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Skillful Grazing Management on Semiarid Rangelands

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Introduction

An acre of semiarid rangeland may contain more than a million grass tillers, most of which will die back to ground level by the end of the growing season in October. Understanding the annual processes of repopulation and seasonal growth patterns of common rangeland grasses is the cornerstone of skilled grazing management.

Semiarid conditions generally occur where annual precipitation ranges from 10 to 20 inches and evening air temperatures are measurably lower than daytime temperatures during much of the summer. The western half of Nebraska is semiarid with a relatively wide transition zone in central Nebraska between consistently semiarid and consistently sub-humid areas. Semiarid regions are characterized by dynamic year-to-year variation in the timing and quantity of precipitation and the ever-present risk of drought.

Skillful grazing managers use their knowledge of grass growth to select grazing systems and to make year-to-year changes in pasture-use sequences that minimize cumulative effects of grazing and drought stress. They optimize the vigor and forage production potential of their rangeland grasses in pre-drought years, which is "Phase I" of every effective drought management plan. When drought occurs, critical dates for reducing stocking rates in the next phases of a drought management plan correspond to **rapid-growth windows**, 30-day intervals during which codominant grasses normally grow most rapidly. There is little hope of measurable yield response to rainfall after drought has continued into the midpoint of these rapid-growth windows. Skillful grazing managers use the concepts in this publication to improve the profitability and longevity of their range livestock enterprises.

Repopulation

A **tiller** is the smallest stand-alone unit of a grass. Basic components of a tiller include a shoot, a crown and roots *(Figure 1)*. Tillers originate from vegetative **buds** that develop on the crowns *(Figures 2a and b)*, stolons *(Figure 3a)* or rhizomes *(Figures 4b and d)* of intact or parent tillers, or from seed. When tillers originate from seed, the process is referred to as sexual reproduction because the seed is produced by male and female floral parts. In contrast, repopulation from nonfloral vegetative buds on existing plants is asexual or vegetative reproduction. Genetic information needed for the growth and development of all plant parts is contained in **meristematic tissue** in seeds and buds.

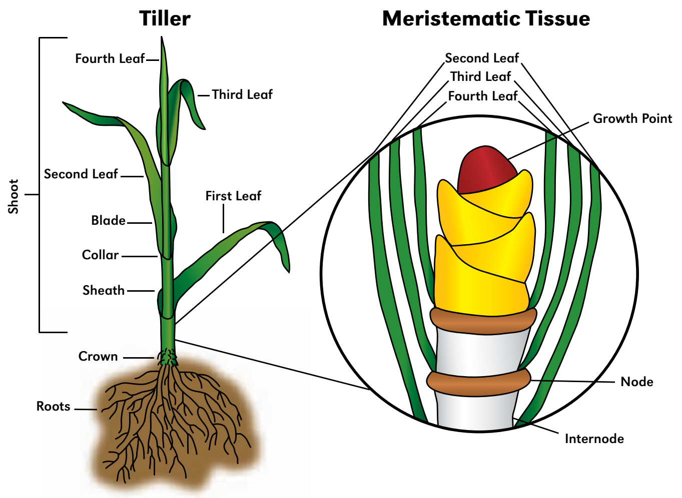

Figure 1. Form and structure of grass tillers (modified from Manske 2004).

Grass seed production on semiarid rangeland is limited by timing or quantity of precipitation in most years. When viable seed is produced, much of it is consumed by birds, small mammals, or invertebrates such as ants or beetles. Species diversity and quantity of viable perennial grass seed in the top soil of rangelands are amazingly low. **Consequently, year-to-year replacement of grass tillers primarily depends on the production and survival of vegetative buds.** Additionally, roots produced by previously established tillers and carbohydrates from parent tillers greatly enhance survival and growth of tillers from vegetative buds compared to seedlings. Few perennial grasses become established from seed on rangeland.

When growing conditions are favorable and plants are not overgrazed, perennial grasses produce new buds every year and supply energy needed to maintain preceding-year cohorts of dormant buds. Generally, only a portion of the buds in perennial grasses break dormancy and develop into tillers in a given growing season. Dormant buds are inactive meristematic tissue. They may be nondifferentiated *(Figures 4d, 5c)* or differentiated *(Figures 4b, 5a)*. Differentiated buds often begin growth in the fall and delay emergence until the following spring. The remaining buds will be viable for several years if the tiller network supplies the energy needed to maintain the relatively small amount of live tissue in dormant buds.

Vegetative Reproduction

Bunchgrasses do not have stolons or rhizomes and instead develop dense clusters of tillers. Examples include little bluestem, needleandthread and prairie junegrass. Bunchgrasses repopulate primarily by tillering. New tillers develop in close proximity to current-year and previous-year tillers because buds primarily are located in the crown at the lower most nodes of parent tillers. Multiple generations of buds often are discernible in bunchgrasses *(Figure 2)*. Density, size and orientation of buds differ among species.

Sod-forming grasses have stolons or rhizomes. Buffalograss reproduces vegetatively by tillering from nodes *(Figure 3a)* on stolons *(Figure 3b)*. **Stolons** are above-ground horizontal stems that root at the tip or at nodes. Buds on the crowns of buffalograss *(Figure 3a)* may differentiate into tillers or stolons. Western wheatgrass, prairie sandreed, switchgrass and sand bluestem are rhizomatous. These species reproduce vegetatively when tillers develop from buds on rhizome nodes *(Figure 4b)*, the end of rhizomes *(Figure 5a)* or on the crowns of parent tillers *(Figure 5c)*. **Rhizomes** are underground stems that produce roots at nodes. Continuous rhizomes produce aerial shoots from buds located at nodes and the rhizome continues to grow under ground (western wheatgrass, *Figure 4*). In contrast, rhizomes that turn up and emerge as a green shoot are referred to as terminal rhizomes (prairie sandreed, *Figure 5;* sand bluestem, *Figure 6*).

The anatomy of rhizomes is similar among species; however, there is considerable diversity in physical characteristics. Rhizomes are composed of nodes and internodes. Buds, roots and rhizome scales can originate from nodes of rhizomes *(Figure 4)*. Elongation of rhizome internodes is pronounced in western wheatgrass *(Figure 4d)* and sand bluestem *(Figure 6b)*. Internode elongation is intermediate in prairie sandreed rhizomes *(Figure 5d)*, and very limited in switchgrass rhizomes *(Figure 7)*. Western wheatgrass rhizomes *(Figure 4)* are long and thin, resulting in widely dispersed populations of connected tillers. This contrasts with the short, stout, scaly, multi-branched rhizomes of switchgrass *(Figure 7)*. Sand bluestem rhizomes *(Figure 6)* turn upward early in growth. This growth form contrasts with prairie sandreed *(Figure 5)* with most of the rhizomes growing horizontally until the terminal rhizome bud differentiates into a tiller.

Management practices that periodically optimize growth of new rhizomes are likely to increase the spread and productivity of rhizomatous grasses. The largest tillers of rhizomatous grasses often originate from the distal, pointed end of terminal rhizomes. Rhizomes also are important for carbohydrate storage and translocation among interconnected tillers.

Season of Growth

Rangeland plant communities are composed of mixtures of species that grow at different times during the spring or summer. Grasses are classified as cool-season or warm-season species generally based on their growth response to air temperature. Maximum growth rates of most **cool-season** (C3) species occur when air temperatures are 65° to 75°F compared to 90° to 95°F for many **warm-season** (C4) grasses. Considerable variation occurs in the range of air temperatures over which measurable growth occurs within each season-of-growth category. In the mixed-grass prairie of western Nebraska, sedges or grass-like cool-season species, are the first to grow in the spring. They are followed by prairie junegrass and needlegrasses, which are followed by western wheatgrass *(Figure 8)*. In the Sandhills of Nebraska, prairie sandreed is the earliest developing warm-season grass followed by bluestems, switchgrass and grama grasses *(Figure 9)*.

Growth Patterns of Different Plant Parts

Green plants convert solar energy to chemical energy by the process of photosynthesis. This reaction is directly or indirectly responsible for all life on earth. During **photosynthesis** *(Figure 10)* carbon dioxide, a gas, is combined with water and solar energy, and converted to **carbohydrates**, a solid. Formation of carbohydrates is a chemical way to store the sun's energy as "food." Carbohydrates produced from photosynthesis provide energy for all plant growth and maintenance. Energy from plant-produced carbohydrates then enters the food chain through herbivores that can be consumed by carnivores.

Carbon dioxide is constantly available in the air we breath and energy is readily available from the sun that rises every day. When air temperatures are favorable for plant growth, soil water is the limiting factor for photosynthesis *(Figure 10)*. Drought reduces the supply of available soil water. Overgrazing reduces the ability of plants to extract soil water. Additionally, reductions in plant cover caused by overgrazing and natural defoliation

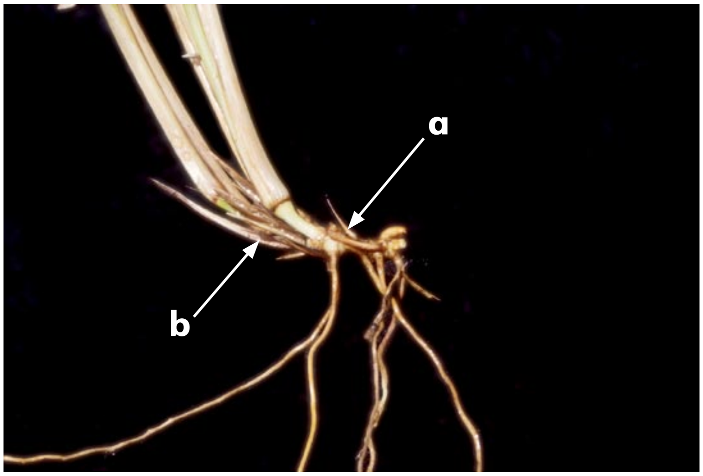

Figure 2. Multiple cadres of buds occur on little bluestem crowns ranging from 1-year-old (b) to 3-year-old (a) generations.

Figure 3. Buffalograss buds (a) originate at nodes where clusters of tillers develop on stolons (b).

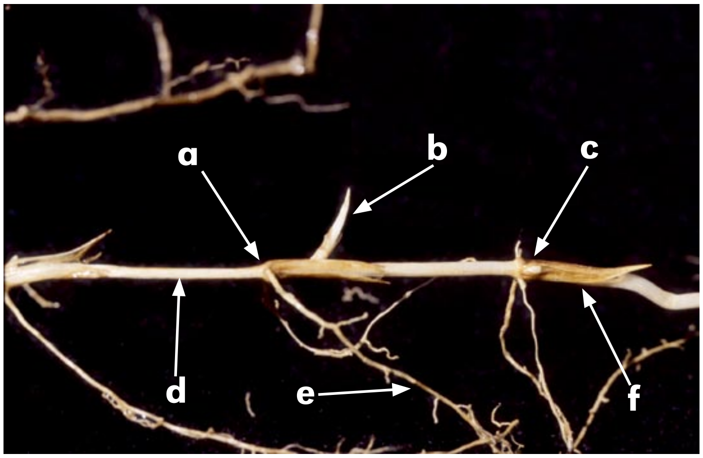

Figure 4. Western wheatgrass rhizomes are composed of a relatively long series of nodes (a) and elongated internodes (d). Buds (b, c), roots (e), and rhizome scales (f) originate at nodes. Stage of development varies among buds on the same rhizome ranging from differentiated (b) to nondifferentiated dormant (c) buds.

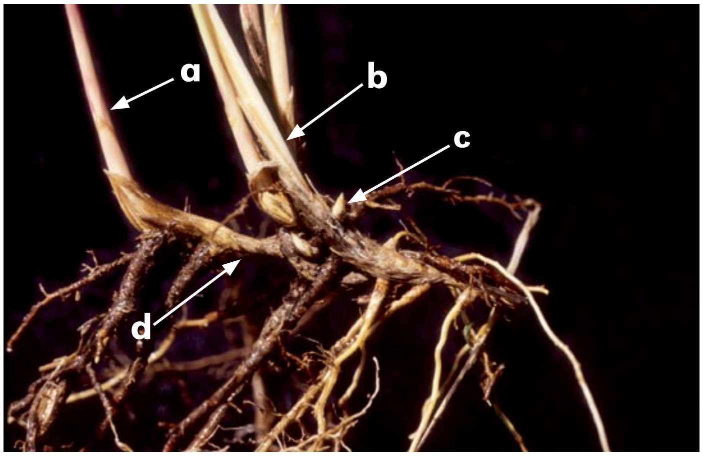

Figure 5. Prairie sandreed tillers (b) originate from extensive networks of scaly rhizomes (d). Buds occur at crowns of parent tillers (c) and at the end of rhizomes (a) with little or no tiller development from rhizome nodes in this species. Bud development ranges from differentiated (a) to dormant (c). Near the end of the growing season, differentiating prairie sandreed buds elongate to just below the soil surface (a). Tillers produced by these buds do not emerge until the following spring.

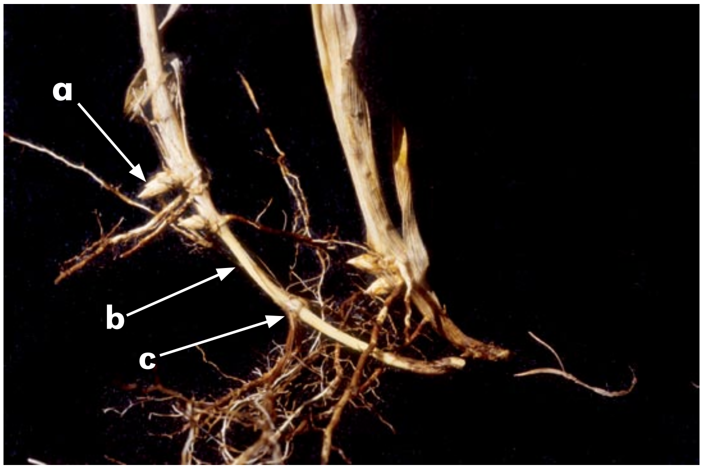

Figure 6. Dormant buds (a) at the crowns of sand bluestem tillers are robust in the fall. There are 2 buds at the crown of each tiller in this figure. Sand bluestem rhizomes are intermediate in length with substantial internode (b) elongation between nodes (c).

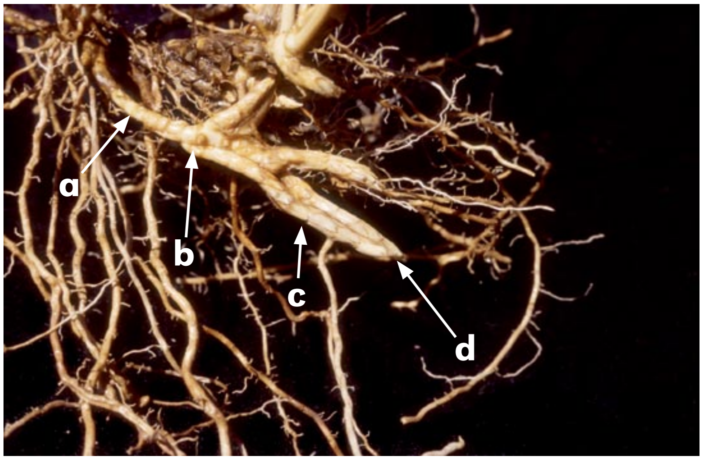

Figure 7. Switchgrass produces numerous short, stout, scaly, branched rhizomes (a, c) with little internode elongation. Buds occur at rhizome nodes (b) and the distal ends of rhizomes (d).

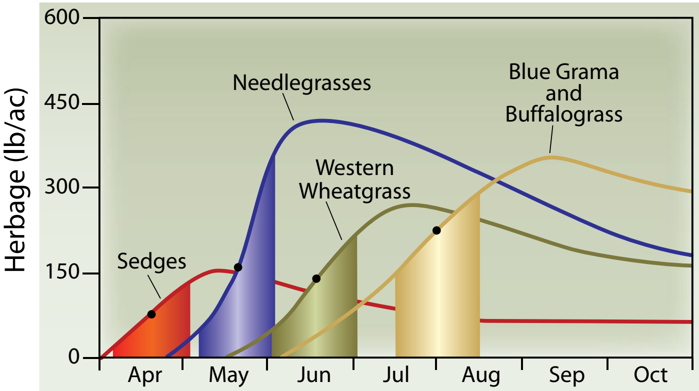

Figure 8. Seasonal distribution of plant growth (lines) and midpoints (●) of rapid-growth windows (shaded areas) for key species on a limy upland range site in western Nebraska.

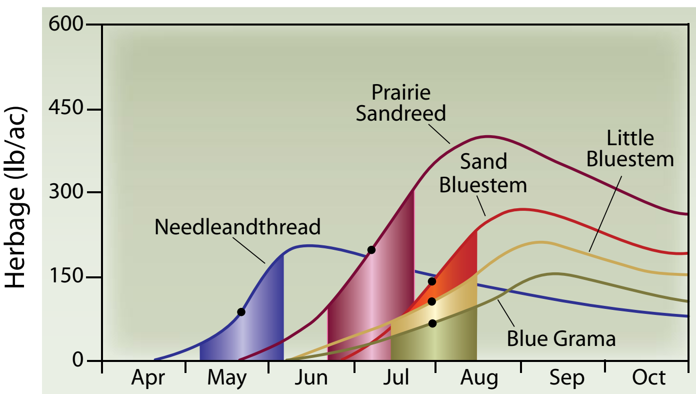

Figure 9. Seasonal distribution of plant growth (lines) and midpoints (●) of rapid-growth windows (shaded areas) for key species on a sands range site in western Nebraska.

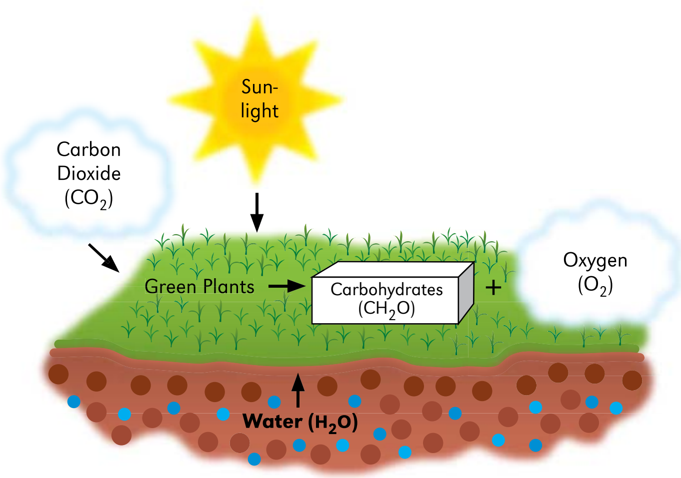

Figure 10. Primary inputs and products of photosynthesis. Biochemical processes of photosynthesis inside plants are extremely complex.

processes, like fire or severe hail, often reduce the amount of rain water that enters the soil because of runoff losses. Grazing effects on protective plant cover, green leaf area and roots have a profound effect on the total amount of carbohydrates produced per acre.

Growth of a plant depends on the supply of carbohydrates. All living plant cells must have carbohydrates to continue life and function; however, photosynthesis occurs only in the presence of sunlight and only in cells with chlorophyll. Plant cells not directly involved in photosynthesis are completely dependent on the translocation of carbohydrates from green foliage or from storage areas known as **sources**. Recipient tissue is referred to as a **sink**. Relationships between sources and sinks of carbohydrates are seasonally dynamic. Rapid growth of roots, new leaf area or seed heads is evidence of a strong sink. Rapid growth does not occur in all plant parts simultaneously. Carbohydrate sinks compete with one another for photosynthates, ie., products of photosynthesis such as starch and sugar. Growth of plant parts is reduced or delayed when green leaf area is removed. Repeatedly interrupting source-sink relationships in consecutive years, when root growth, bud formation, stolon growth or rhizome growth are seasonally most rapid, reduces subsequent-year forage production potential of most mid- and tall grasses.

The priority for use of carbohydrates in plants during the growing season is the initial development of leaves in the spring, followed by replacement of leaf area after heavy defoliation. If environmental conditions are favorable, a percentage of tillers within each grass species will produce stems that become a sink for carbohydrates. Movement of carbohydrates to deep roots (root replacement) tends to occur primarily in the first half of the growing season before stem elongation. Photosynthate movement into rhizomes increases measurably when tillers are in the boot stage, when developing seed heads still are inside the leaf sheaths. Replenishment of roots in the top 4 to 8 inches of soil occurs intermittently throughout the growing season with the greatest amount of translocation occurring after tillers have completed most of their growth for the year. Roots produced in the autumn generally have the longest life span. Carbohydrate reserves are accumulated in crowns and rhizomes in the autumn and used to keep dormant buds and below-ground plant parts *(Figures 2 through 7)* alive from killing frost to spring green-up.

Vegetation Manipulation

During the growing season, dormancy of vegetative buds is controlled by the growth and development of tillers near the bud. Bud dormancy appears to be affected by hormones produced in growing points, the upper tip of the meristem that produces each tiller *(Figure 1)*, and by microenvironmental variables near the bud. As long as the growing points of nearby tillers are intact, most nondifferentiated buds *(Figures 4c, 5c)* continue to be dormant. The growing point of a tiller is elevated up through the center of the leaf sheaths *(Figure 1)* and develops into a seed head when growth is not interrupted. If the growing points of nearby tillers are damaged or removed by grazing, hail, fire or insects, previously dormant buds may begin to produce new tillers, if air temperatures and soil water are suitable for growth of that species. Emergence of the inflorescence in parent tillers and the development of seed will delay or preclude a break in bud dormancy, especially when environmental conditions are unfavorable for plant growth.

Forage quality of grasses declines as tillers mature or age. Nutrient density and digestibility decline most rapidly when tillers produce stems and seed heads. Consequently, it has been suggested that ranchers could routinely improve beef production

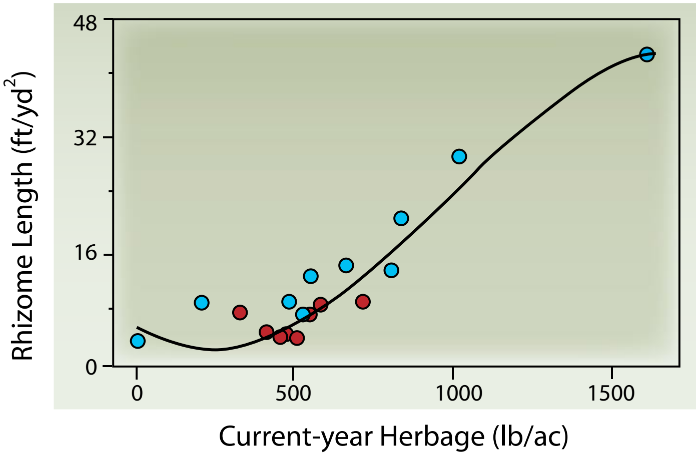

Figure 11. Effects of current-year herbage on the length of new prairie sandreed rhizomes in a drought year (●) and a year with average precipitation (●).

by using "timely intensive grazing" to stimulate a flush of nutrient-dense growth from dormant buds during the summer. Attempts to overcome the natural rhythm of plant growth are not likely to succeed in most semiarid rangelands in the northern Great Plains because air temperature and soil water often are simultaneously favorable for each plant species for only 30 to 45 days. It also is unlikely that grazing will increase total dry matter production per acre. When a relatively large number of new tillers are initiated, the amount of forage produced by heavily grazed plants often is not enough to support additional grazing without the risk of erosion or reduced hydrological condition on semiarid rangelands in most years. **Hydrological condition** refers to the quantity of litter and standing herbage needed to minimize runoff when precipitation exceeds the infiltration capacity of the soil. Additionally, diminished root systems and inability of heavily grazed species to restore carbohydrate levels will reduce drought tolerance and lower forage production potential of preferred species in the subsequent growing season.

Growth of Rhizomes

In addition to producing buds for repopulation, nutrients are translocated through rhizomes from nongrazed to grazed tillers and from parent to daughter tillers for several years. Growth of new rhizomes is seasonally most active in the boot stage of development, when tillers begin to elongate. Rhizome growth is dependent on the amount of current-year herbage. Therefore, grasses produce more rhizomes when precipitation is favorable compared to periods of drought, and vigorous grasses produce greater weight and length of rhizomes than overgrazed plants.

Total length of new prairie sandreed rhizomes is relatively constant until current-year herbage exceeds a threshold, after which substantial rhizome growth occurs *(Figure 11)*. Highly palatable grasses are unlikely to produce abundant amounts of new rhizomes in pastures that always are used for summer grazing. Periodic full growing-season deferment, nonuse from spring green-up to killing frost, may be required to maintain vigorous populations of palatable rhizomatous grasses in moderately stocked "summer" pastures. Overgrazed populations may require consecutive years of full growing-season deferment for measurable increases in rhizome length. Heavy defoliation before threshold levels of herbage have been produced would preclude measurable increases in rhizomatous grasses.

One of the greatest benefits of rotation-grazing systems is the ability to shift the time of grazing among pastures every year. Deferring grazing until seed heads have emerged is likely to maintain or increase the vigor of key species because reproductive tillers are less likely to be grazed than tillers without seed heads. Measurably larger photosynthetically active surface areas on reproductive tillers compared to vegetative tillers results in the production and maintenance of more buds and rhizomes.

Grazing and Drought Interactions

Total amounts of plant biomass are greater below than above ground in most grassland ecosystems. A large percentage of total root length is near the soil surface where diurnal (24 hour) fluctuations in soil temperature and water content are most dramatic. Root mortality in the top 4 inches of soil is relatively high when drought occurs. Lifetime efficiency of roots is reduced by drought stress. Roots also are sensitive to defoliation. Heavy defoliation of green plants stops root growth for one to two weeks. The percentage of total root length lost increases as rooting depth increases.

Overgrazing is a "root-mining" process. Cumulative effects of overgrazing on mixed-grass or tallgrass prairie are insidious in years when precipitation is above average. Progressive declines in root length are not readily apparent when looking at above-ground plant growth. These declines make preferred grass species increasingly susceptible to soil-water deficits when drought occurs. The inverse is true for shortgrass prairie where reduced root length becomes apparent only when precipitation is above average and soil water moves beyond the rooting depth of overgrazed plants.

In the absence of drought, heavy defoliation of sand bluestem in July when herbage production is normally most rapid *(Figure 9)*, reduced total end-of-season root length by 32 percent compared to clipping dormant plants in October *(Figure 12)*. Clipping sand bluestem plants in June before rapid plant growth, which corresponds to stem elongation, had the least effect of summer defoliation on total root length. Multiple mid-month defoliation treatments during the growing season were devastating to root growth. Clipping plants in June and again in August after 60 days of deferment reduced end-of-season root length by 43 percent *(Figure 12)*. In contrast to measurable declines in root length, a single year of heavy defoliation had no effect on total current-year above-ground herbage production of sand bluestem.

Cattle are unlikely to overgraze warm-season tallgrasses on semiarid rangeland when pastures are deferred until mid-August because the tillers have aged and declined in palatability. Additionally, cattle will avoid grazing reproductive tillers that produced seed heads. Periodically deferring grazing in selected pastures until August will help maintain or improve vigor of most tallgrasses. Grazing Sandhills pastures two or more times during June through August is likely to reduce the number of reproductive tillers and increase the risk of heavy defoliation in the second grazing period.

Rapid growth occurs in grasses when air temperatures and soil water are simultaneously favorable. Rapid rates of herbage production are associated with stem elongation. Optimum air temperatures differ among species *(Figures 8, 9)*. Fifty to 80 percent of the annual herbage production of most species occurs during a 30-day time period for mid- and tallgrasses on semiarid rangeland. These rapid-growth windows are best defined by growing degree days. Species sequences are the same each year; however, initiation of rapid growth may change by one to two weeks as cumulative degree days change from year to year. Overgrazing and drought reduce the number of days during which grasses can grow rapidly.

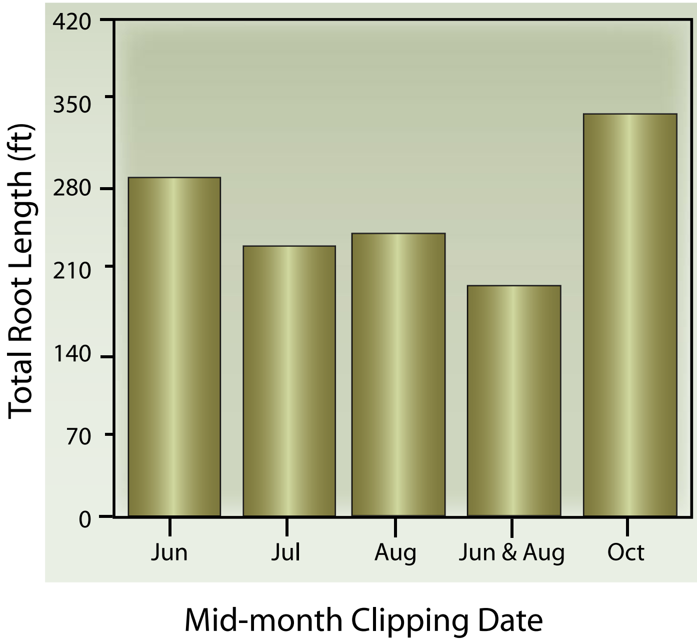

Figure 12. End of season total length of sand bluestem roots after mid-month clipping treatments to a stubble height of about 3 inches (Engel et al. 1998).

Tillers begin to emerge 30 to 45 days before rapid-growth windows occur *(Figures 8, 9)*. For example, more than 50 percent of prairie sandreed tillers emerge by mid-May in western Nebraska and 80 percent are up by mid-June when the rapid-growth window of this species begins *(Figure 9)*. Severe drought stress during rapid-growth windows will kill half or more of the tillers, reducing forage production potential for the current year and diminishing the number of buds for repopulation in subsequent years. Reductions in grazing pressure should be timely and proportional to the percentage of the forage normally produced by drought-stressed species.

Drought Management

Knowledge of seasonal patterns in herbage production is critical for implementing timely drought management decisions. When drought persists into the rapid-growth windows of codominant species, forage production potential is seriously impaired for the rest of the "summer" grazing season. Failure to reduce grazing pressure during these windows will result in the combined stresses of overgrazing and drought that are likely to cause long-term declines in forage production potential.

About 50 percent of the annual forage resource on limy upland and silty ecological sites in western Nebraska and the adjoining semiarid region is produced by sedges and needlegrasses *(Figure 8)*. Consequently, 50 percent reductions in carrying capacity are likely to occur on these sites when severe drought persists into mid-May. Continuation of drought into mid-June will negatively affect about 75 percent of the annual forage production potential because of drought stress on sedges, needlegrasses, and western wheatgrass.

Vegetation in good-to-excellent range condition on sands or sandy ecological sites in the semiarid region of the northern Great Plains often is dominated by warm-season tallgrasses *(Figure 9)*. The combination of cool-season species and the earliest developing warm-season grass, prairie sandreed, generally account for half of the annual forage supply. Productivity of these species is seriously impaired when drought persists into mid-May and early July, respectively *(Figure 9)*. Persistence of drought or dry conditions through late July will cause measurable reductions in forage production of the entire plant community. There is little hope of measurable yield responses to rainfall after severe drought has continued into the mid-point of these rapid-growth windows.

Plant-year Precipitation

Livestock production and natural resource management objectives should be the basis for stocking rate and other grazing management decisions. Critical dates for destocking pastures in drought circumstances should be based on seasonal plant growth patterns and **plant-year precipitation**: October of the preceding year through September of the current year. Moisture accumulated between killing frost of the preceding year and spring green-up of the current year results in greater yield per inch of water than summer precipitation. Conversely, little or no accumulation of soil water during the dormant season increases the need for timely destocking to avoid damaging rangeland vegetation. Additionally, grazing history, precipitation regimes and end-of-season residual herbage during the preceding two years determine the susceptibility of rangeland vegetation to drought stress. Unfavorable conditions during the preceding years predispose pastures to measurable damage if grazing pressure is not reduced at the appropriate time.

Current soil water status and precipitation and temperature forecasts for the next one to three months are available at the University of Nebraska–Lincoln (UNL), National Drought Mitigation Center Web site (drought.unl.edu/dm/index.html). This site also is accessible by entering "Drought Monitor" in your search engine. Areas mapped on this site as extreme or exceptional drought during the growing season are likely to have a one- to two-week delayed response to rainfall. Additionally, the process of "wetting-up" very dry soils in these areas reduces the availability of rainwater to plants. Excessive grazing pressure will further reduce or preclude yield responses to even measurable amounts of precipitation.

Delays in plant response to precipitation should be expected when current plant-year precipitation in your immediate area is 75 percent or less of long-term average (*Figure 13)*. For example, based on the precipitation information in *Figure 13*, destocking on limy upland ecological sites *(Figure 8)* in the southern Panhandle should have been 50 percent by mid-May and 100 percent by mid- to late June 2002. Given the severity of drought in the preceding year, turn-out of cattle onto summer pastures in 2003 should have been delayed by two to four weeks with less than pre-drought summer stocking rates. Relatively low dormant season precipitation before the 2004 growing season would preclude any increase in stocking rate. Delaying turn-out on summer pastures in 2004 would have been beneficial. Forecast information from the Drought Monitor Web site should be used to implement progressive phases of drought management plans, especially drought-induced sale of livestock.

Grazing Systems

Seasonal changes in the botanical composition of livestock diets on rangeland correspond to seasonal patterns of plant growth. Cattle are selective grazers. They select immature tillers over mature tillers and leaves over stems. Consequently, livestock use of each species tends to be highest when tillers are vegetative, predominantly leaves, and progressively lower as tillers age or transition into reproductive tillers. Defoliation of grazed mid- and tallgrass tillers will likely be 50 percent or higher early in the growing season when tillers are vegetative. Subsequent-

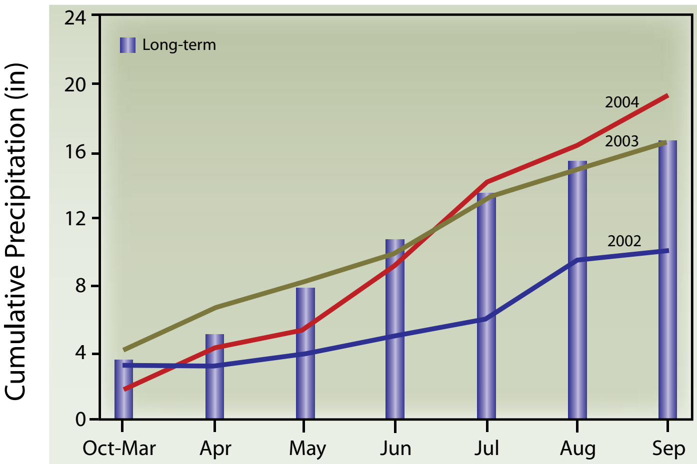

Figure 13. Cumulative plant-year precipitation (October of the preceding year through September of the current year) for the 2002, 2003 and 2004 growing seasons in the southern Nebraska Panhandle.

year herbage production is most likely to be reduced if a high percentage of tillers are grazed when they are elongating because removal of elevated growing points ends the growth of grazed tillers. Leaf replacement must then come from new tillers. This **"regrowth"** is costly because it requires a considerable amount of carbohydrates for initial tiller development from buds. Tillers grazed before stem elongation continue to grow because the growing points are not removed. When precipitation is average or above average, codominant grass species generally recover from grazing stress by the end of the current growing season in pastures that are grazed before their respective rapid-growth windows and then deferred until killing frost.

The percentage of tillers grazed in a pasture increases as grazing pressure increases. Averaged over the entire pasture, grazing pressure is relatively low under continuous summer grazing. However, allowing cattle to graze plant species they most prefer throughout the summer for years results in overgrazed areas near stock tanks and on level to gently rolling areas. Even at low to moderate stocking rates, range condition in these overgrazed areas cannot be improved under season-long continuous summer grazing.

Range condition can be improved by alternating summer and dormant-season grazing or by using rotation grazing with an appropriate number of pastures during the summer grazing season. **However, shifting from continuous summer grazing to a two-pasture deferred-rotation system would be counterproductive.** Using one or both pastures more than once during the summer increases the risk of preferred species being heavily defoliated several times each growing season in consecutive years. When each pasture is grazed only once, movement of cattle from the first to the second pasture often occurs during the rapid-growth window of one or more key grass species. For example, splitting the summer grazing season on limy upland ecological sites *(Figure 8)* between two pastures likely will result in a late June to early July move. This will double the grazing pressure on western wheatgrass during its rapid-growth window in both pastures in consecutive years. Movement of cattle on sands range sites *(Figure 9)* is likely to occur during July, doubling grazing pressure during the rapid-growth windows of prairie sandreed and sand bluestem in consecutive years.

The risk of overgrazing preferred species in consecutive years can be resolved by using four or more pastures for rotation grazing. Progressively shifting the first-grazed pasture by one in the numerical sequence of four changes the time of grazing over years. However, this clock-work approach may result in overgrazing of a key species in two consecutive years in each four-year cycle between the first and second or second and third pastures in the sequence. When "summer" grazing seasons are five to six months long, the pasture grazed last in the preceding year should be the one grazed during the rapid-growth window of key species in the current year. Adding one or two additional pastures to rotation systems will make it easier to change pasture-use sequences and avoid consecutive years of heavy use of key grass species. Additionally, avoid using summer grazing seasons shorter than four months because grazing pressure is concentrated during the rapid growth windows of key forage species.

The highest levels of forage production and sustainable stocking rates on Sandhills rangeland in western Nebraska have been accomplished with deferred-rotation grazing systems, in which every pasture receives a full growing-season deferment from spring green-up to killing frost every third year. Clearly, this management scheme is most feasible with a cow-calf enterprise where cows are on the ranch all year. Practices that improve the vigor and productivity of preferred grass species also are likely to increase populations of highly palatable forbs such as stiff sunflower and reduce populations of unpalatable forbs such as western ragweed.

Summary

Understanding how grasses grow and how semiarid environmental constraints affect plant growth are critical for long-term success in ranching. Grasses grow rapidly only when air temperature and soil water are simultaneously favorable. Optimum air temperatures differ among most species. Fifty to 80 percent of the annual herbage production of each species occurs during a 30-day, rapid-growth window for mid- and tallgrasses on semiarid rangelands. Overgrazing and drought reduce the number of days during which grasses can grow rapidly. When drought persists into the rapid-growth window of a given species, forage production potential of that species is seriously impaired for the rest of the year. **Failure to reduce grazing pressure during rapid-growth windows of codominant grasses will result in the combined stresses of overgrazing and drought that are likely to cause long-term declines in forage production potential.** Little or no accumulation of soil water during the preceding dormant season increases the need for timely destocking to avoid damaging rangeland vegetation. Maintaining healthy and diverse plant communities provides a buffer against irregular distribution of precipitation and drought that are common to semiarid rangelands.

Many rangeland grasses and sedges are rhizomatous. Rhizome growth is dependent on the amount of current-year herbage. Therefore, grasses produce more rhizomes when precipitation is favorable compared to periods of drought and vigorous plants produce greater weight and length of rhizomes than overgrazed plants. Overgrazing is a "root-mining" process. Cumulative effects of overgrazing are insidious in years when precipitation is above average because declines in root length are not readily apparent when looking at above-ground growth on mixed-grass or Sandhills prairie. The inverse is true for shortgrass prairie where reduced root length becomes apparent only when precipitation is above average and soil water moves beyond the rooting depth of overgrazed plants.

Excellent rangeland stewardship can be accomplished by using moderate stocking rates and following the guidelines discussed in this publication. When feasible, use deferred-rotation grazing systems with four or more pastures or rest-rotation systems with five or more pastures to reduce the likelihood of overgrazing key species in consecutive years. Do not use two-pasture deferred-rotation grazing systems. Avoid using summer grazing seasons shorter than four months because grazing pressure is concentrated during the rapid-growth windows of key forage species. Providing pastures with a full growing-season deferment from spring green-up to killing frost once every three years greatly enhances subsequent-year forage production potential.

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