reduced photosynthesis, cell division, and cell expansion in the apical meristem which leads to death of the shoot. This is termed "scalping" by turf managers.

Scalping of turf species has much in common with the overgrazing of culmless aftermath shoots in grasses like big bluestem, little bluestem, and Indiangrass. These species are often classified as "decreasers" under heavy grazing. These species will often decrease under grazing allowing grama grasses and buffalograss to prevail. These two have a lesser tendency to produce elongated leaf sheaths, and the growing points of shoots remain low. This describes how overgrazed tall-grass prairies became short-grass prairies.

An early bite can be taken successfully on pastures if the manager knows the phase of development of the grasses. It is important to preserve critical meristems for regrowth purposes. Grasses become somewhat more tolerant of intensive grazing once the flowering shoots have started culm development (mid-jointing stage). Utilize the grass before the seedheads emerge from the shoot.

Management Scenarios

Scenario: Effects of mowing a mixed stand of bromegrass and timothy when bromegrass is in the early-transition stage and timothy is as yet in the vegetative stage.

Expected results: Bromegrass will be "decapitated" because internode elongation has elevated the meristematic zone of the culm (growing point) to a vulnerable height. Recovery will be via new shoots arising from basal buds in crown tissue. In contrast, timothy shoots will continue development because the growing point was nested deep in the base of the shoot. This mowing would favor timothy.

In contrast to the above demonstration, the grass mixture could be mowed when the bromegrass had reached the late-boot to early-heading stage, when timothy was in the early transition stage. The expected results? The timothy would have been "decapitated" in an untimely manner. Removal of the shoot primordium at "early transition" suppresses timothy because basal sprouts are not yet capable of producing prompt, competitive growth.

SHORT AND TALL GRASSES

The Great Plains of North America is one of the largest expanses of grassland in the world. It extends westward from the deciduous forest of the Appalachian Mountains to the foothills of the Rocky Mountains and southward from Canada to Mexico.

The east-to-west gradient of increasing altitude, decreasing precipitation, and increasing temperature and the north-to-south gradient of temperature and humidity have created zones of tall, medium, and short-grass prairies. This vast prairie region is comprised chiefly of warm-season grasses which tolerate the climatic extremes.

Tall Grass Prairie

Historically, the tall-grass prairie consisted of big and little bluestem, switchgrass, and Indiangrass. These species thrive in zones of 30-40 inch annual precipitation and reach 6-8 feet in height. Within this zone, cordgrass (*Spartina* spp.) and reed grass (*Phragmites* spp.) are dominant species in the wet lands. Thousands of years of tall grass dominance (owing to managed and natural fires preventing forest development) created a rich, fertile soil which now characterizes the corn belt of the USA.

Medium Grass Prairies

The mixed grass prairies found in the 20-30 inch rainfall belt represented a transition zone comprised of a mixture of tall, medium, and short grasses (US Precipitation Map). Medium height species included little bluestem (*Schizachyrium scoparium*), side oats grama (*Bouteloua curtipendula*), and dropseed (*Sporobolus* spp.). These grasses reached a height of 3-5 feet.

Short Grass Prairies

The short grass prairies found in the 15-25 inch annual precipitation zone are dominated by blue grama (*Bouteloua gracilis*) and buffalograss (*Buchloe dactyloides*). This semiarid climate zone extends from central Nebraska westward to the Rockies, and from Texas to Saskatchewan.

The major tall-grass prairies of the Midwest and Great Plains were quite overwhelming to early settlers. Tall-grass prairies have been described as oceans, and some found them too vast to cross. After the American Revolution, settlers and pioneers waited almost 40 years (1840-1880) before settling 700 million acres of bountiful prairies.

Without large numbers of domesticated animals and plows the tall-grasses seem too massive to control. Pioneers felt more comfortable with trees and felt land that grew only grass was inferior. They mistakenly reasoned that if there wasn't enough rain for trees, then there wouldn't be enough rain for crops. They avoided the "Great American Desert." Some historians felt that the Native Americans of the prairies were more feared than Native Americans of the woodlands and this feeling contributed to the slow acquisition of the prairies.

Other practical factors entered into the matter: few navigable rivers, the different prairie soil did not respond to the plows available, few railroads extended into the prairie, settlers often did not own enough horses and mules, and few available trees for building homes, fences, tools and fuel. So, much of the tall-grass prairies was given away. But with a poor understanding of the growth habits of prairie grasses, and the inability to predict the response of these grasses to overgrazing, immense areas of the medium and tall grass prairie regions were seriously degraded within 50 years. Medium grass prairies often reverted to short-grass prairies because the latter grasses were more tolerant to intensive defoliation.

The terms tall-grass and short-grass typically refer to native range species, all of which are perennial types. Introduced species that are now very common, such as perennial ryegrass or tall fescue, vary widely with respect to height. Some are suited for turf while others for forage purposes. Therefore, the tall-grass and short-grass terms are used in more of a historical sense.

Cool- (C_3) and warm-season (C_4) Grasses

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*.

Sunlight
Carbon dioxide (CO_2) + water (H_2O) -> carbohydrate (food) + oxygen (O_2) green plant material

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 approximately 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*.

The C_4 photosynthetic system found in warm season grasses 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 plants. C_4 plants may use up to 50% less water to produce a unit of dry matter. 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. In contrast, warm-season grasses which start their growth in late spring generally have a favorable soil moisture profile in early summer.

There is no "all-season" plant available. Producers must recognize the limitations of plant seasonality and take advantage of the variation in grasses. Incorporate both cool and warm-season pastures to provide a longer grazing in climates with a hot period during the summer.

C_4 plants are also more efficient in nitrogen utilization. Warm-season plants recover more N from a given amount of available soil nitrogen than the cool-season plants due to increased soil microbial activity in the summer. In contrast, 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 better to fertilizer under humid climates.

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 may become dormant early in the fall.

These physiological factors also 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. Normal reduction in cool-season growth and quality during the summer is an important factor in grass utilization. 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 a good strategy.

Carbohydrates in Grass Growth

The main function of a grass plant is to utilize sunshine to make food (carbohydrates). Carbohydrates are needed during the growing season when the plant must maintain itself, to continue growing after defoliation or dormancy, and for maintenance during the winter. The perennial plant must survive winter and renew growth in the spring. Carbohydrate storage organs become extremely important when they are the only available source of energy. Carbohydrate storage organs include stem bases, roots, rhizomes and/or stolons.

Grass plants can utilize the sun's energy only during daylight. When the leaves produces more carbohydrate than is needed for growth and maintenance, some of the production can be shipped (translocated) to the storage organs. When production is insufficient to meet the demands of the plant, the stored carbohydrates are called on for continued growth. This situation causes no problem unless the stored carbohydrates are depleted.

Growth has priority over storage for carbohydrate use. This is why uncontrolled grazing can totally deplete a plant's stored carbohydrates. As grazing managers, 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.

Proper grass management must consider the demands of growth and their impact on stored carbohydrates. And, even when there are sufficient carbohydrates, the growing points must remain intact to utilize them.

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*. It also decreases when the plant is defoliated and there is demand for energy to support growth of new shoots.

Carbohydrate storage increases when:

- Leaf area is more than adequate to meet growth demands.
- Growth rate is slow (cool autumn temperatures).

Carbohydrate storage decreases when:

- Leaf area is inadequate to meet growth demands.
- Growth rate is rapid (spring).
- Carbohydrate reserves are depleted.

ENVIRONMENT

This discussion of grass growth and regrowth assumes a suitable environment for plant development. Grass growth processes will not follow the stages described in this project when insufficient water, infertility, or other environmental factors stress the grass plants. When grass growth is stunted in some way, forage managers need to look at possible factors to determine what is lacking. Grass has been described as the healing balm for the wounds that Mother Nature suffers at the hand of mankind. Grass is very resilient and amazingly versatile, but growth and production is greatly affected by environmental factors. Unlike legumes, grasses cannot fix nitrogen from the atmosphere. Nitrogen, potassium, and phosphorus are critical for grass growth. Other elements are also needed. Adequate and timely water will directly influence yield. Flooding and fires often will not eradicate grass and may have long-term positive effect but they will minimize seasonal production. Adequate drainage also is important. When studying about grass growth and subsequent regrowth after mowing or grazing, consider the environmental influences.

The influence of day length, temperature, vernalization, adaptation, tolerance to flooding, drainage capacities, heat, drought and frost all have impact on how a grass will grow and regrow. Each of these topics is a study in itself but, for now, awareness of their impact should be helpful in management decisions.

Grasses are broadly classified as summer annuals, winter annuals, or perennials. There are no biennial grasses. The intended use dictates which group is most suitable for a given situation.

Annuals

Annual grasses are represented by the major grain crops (corn, sorghums, wheat, rye, barley, oats), and by many weedy types which infest fields and pastures. Broad categories include:

1. Winter annuals: cool-season species which germinate in late summer or fall,
2. Summer annuals
    1. Cool season species seeded in the early spring, and
    2. Warm season species seeded in late spring or early summer.

Annuals complete their growth cycle in a single growing season and reproduce only by seed whereas perennial grasses reproduce vegetatively as well as by seed. Seeds represent the major storage organ for excess photosynthate. With no storage organs, such as rhizomes, stolons, or tubers, there is no means for vegetative reproduction. Annuals usually grow back after mowing or grazing. Regrowth arises from buds found on the lower nodes of the stem. This type of regrowth is called aerial branching because the new shoots arise from adventitious buds on stems as opposed to basal buds in the crown zone. Aerial branching is an efficient regrowth mechanism. For example, annual ryegrass and Sudangrass, which exhibit this growth habit, can be grazed several times during the summer. Many weedy grasses are noted for their ability to recover from defoliation. Their control usually involves use of selective herbicides.

Winter Annuals

Winter-hardy varieties of common cereal grains are planted in late-summer or fall, sufficiently early to allow seedlings to develop a crown and produce winter-hardy shoots (tillers). With resumption of growth in the spring, additional tillers are produced. With environmental conditions favoring floral induction, the shoot apex of each tiller produces a floral bud. The developing seedhead becomes a storehouse for sugars not needed to support further vegetative growth. As with annual grasses, winter annuals do not develop organs for storing food reserves; therefore, with advancing maturity the plant becomes senescent and dies.

Winter-annual cereal grains are often harvested for hay or silage when seedheads emerge from the boot. As seedhead development is disrupted, new tillers may arise from lower stem nodes as previously described with annual grasses. This recovery growth may represent an important source of forage.

There are several winter annual bromegrasses that are troublesome to many forage managers; hairy chess, downy brome, and cheat. Proper management can serve to reduce these unwanted species.

Summer Annuals

Summer annuals are species that are planted in the spring and complete their growth by the autumn. Summer annuals can be cool season or warm season. In northern latitudes, where cold temperatures threaten winter survival of fall-seeded cereals, growers select cultivars that are adapted to spring seeding (for example: spring wheat, spring oats, and spring barley). When seedheads ripen in early summer the plant becomes senescent and dies. However, if seed head development is disrupted by grazing or mechanical harvesting, further growth may follow due to aerial branching.

Forage type sorghums and millets (including the weedy types) represent warm-season annuals. Seed germination is favored by relatively warm soil temperatures, thus maximum vegetative growth occurs in late spring and early summer. Again, if seedhead development is disrupted, regrowth arises by virtue of aerial branching where new shoots arise from buds located in basal stem nodes. Sudangrass, related forage sorghums, and various millet cultivars provide mid-summer growth for managers who wish to calendarize their grazing systems.

Biennials

Biennials are plants that take two entire seasons to reach the reproductive stage. The first year is a time for accumulating food reserves in storage organs. The second season produces reproductive flowers and seeds. This is in sharp contrast with winter annuals which germinate in the fall and die the following season when seeds ripen.

There are no true biennial grasses. Nevertheless, in some climate zones, species like annual ryegrass may behave like a biennial, producing forage for two seasons when planted in the spring.

Although there are no biennial grasses, there are biennial forage crops. These include the Brassica family (turnips, rape, kale, etc.) and some legumes such as sweetclover (*Melilotus* spp.).

Horticultural root crops, such as beets, carrots, and parsnips, some vegetables like onions and cabbage, and some ornamental shrubs like hollyhock, are true biennials.

Perennials

Perennials are plants that continue to grow indefinitely or that regrow each year. Most of the commonly used forage grasses function as perennials, reproducing vegetatively as well as by seed. With perennials, vegetative reproduction involves development of winter-hardy crown tissue which contains buds and tillers that resume growth with the onset of spring temperatures.

Short-lived Perennials

Forage grasses which perenniate for 3-5 years are typically referred to as short-lived perennials. Perennial ryegrass is an example of a short-lived perennial forage grass. However, any perennial that is mismanaged will be short lived.

Life Cycles of Common Forage Grasses

The following are examples of annual and perennial grasses:

Annuals: annual ryegrass, annual bluegrass, pearl millet, corn, and sorghum / Sudangrass.

Perennials: orchardgrass, tall fescue, perennial ryegrass, Kentucky bluegrass, smooth bromegrass, meadow foxtail, timothy, colonial bentgrass, bermudagrass, reed canarygrass, wheatgrasses, big bluestem, switchgrass, and Indiangrass.

Practical Implications

Annuals

Annual species are by nature short-lived plants and must be planted each year. Most are planted in the spring. Winter annuals are planted in the fall, early if you want fall grazing or greenchop feed.

Winter annuals such as wheat, rye, winter oats, and winter barley are cereal gain crops, however, they can be used as cover crops or as nurse crops for new seedings of perennial grasses and legumes.

Cover crops vs companion or nurse crops

A cover crop is typically seeded in the fall to prevent erosion during the winter and to add organic matter to the soil. The cover is normally plowed or otherwise tilled into the soil in the spring prior to planting a crop such as corn, soybeans, vegetables and such. When tilled into the soil, cover crops may be called green manure crops-being used to improve soil fertility. Cover crops follow a crop. Companion or nurse crops are used concurrently. When used as a companion crop, the winter annual is seeded in early-fall together with a perennial grass and legume. The following spring, the companion crop is cut for hay and silage and the perennials species takes over.

Perennials

Perennials have more uses. In crop rotations the sod crop may be plowed after only two or three years. With livestock as the major enterprise, the intent might be to maintain the sod for an indefinite period, to be reseeded when the desirable species disappear. Optimal management suggested by this project includes prompt, high regrowth rates after defoliation, and extended pasture life.

Grass Growth

How grass grows is only part of the secret to better management. Grasses can be most productive when clipped by mowers or bitten by animals. The word defoliation comes from "folium," Latin for leaves. So the word itself is a great reminder that leaves are the primary target when harvesting grass. And the term defoliation assumes those leaves will be removed prematurely (not as a result of death).

Defoliation can be productive or destructive. There are several areas where plants grow (roots, leaves, culm, rhizomes, stolons, and crown). But regrowth from the leaves is most important for efficient regrowth after defoliation. For optimal regrowth following defoliation there must be cell division and expansion in certain meristem systems. Knowledge about the location and specific function of these meristems is critical for successful forage management.

Meristem systems

1. Apical meristem: the apex (primordium, growing point) of a shoot or tiller eventually produces leaves, stems, and seed heads.

2. Intercalary meristem: located where a leaf blade (lamina) joins the sheath, represents the collar of a grass plant. The intercalary meristem accounts for the increasing length of leaves and sheaths.

3. Shoot or tiller: a cylindrical bundle of relatively immature leaf blades enclosed by sheaths or more mature leaves. Leaves are formed from successive layers of cells in the apical meristem.

4. Basal buds: shoot initials in crown tissues which develop into new tillers (recovery growth) when defoliation destroys the growing point of the "mother" shoot.

Successful regrowth after defoliation will depend on productive meristem systems.

Grazing affects grass growth/regrowth differently than mowing. Mowing can often cut too low and completely, but can be used wisely to encourage certain regrowth mechanisms. Grazing livestock are more selective. They don't defoliate as low or completely, and are players in the plant-soil-animal continuum. Each animal species interacts differently with plants and each plant species responds differently to the grazing habits of the animal. Careful attention to this interaction will help forage-livestock producers be more successful. Plant-animal interaction will be presented with a discussion on defoliation and some general keys to grazing management.

The net effect of defoliation can be either detrimental or beneficial. Often discussed is the severity of defoliation, characterized by grazing height, frequency, duration and rest interval, but the critical issue is: "What growing points must remain for productive regrowth?"

Proper defoliation can increase total production. If a grass is allowed to head out and only harvested once at the end of the growing season as is done with grain crops, the total yield will be much less and quality will be lower than if it is harvested several times during the growing season. If harvesting considers plant requirements (i.e. water, fertilizer, height of cutting, frequency, etc.) the forage is maintained in an active growing and tillering phase longer than if allowed to mature naturally. As long as the plant is vigorous and an active growing point remains, forage production can continue. Forage production will decline as the plant nears fall dormancy. Consequently, the goal of grazing management is to maintain the meristems in an active growth phase under the most suitable conditions for as long as possible and then provide conditions for retillering and/or carbohydrate storage.

The degree of defoliation during the growing season should be designed to allow enough leaf area to remain to provide carbohydrates for regrowth rather than using stored carbohydrates. Previously, defoliation during the early stages of growth was thought to be most detrimental because root carbohydrate reserves are lowest at that point and regrowth required a major draw of carbohydrates. However, vigorous plants have a great capacity to replenish carbohydrate reserves during the season of peak growth. Consequently, severe defoliation during the late part of the growing season is more detrimental than early season defoliation followed by rest. Late in the season environmental conditions do not favor the rapid growth observed in early season.

Energy reserves increase in crowns during the latter part of the growing season and buds for next year's tillers develop. Consequently, severe defoliation near the end of the growing season will reduce the production of crown tissue and cause a decline in forage production the following year.

Generally, plants are not capable of supporting rapid growth in their shoots and roots simultaneously for an extended period of time. If pastures are grazed severely, root growth stops and roots may die. If overgrazing continues, the grass has little leaf area to carry on photosynthesis so the plant is low in energy. Leaf growth has first call on carbohydrates from photosynthesis so there is no downward movement of carbohydrates for root growth. Roots then die and the plant has only enough energy to maintain a shallow root system. The result is a pasture that is much more susceptible to stress conditions such as dry weather and weed infestation. Even if plants stay alive, there may be enough open ground for weeds to establish if they have little competition for light. This whole process accelerates as unfavorable conditions increase. The pasture begins to deteriorate as desirable pasture plants are replaced by plants that are of low palatability and avoided by livestock or require less in regrowth.

The grazing animal can be used to alter pasture composition. Coordinating the natural selectivity of livestock with the period of active growth of undesirable species is a very useful management tool. Many times shifts in species composition are the result of mismanagement. However, knowledge of plant growth and animal behavior enables the producer to cause a desired shift rather than be a victim of an undesirable shift. For example, if a cool-season grass is invading a warm-season pasture, the cause could be heavy grazing in the summer with little or no spring or fall grazing. This grazing management scheme would favor cool-season grasses and harm warm-season grasses. A possible alternative that would shift the species composition back towards warm-season dominance would be intensive grazing in the spring and fall and non-use or limited use during the summer for a year or two. Legumes and grasses can be kept in good balance when grazing management is designed with the growth and regrowth of each in mind.

A livestock producer must visit his pastures frequently, to not only check the livestock, but also to check on the grasses. Anticipate what is happening with the grasses and correct any potential problem before it is apparent in reduced livestock performance.

Keys to Successful Grazing Management

Perennial forages are a renewable resource. They don't require planting every year and grow with predictable annual cycles. With the basic understanding of how grasses grow, knowledgeable adjustments in grazing systems can enhance grass growth. Here are some key points:

3. Bud and carbohydrate management: Buds are formed during the season prior to winter dormancy. Carbohydrates are stored late in the growing season. Consequently, fall management is a critical period and adequate time should be provided after grazing and before dormancy for carbohydrate accumulation and bud development to ensure an over-wintering reservoir.
4. Remaining leaf area management: Adequate remaining leaf area (residual dry matter) will minimize plant dependency on carbohydrate reserves. This will insure continued root growth and carbohydrate storage for winter. Remaining leaf material also enhances the microclimate for growth during the growing season and improves rain interception, insulation, and snow capture.
5. Defoliation: Optimum grazing management avoids repeated, severe defoliation of a tiller without a recovery period (planned non-use). This recovery period is often call a "rest" but that gives an impression of little growth occurring. In reality, the grass is productively preparing for more growth. Fresh growth is highly palatable and livestock will graze selectively. Therefore, the duration of livestock occupation must be controlled to optimize plant and animal production. Repeated severe defoliation of desirable plants or areas in pastures can be reduced by decreasing stocking density and reducing the duration of grazing.
6. Tiller management: Since grasses are more productive with defoliation, timely canopy removal can be used to stimulate tillering (regrowth). This will be dependent on the species, environment, and previous management.
7. Livestock nutritional needs: To optimize animal performance (gain/head) and pasture production (gain/acre), the duration of non-use is critical. Non-use periods should be long enough to allow the plant to recover from defoliation, but short enough to avoid plant maturity when pastures are used more than once per season. Successful grazing management must also consider the type of livestock and their nutritive needs. Producers must match the nutritive needs of their livestock and management goals for livestock performance with the seasonal quality of available forages.

8. Grazing program: Appropriate grazing management will be dependent on the individual operation. Controlled grazing programs allow stocking rates to be sustained at higher levels compared to continuous, season-long grazing because of improved harvest efficiency. Grazing distribution, season of grazing, and degree of use must all receive emphasis in the grazing program. On occasion, it may be necessary to intensively graze a pasture late in the season. If the grass has been properly managed in previous years, it will recover from this late season grazing; however, the same pasture should not be the last pasture grazed the following year.

Successful livestock production cannot be accomplished by ignoring either plant or animal requirements. It will require several kinds of forages, several pastures, and a grazing plan. Understanding where and how forage plants grow is the best way to utilize several kinds of forages. Remember, not all grasses grow and regrow in the same manner.

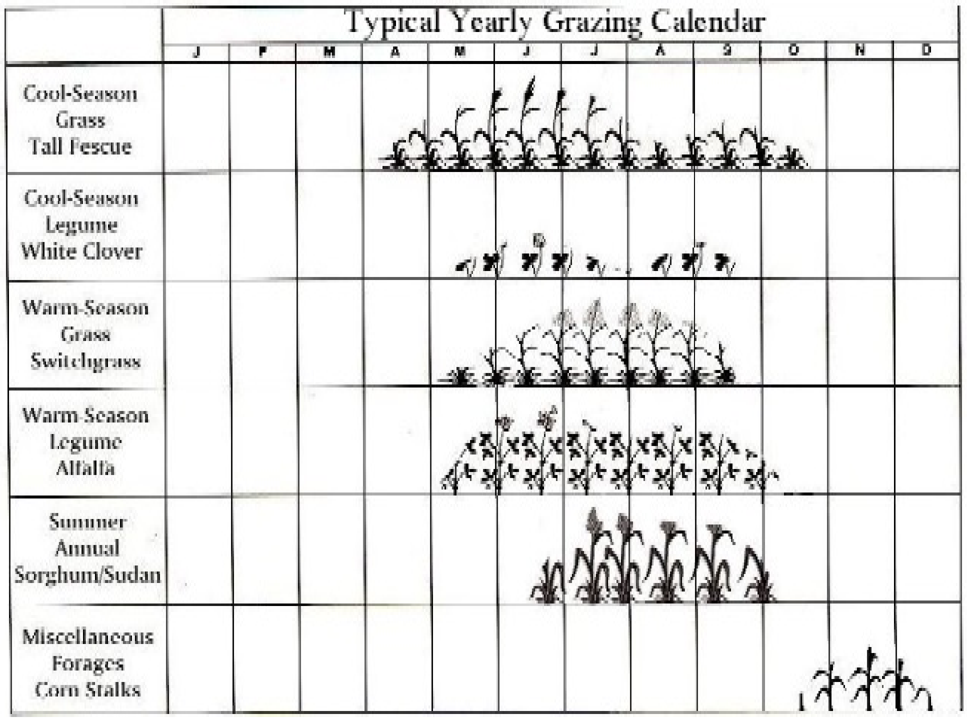
Understanding the growth/regrowth habits of an individual grass easily translates into management decisions. However, when different grasses or grass/legume combinations are growing together, which may result from planning or from weed infestation, the management decisions require more strategy.

Advantages of Mixtures

The advantages of mixing a grass and a legume center on utilizing the best qualities of each. A mix may:

- extend the growing season of a pasture
- improve the quality of forage
- reduce nitrogen fertilizer requirements due to legume's nitrogen fixation capacities
- prove more adaptable for a wider range of conditions
- improve flexibility to survive environmental conditions
- reduce susceptibility to insect and disease attacks

Here is a graphic depicting a probable pasture production profile for various forages in the northern hemisphere. As you can see, there are times when other feed will be needed. Utilizing another grass or legume that flourishes during the less productive periods extends the season of production and maintains the quality of feed.



The above graphic depicts a simplistic growing season of an area with the traditional four seasons. Growth patterns will vary in areas with different climates.

Mixtures can improve the feed quality. Legumes typically have a higher protein content than grasses. Growing animals have a high protein requirement that can be met to a large degree by adequate legumes in the forage mix. Furthermore, the palatability and digestibility may also be improved with legumes. If hay or silage making is the goal, the thoughts of using mixtures should consider those species that can harvested at the same time.

Planting a legume with a grass does not mean all nitrogen fertilizer needs will be met. However, grasses can eventually benefit from being planted in soil where legumes fixed atmospheric nitrogen.

A mixture of species in a pasture can adapt to a wider range of conditions. Some species tolerate wet conditions, some dry, some acid, and some alkaline or sodic soils. Mixtures provide some insurance to unexpected conditions or a variety of conditions which may occur in a single pasture.

A rule for mixtures is "remember simplicity." A large number of species in a mixture, sometimes called a "shotgun" mixture, should be avoided. Often a single grass and a single legume will best provide the benefits intended. A simple mixture means a producer can know how each species grows and regrows. Then management decisions reflecting that knowledge can lead to successful yield, quality, and persistence.

Although much of this project assumes that livestock will be defoliating the grass plants, the art of timely mowing can result in more than simply harvesting for hay or silage. Mowing is a critical management practice in optimizing forage production from pastures. Mowing is different than grazing in two ways: 1) mowing usually results in a uniform cutting height and 2) the height can be predetermined. Since the mower can be set for a particular height, understanding how grass grows and regrows should guide that height decision.

Mow the grass at a height that is advantageous for grass regrowth mechanisms and for stand longevity. Mowing can achieve at least two basic purposes: 1) it can keep a majority of tall growing weeds from going to seed, thereby reducing weed problems in the pasture, and 2) mowing can keep grasses in a vegetative state longer, where leaf surface area will be maximized and the plant will not produce a seed head. Under an intensive rotational system, where large numbers of livestock are pastured on relatively small paddocks for short periods of time, little mowing will be required. With less intensive rotational programs or continuous grazing, more mowing will be required as livestock have the opportunity to selectively graze various plant species. Mowing should be done immediately after livestock are removed from the pasture. Mowing off tall, uneaten plants will stimulate new growth. Clipping a pasture as seedheads emerge can redirect plant energy from reproductive growth to other areas. Set equipment to leave 3 to 5 inches of growth for tall grass species like orchardgrass and tall fescue, and 2 to 3 inches for low growing species like bluegrass pastures.

"Topping your pastures" may be very beneficial and is discussed in section V of Management Scenarios in the Management section of this project.

ANIMAL HABITS

Grasses and other types of forage are consumed by all classes of domestic animals and many classes of wildlife. Grazing animals, however, differ in their grass consumption habits. Dog foods contain some grains (from annual grasses); poultry rations contain some grain to supply vitamins, minerals, and proteins; and swine may consume some forage grasses. But it is horses, goats, sheep, and dairy and beef cattle that may get all their feed from forage. The differences in how much and what is consumed result from the different digestive systems and abilities to handle food containing cellulose and lignin. Cattle and sheep have advantages for utilization of forages over single-stomach animals. It is also important to look at how different animals chew their food and interact with a pasture to really understand how to best utilize the growth and regrowth of grasses. Palatability and digestibility of grasses will be discussed in the animal consumption section, followed by the chewing habits of the main forage livestock, as well as the effects of trampling of grass plants by livestock, and the effects of pasture fouling by urine and manure.

Cows

As heavier animals, cows can inflict more damage onto a pasture than lighter animals such as sheep. Wet pastures are less able to bear the weight of the cow and wet pasture is more damaged than if it had been a dry field. While cows feed on the grass on the other side of a fence, they usually trample the area around the fence.

Horses

Like cows, horses are heavy animals. They tear up wet pastures easily; grasses are no match for their shoed hooves. Horses are often left outside during the winter causing their pasture to be badly damaged or transformed into mud and muck.

Sheep

As lighter animals, sheep do not cause as much trampling but they can over-graze and extensively damage pastures.

Different animals select, bite off, and chew plants differently. Each animal type has a tool or set of tools that help them gather food (prehension), grind it (mastication), and swallow (deglutition). Pigs use their snout to get the process started. Poultry scoop up food bits. This section discusses the main livestock involved in forage production, beef and dairy cows, horses, sheep, and goats. Forage-livestock managers should consider the differences in livestock chewing in establishing grazing programs.

Cows

Equipped with a long and dexterous tongue, the cow can wrap its tongue around plant parts and pull the food into its mouth where it is placed between its lower jaw and a pad on the upper surface. Once in the mouth, the cow swings its head to severe the plant parts and chews the food slightly, and mixes it with saliva before swallowing. Later the cow will regurgitate the food to chew and grind it again. This process is called rumination or chewing the cud. The actual chewing portion of a cow's day consumes eight hours and ruminating takes about 12 hours. Cows can take around 890 bites per hour for about 8 hours a day. Due to the design of the cow's lips, teeth, and jaw a cow can't easily get closer than 2 inches from the soil. An ideal height of grass is about 6 inches, higher or lower than that will consume more time and energy for the cow. Cows will not graze much longer than 8 hours, so grass at the proper height will increase intake and improve animal nutrition. Cows also prefer not to eat around their own paddies but are willing to graze after a different type of animal has defecated. Cows like to graze on rolling land, although they are able to graze anywhere.

Horses

A horse will eat more often than a ruminant animal because it doesn't spend time ruminating, but it will eat a smaller amount per session because its stomach is smaller on a per body weight basis. Horses have upper and lower sets of front incisor teeth used primarily for biting while the back set of molars are used mainly for grinding food. A strong, sensitive, upper lip gathers the food and brings it to the incisors. Its short tongue is less essential to the eating process. The upper teeth are wider which causes wear on the teeth from grinding and sometimes there is a need for their teeth to be filed. Horses can graze a pasture to the soil level because the teeth and head can get so close to the sod. They tend to section off their pastures into eating and spoiling areas.

Sheep

While cows may best utilize their tongue, sheep use their lips and teeth as their primary forage gathering tools. Cleft lips move away from their teeth on the lower jaw and help bring food in, while the upper jaw has a dental pad that is about 1.6 inches wide. Together, the teeth on the lower jaw and the pad on the upper jaw sever the leaf blades. Such a mouth structure allows sheep to bite closer to the ground than cows and the ability to be more selective. The ideal grass height for sheep is about 4 inches.

Both cows and sheep are ruminant animals which mean they have four stomachs through which they cycle feed. This requires time for rumination or the regurgitation of the bolus that was made from bites of forage and rechewing, preparing for easier digestion. So, cows and sheep need time for both eating and ruminating. Maximum efficiency is achieved by providing abundant forage at an optimal height.

Goats

Much like sheep, goats also have teeth on their lower jaw and a strong dental pad on their upper lip. The upper lip is incredibly mobile and with the help of a strong tongue, goats can selectively grab and are able to avoid thorns and spines. Goats select woodier browse and will choose young, tender leaves and twigs, before grasses and legumes. Thus, young trees will need to be protected in agroforestry systems.

Just as livestock performance is conditioned by the quality and quantity of feed consumed, the excrements of such feed stuffs, when distributed over the pasture, influence the productivity of the pasture.

Urine and manure are effective sources of fertilizer when added to the soil. Uneven distribution, however, causes varying effects on plant growth. Some spots receive excessive amounts while others suffer from low fertility. Under intensive grazing management, manure is more evenly distributed. In addition, pastures can be dragged to reduce spot grazing.

Cattle defecate 11-12 times daily and urinate 8-11 times daily, with more dung being excreted at night than during the day. Dung pats cover less than 2.95 square feet and urine patches 0.98 to 1.31 square feet. Even though excreta may be beneficial, only a limited area is covered, particularly in open ranges where it is concentrated near sources of salt and water or near shade. Urine deposits will provide concentrated N and K which stimulate grass growth but benefits are governed by rainfall and temperature. Dung provides N, P, Ca, and Mg and is often buried into the soil within 4-5 days by dung beetles. Without the beetles, dung deposits may remain for 3-12 months in warmer climates. Livestock may readily graze urine spots but usually avoid the odor of dung deposits and eventually the less palatable grass plants that have matured there. This justifies dragging (a method of spreading manure) and intensive grazing.

Although most of the pasture is not greatly affected by excrement, managers can use this knowledge in determining traffic lanes, water locations, salt availability, day/night paddocks, and fertilizer needs.

Palatability is the preference an animal has for a particular feed when offered a choice. Palatability only matters when there is a choice of food for the livestock. It is affected by texture, aroma, succulence, hairiness, leaf percentage, fertilization, sugar content, and other factors. Just as humans tend to eat more at a dinner of delectable specialties, livestock will eat more if the palatability is high. Animal performance is not solely based on palatability, even though it is a significant factor. As a basic rule, grass is more palatable to animals when young, tender, and leafy. As the flowering stems mature, the roughage becomes less palatable. Forage plants have two basic components: cell contents (protein, sugar, and starch) and structural components of cell walls (cellulose, hemicellulose, and lignin). Cell wall components govern the rate of digestion and therefore the rate of intake. The cell wall components are less palatable and livestock will choose the younger plants. This concept is important because young grass plants need enough time and growth to have enough leaves, the basic site for photosynthesis. Some have likened the surface area of leaves to the square footage of a warehouse. The more leaves, the more production. So livestock selectively nibbling off the new leaves can be detrimental. From the plant's perspective, grazing is least harmful at maturity. But from the animal's vantage point, grazing immature plants is favored since both palatability and digestibility are better. Wise forage-livestock managers plan their harvesting, grazing or mowing, to balance the best quality feed with the best regrowth opportunities of the plants.

Livestock will avoid plants near dung deposits, first because they are malodorous and later because the plants have had time to mature and are then less palatable. Plants in urine spots are not usually avoided because the urine is quickly volatilized (vaporized) or leached.

Managers help meet livestock demands by calendarizing their pasture systems using separate areas for cool and warm season species. Variation in seasonal productivity provides a source of high quality pasture for spring and mid-summer grazing.

To a young grass seedling, the size and grazing habits of the livestock on a pasture can mean total destruction. Every pasture will experience the loss of plant material because the plants could not survive the traffic of livestock. Certain species are more sensitive to trampling. Stage of maturity also influences the effect of heavy traffic. Livestock size also is important. Trampling, or treading as it is termed in some references, damages pastures of all soil types, soil moisture levels, plant species, or livestock species. Forage yields are reduced most when animals are allowed to graze plants on wet soils. Trampling is more detrimental on clay soils than sandy soils. Shorter forage may be more damaged than tall forages if the stand is not well established, and trampling promotes more prostrate than erect growth. And, of course, trampling packs the soil which reduces the moisture infiltration into the soil.

The above information can lead a manager to consider what species will best tolerate livestock traffic. Then grass growth and regrowth concepts can be applied to the specific grazing system. For example, perennial ryegrass and white clover mixtures are more tolerant of trampling because of the prostrate growth habit of white clover than a mixture of orchardgrass and red clover, an upright clover. Reed canarygrass can be very resistant to trampling if managed properly. Switchgrass and big bluestem are flood tolerant warm season grasses. Cross fencing might also be considered if pastures have some sloping areas that could be saved for rainy periods.

Grazing/Recovery Times

A grazing/mowing trial with smooth bromegrass and Ladino clover was designed to study the relative importance of two variables: the length of the grazing period and the length of the recovery period. Twenty different grazing systems were studied. Grazing periods of 2, 4, 8, and 16 days were compared on paddocks designed with grazing intervals of 8, 16, 24, 32, and 40 days. The stocking rate of yearling ewes was adjusted daily to ensure the desired degree of defoliation. The area of each paddock was calculated on the basis of the predicted growth rate of the forage, and with the digestible nutrients required by two ewes for each of the assigned grazing periods.

On the first day of grazing a paddock, a companion plot in an adjacent area was mowed, leaving a 2-3" stubble. This intensity of defoliation was likewise the goal for grazed paddocks; however, it was seldom achieved. The mowing interval for the companion mowed plots equaled the sum of days grazed plus days' rest.

The premise was taken that in any grazing system, the paddock most representative of the system would be the one grazed in the middle of the cycle. Thus, the prescribed treatments were deferred from "time zero," taken as April 30, for a period equal to one-half the total number of days in the cycle (grazing plus rest). This decision introduced an important variable; however, it was not considered important when the trial was designed. Imposing the initial grazing and mowing treatments at successively later dates provided the opportunity to study the effects of defoliation at different developmental phases of smooth bromegrass. Further, the sharp contrast in rates of grass recovery following grazing versus mowing, revealed that at certain growth stages, mowing destroyed vegetative meristem systems that were spared in grazed plots.

Lessons Learned

* **Early-spring management precautions**

With many cool-season grasses, the main goal of offering livestock an "early bite," while grass shoots are still in the vegetative stage of shoot development, is to ensure prompt competitive recovery of the desired species. Prompt regrowth depends on the degree to which the shoot apex (active above-ground meristem system) is safeguarded.

At "early-jointing," corresponding closely with the transition stage, the shoot apex should be considered to be the chief mechanism for regrowth. It is easily found at the base of a shoot by splitting the shoot lengthwise. The shoot apex (growing point) contains the rudimentary seedhead and undeveloped nodes and internodes of the central stem (culm). Nodal tissue includes meristematic zones which account for leaf sheath and leaf blade development. It is self-evident that the growing point, together with the associated meristem, represents a critical zone on the grass shoot.

Grasses which are prolific seed producers, having a high percentage of flowering shoots, are particularly vulnerable to mismanagement at the early-jointing stage of stem development because many of the shoots may be either denuded (leaves severed below the collar zone but above the shoot apex) or decapitated (shoot severed below the shoot apex). A denuded shoot will have a seed head but perhaps only a portion of the flag leaf, whereas with decapitation, no vegetative system remains. The grass must recover from new shoots arising from basal buds in the crown system. Thus, it is wise to avoid close grazing during transition until basal sprouts in crown tissue appear to be ready to produce aftermath shoots.

In this experiment, initial treatments were imposed on certain paddocks during the first week in May. Internode elongation had commenced in bromegrass shoots. The ewes grazed slightly above the growing point but below the collar zone of May leaf blades. Consequently bromegrass recovery growth consisted chiefly of naked (denuded) flower stems with poorly developed seed heads. When ewes returned to paddocks having long rest intervals, they found the recovery growth to be unpalatable. Ladino clover was dominant because of minimal grass competition.

In sharp contrast, plots that were mowed, leaving a 2-3" stubble, recovered from new shoot initials in crown tissue since the growing point of essentially all of the shoots were destroyed. Recovery was severely delayed because, in early May, aftermath shoot initials are not well developed. Slow recovery allowed clover, broad-leaved weeds, and weedy grasses to flourish. Grazing would have produced a similar effect had the stocking rate been heavier, forcing the ewes to take a second bite of the remaining stubble.

When the comparative effects of mowing and grazing are evaluated, it is essential to take careful note of the condition and vulnerability of regrowth mechanisms so as to avoid the ill effects of untimely denuding and/or decapitation of grass shoots. The treatment effect imposed by undergrazing should be similar to the effect imposed by clipping.

* **Mid-spring management precautions**

When bromegrass (and other susceptible "jointed" grass) shoots approach the late boot to early heading stage, livestock numbers should be increased to ensure that the available forage will be consumed in a timely manner. Once seedheads appear, forage quality and palatability decrease rapidly. Ungrazed seedheads should be clipped to encourage regrowth from shoots in the crown.

* **Aftermath shoot management**

With smooth bromegrass, aftermath shoots tend to produce culms with distinct internodes after approximately five weeks recovery. This growth habit raises the growing point of the aftermath shoot to a vulnerable position. Without exception, close grazing or clipping destroyed the growing point of a high percentage of the shoots resulting in varying degrees of summer dormancy and weed invasion. Longer rest periods provided for the development of new shoot initials in the crown zone. Summer dormancy was not a problem with these systems. Paddocks grazed prior to culm development (24-day rest interval) continued growth, however, subsequent grazing events were untimely with respect to the location of the growing point and summer dormancy followed.

This experiment exposed the risks involved when the grazing-rest intervals are fixed, as opposed to being flexible, where grazing pressure and/or degree of defoliation are adjusted according to the vulnerability of meristem systems which will account for recovery growth.