Biologically Effective Grazing Management

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Beneficial Relationships of Grazing and Grass Growth Processes

Grazing management that elevates the health status of plants on grassland ecosystems will produce greater herbage weight, higher quality habitat for wildlife, and stronger livestock performance with more pounds of calf per acre than grazing management that just maintains grasslands in average condition. The key to improving grassland ecosystem health is implementing grazing management practices that meet the biological requirements of the plants and coordinate grazing periods with grass growth stages to stimulate beneficial processes within grass plants and the ecosystem.

Grassland ecosystems depend on grass defoliation by grazing animals to stimulate beneficial processes that enhance plant health and biological functions. Plants are the primary producers in the grassland ecosystem. The solar energy they convert into chemical energy during photosynthesis is the primary source of energy driving all ecosystem processes, so the performance levels of the plants regulate the performance levels of the other grassland ecosystem components, including livestock weight gains and wildlife populations.

Stimulation of Grass Defoliation Resistance Mechanisms with Grazing

Grasses have developed specialized growth characteristics and biological mechanisms in response to a long history of grazing. Grass plants evolved 20 million years ago with early herbivores that are now extinct. During this coevolution, grasses developed biological processes that help the plants withstand and recover from defoliation. This complex of processes, called defoliation resistance mechanisms, accelerates both the growth rate of the grazed plant and its development of foliage and roots. Two biological processes of primary concern to grassland managers are the increased beneficial activity of soil organisms and the stimulation of grass vegetative reproduction by secondary tiller development from axillary tiller buds.

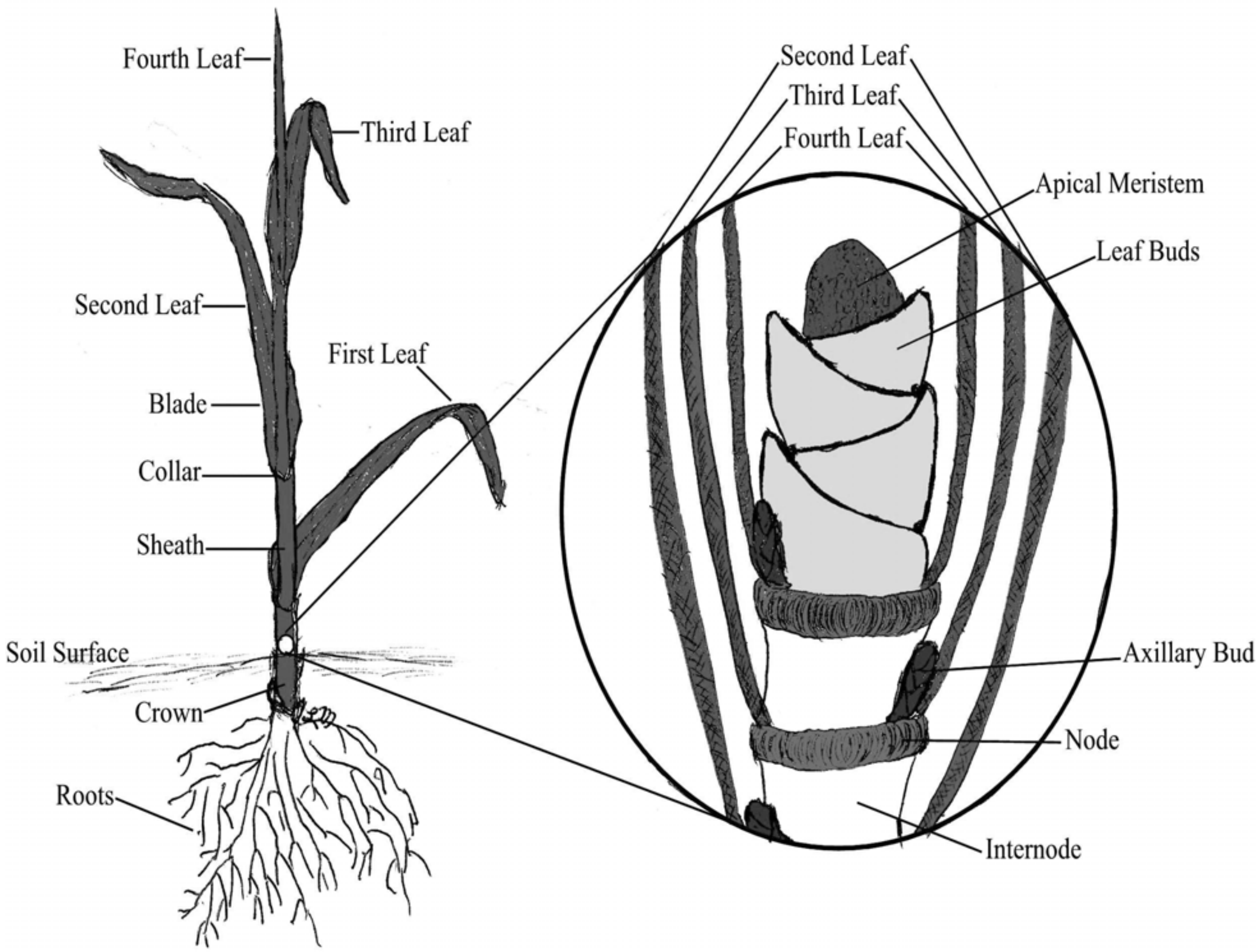
Coordinating defoliation with grass growth stages can meet the biological requirements of grass plants and enhance plant growth by stimulating the defoliation resistance mechanisms grass plants have developed. Plant response to defoliation depends on the amount of material removed and the growth stage of the plant. Removing too much leaf area or grazing too early or too late in the season impedes the defoliation resistance mechanisms. Properly timed grazing that removes only a small portion, about 10% to 33%, of the leaf material on 60% to 80% of the plants in a pasture where grasses are between the third-leaf and flowering stages activates the beneficial biological processes and results in improved health of grassland ecosystems and a 30% to 45% increase in herbage production. Producers can manipulate these processes with biologically effective grazing management to enhance grass herbage production and reduce pasture and forage costs.

Structure of Grass Tillers

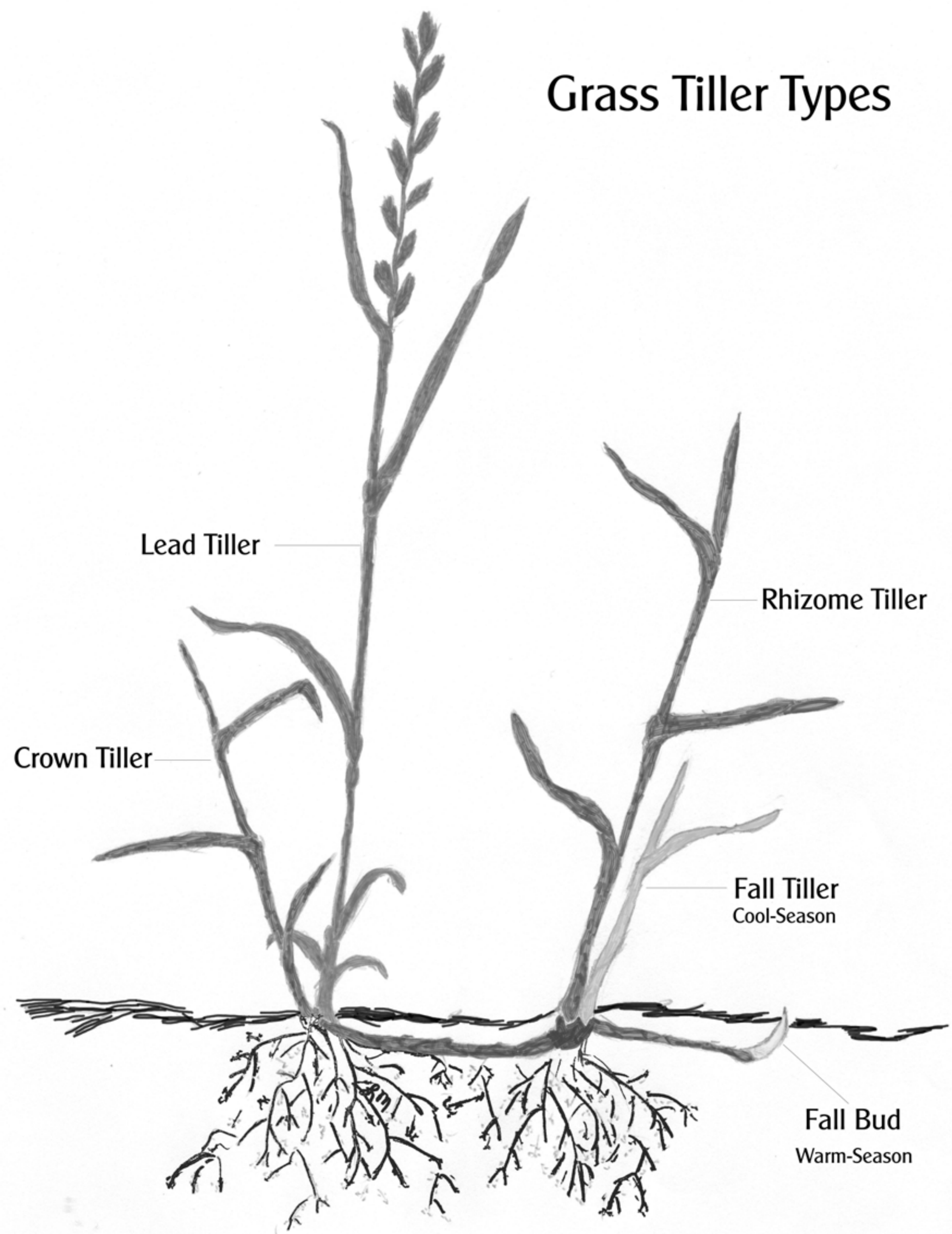
The basic unit of the grass plant is the tiller, which consists of a shoot and roots. The structure of the shoot, a repeating pattern of four-part units called phytomers, allows the shoot's progressive development. The tillers of most grass species in the Northern Plains comprise 6 to 8 phytomers. The four parts of the phytomer are

1. a leaf, consisting of a blade and sheath, with a collar separating the two structures;
2. a node, the point of leaf attachment to the stem;
3. an internode, the length of stem between two nodes; and
4. an axillary tiller bud, the area of tissue that can develop into a new shoot.

The crown of a grass plant is the lower portion of a shoot and has at least two nodes that can produce roots. Before flower development, the shoot consists of several closely spaced nodes. The node at the top, or apex, of the stem is the location of the shoot's apical meristem, an area of new cell formation. The cells in this area can develop into either leaf buds or flower buds, depending on the growth stage of the shoot. Leaves form on alternating sides of the shoot, with the oldest leaf outermost and each new leaf growing upward, protected by the surrounding sheaths of the lower leaves. A leaf bud contains about the same number of cells as a fully expanded leaf. The leaf



Grass Tiller at 3.5 Leaf Stage


Grass Tiller Types
Lead Tiller
Rhizome Tiller
Crown Tiller
Fall Tiller
Cool-Season
Fall Bud
Warm-Season

grows as the cells' size and weight increase, beginning with cells at the tip of the blade.

Because grass plants have the oldest cells at the leaf tip, grazing animals can remove portions of a leaf without stopping the growth of the shoot. Leaves may continue to grow from existing buds and from new leaf buds developed in the shoot's apical meristem, or growing point. The apical meristem of most grasses remains close to the ground and below the reach of the grazing animal when the shoot is in the vegetative, or non-flowering, phase. This growth structure makes grasses well adapted to defoliation by large herbivores.

Vegetative shoots develop from the main shoot by the process of tillering. A vegetative tiller is a shoot derived from vertical growth of an axillary bud and is a complete unit with roots, stem, and leaves. There are two types of tillers: crown and rhizome. Crown tillers grow vertically, close to the lead tiller, and tend to have a tufted or bunch-type growth habit. Rhizome tillers grow horizontally, away from the lead tiller, for a distance before vertical growth. This type of tillering results in the spreading or creeping growth habit of sod-forming plants.

Grasses in the Northern Plains can produce both crown and rhizome tiller types. Each grass species tends to produce more of one of the tiller types and develops a characteristic growth habit. Increasing production of the other tiller type can be manipulated by managing defoliation to occur at times specific for individual grass species.

Stimulation of Rhizosphere Organism Activity with Grazing

Properly timed grazing can enhance the mutually beneficial relationship between rhizosphere soil organisms and the roots of the grass plant. The rhizosphere--the narrow zone of soil around the roots of perennial grassland plants--contains bacteria, protozoa, nematodes, mites, springtails, and endomycorrhizal fungi. The grass plant's roots release carbon compounds, including simple sugars, to these organisms, and the rhizosphere organisms release mineral nitrogen that the plant's roots absorb. Grassland soils have abundant quantities of nitrogen, but most of it is in the organic form and unavailable for direct use by plants. Soil microorganisms convert organic nitrogen to mineral nitrogen, the form that plants can use. Activity of the soil microorganisms increases with the availability of carbon compounds in the rhizosphere, and the elevated microorganism activity results in increased mineral nitrogen available to the grass plant. The endomycorrhizal fungi also provide phosphorus, other mineral nutrients, and water that the plant needs for growth.

Grazing lead tillers between the third-leaf stage and the flowering stage can increase the amount of carbon compounds the defoliated plant releases into the rhizosphere. The increase in mineral nitrogen made available by elevated rates of microorganism activity allows the plant to accelerate growth and recover more quickly from defoliation. This beneficial activity does not seem to occur when grazing is conducted during the middle and late growth stages of the grass plant.

Stimulation of Fungi That Improve Soil Structure with Grazing

Biologically effective grazing management can stimulate activity of a second type of beneficial soil fungi. These fungi improve soil structure. Ectomycorrhizal fungi previously unknown in the mixed grass prairie were recently found in association with roots of grass plants managed with the twice-over rotation grazing system, which coordinates grazing periods with grass growth stages when defoliation resistance mechanisms are stimulated. The slow-growing ectomycorrhizal fungi develop a sheath around perennial grass roots and do not enter tissue of the host plant as endomycorrhizal fungi do.

The ability of ectomycorrhizal fungi to improve soil quality results from their excretion of large amounts of insoluble polysaccharides with adhesive qualities. These substances stabilize soil particles and bind them into water-stable aggregates that range from about the size of air rifle pellets to the size of large marbles. An increase in water-stable aggregates increases soil pore size and distribution. The changes in soil quality improve soil oxygenation, water infiltration, and root distribution and decrease erodibility.

The rooting depth of rangeland soils at the location where ectomycorrhizal fungi were first discovered increased from 2-3 inches to 18-24 inches after seven years of management with the twice-over rotation system. The activity levels of ectomycorrhizal fungi are greater on pastures managed with the twice-over rotation system than on pastures under other grazing management because of the enhanced symbiotic relationship between the rhizosphere and healthy rangeland grasses.

Grazing Threshold at the Third-Leaf Stage

Turning livestock onto native rangeland too early in the spring damages plants and limits herbage production because grazing at this time removes leaf area from grass that has not recovered from winter dormancy. Grass cannot withstand defoliation before reaching the third-leaf stage, after plants have produced sufficient foliage to support growth. The practice of starting grazing before grass tillers have produced three new leaves reduces the forage available to livestock later in the season and decreases profits.

The grass shoot's production of three to three and a half new leaves during the growing season is the most reliable indicator of when grazing may safely begin. After the lead tiller has reached the third-leaf stage and been exposed to the triggering photoperiod, the apical meristem changes and begins to produce flower buds rather than leaf buds, although previously formed leaf buds continue to grow and develop. Defoliation of leaf material before the shoot has reached the third-leaf stage can disrupt the formation of leaf buds and the expansion of existing young leaves for the shoot, weaken the plant, and diminish the plant's ability to produce herbage.

The date on which the third-new-leaf stage is reached varies by plant type. Most native range cool-season grasses are ready for grazing in early June, and warm-season species are ready for grazing in mid June.

Research shows that starting grazing on native rangeland in early May results in a loss of 75% of the potential herbage and that starting grazing in mid May results in a loss of 45% to 60% of the potential herbage. These reductions in herbage production lead to reductions in stocking rate, calf weight gain per day, calf weight gain per acre, net returns per cow-calf pair, and net returns per acre. Delaying grazing until early June on rotation grazing systems or until mid June on seasonlong treatments allows for greater growth of the potential herbage
production and produces greater economic returns for the cow-calf operation.

Cool-season domesticated grasses can serve as alternative spring forage sources until native range grasses are ready for grazing. Like native rangeland, complementary spring domesticated grass pastures should be grazed only after plants arrive at the third-leaf stage. No perennial grasses develop the third new leaf before late April, but domesticated grass species such as crested wheatgrass and smooth bromegrass reach the third-leaf stage three to five weeks earlier than cool-season native species. Pastures of domesticated grasses can support grazing livestock from early May until grazing on native rangeland can begin safely in early June.

Stimulation of Vegetative Reproduction by Tillering with Grazing

Grazing that removes a small amount of young leaf tissue from lead tillers after the third-leaf stage and before the flowering stage can manipulate increases in vegetative reproduction by tillering. Biologically effective grazing stimulates this mechanism by reducing the amount of a growth-controlling hormone the leaf tissue produces to suppress reproduction by vegetative tiller buds.

Apical meristem and young leaf tissue of grasses produce a hormone that inhibits the growth of the tiller buds on the crown of shoots. If no defoliation occurs, the lead tiller inhibits secondary tiller development through a process called lead tiller dominance. This biological process continues until inhibitory hormone production declines around the flowering stage. Usually only one secondary tiller develops from the 6 to 8 tiller buds that were formed with the previous set of phytomers. This secondary tiller asserts dominance by producing inhibitory hormones that prevent activation of growth of the remaining tiller buds. These undeveloped axillary tiller buds do not carry over viability into the next season and so represent lost potential herbage production.

Biologically effective defoliation by grazing after grasses have reached the third-leaf stage but before they have reached the flowering stage removes a portion of the leaf material of the lead tiller and reduces the tiller's production of the inhibitory hormone. With this reduction in the level of inhibitory hormone, the growth hormone can activate several tiller buds to begin development of a second set of tillers that will grow and produce greater herbage weight during the middle and late portions of the growing season.

All grass species in the Northern Plains have strong lead tiller dominance except Kentucky bluegrass and meadow bromegrass, which have weak lead tillers and low levels of inhibitory hormones. Grass species with weak lead tillers have relatively more tiller development while soil water is abundant. Plants with weak lead tillers have greater demands for water than do grasses with strong lead tillers. Tiller development and growth processes cease in weak lead tiller species at soil water deficiency levels that only slightly affect tillering and growth processes in strong lead tiller species.

Grasses with strong lead tillers produce one set of lead tillers and one set of secondary tillers. Effective grazing management during the early portion of the grazing season can increase the number of secondary tillers that develop during later portions of the grazing season, but the growing season length does not permit the development of a third set of tillers.

The number of sets of tillers determines the number of times each pasture in a rotation system can be grazed. Two sets of tillers permit two rotation grazing periods. Rotation systems that graze each pasture more than two times are not coordinated with grass plant growth and do not effectively meet grass plants' biological requirements. Arbitrary rotation of cattle in a sequence that is not coordinated with grass plant developmental stages and that does not meet the biological requirements of grassland plants does not produce satisfactory results.

Grass plants are damaged when too much leaf material is removed by grazing. During the growing season, grazing that deprives the shoot of sufficient leaf area to support tiller growth and development or that removes leaf buds or the apical meristem has the potential to stop the growth of the shoot and reduce plant density and limit herbage production for the season. Grazing too early or too late in the season removes a higher proportion of leaf material and results in even greater decreases in plant density and herbage production.

Sexual Reproduction in Grass Plants

Sexual reproduction is the process of seed production and the uncertain growth of a seedling. Changes in day length trigger the lead tiller to begin the process of sexual reproduction. Flower buds are produced by the apical meristem following the third-leaf stage, but these cannot be seen without dissection of a tiller. The first external sign of flower stalk development is the swelling of the sheath that encloses the flower head. This stage of grass plant development, referred to as the "boot" stage, marks the shoot's transition from the vegetative to the reproductive stage. Most cool-season plants enter the reproductive stage before 21 June, the longest day of the year, and most warm-season plants enter the reproductive stage after 21 June. Flowering, fertilization, and seed development--reproductive plant growth stages--soon follow.

Sexual reproduction is not the only method by which perennial grasses are perpetuated. Plants need not produce viable seed each year for a grassland to remain healthy. In North American prairies, the primary form of grass reproduction is vegetative, and defoliation management designed to enhance sexual reproduction through seed production does little to improve the prairie ecosystem and increase herbage production. Strategies that defer grazing until after seeds have developed are neither biologically nor economically effective.

The nutritional quality of grass plants diminishes sharply after the flowering stage. On pastures managed to produce grass seed, the growth of secondary tillers has not been stimulated by grazing between the third-leaf and the flowering stage, so the quantity and quality of herbage produced are lower than the quantity and quality of herbage produced on biologically managed rotation pastures. Because of these reductions, deferring grazing to allow seed production decreases livestock weight performance. The ecosystem energy and resources directed toward sexual propagation could be better directed into vegetative tiller production.

Vegetative Tiller Development

Very few perennial grasses grow from seed in established grasslands. Almost all young plants are vegetative tillers that have grown from axillary buds on the crowns of established plants. The lead tillers are most conspicuous during the early and mid portions of the growing season as the tillers progress through typical growth stages. After the lead tillers have flowered, secondary tillers can grow from axillary buds.

Secondary tiller growth can be suppressed or stimulated by the timing of grazing periods. Most secondary tillers do not complete their growth cycle during one growing season. Those that have not entered the sexual reproduction stage can overwinter and complete their growth stages the following year as lead tillers. Under some environmental conditions, like severe drought, lead tillers in which the apical meristem does not convert and begin to produce flower buds can overwinter and resume growth the following year. Lead tillers that have overwintered progress through their growth stages at abnormal times because the physiological processes were triggered by the photoperiod changes of the previous growing season.

Grasses start growth of next year's plants in late summer or early fall, during winter hardening--the plants' process of preparing for winter. Warm-season grasses produce a relatively large fall bud but suspend additional growth until the next spring. Cool-season grasses produce fall tillers with one and a half to four leaves during the winter hardening process. The fall tillers, which grow from the current season's axillary tiller buds on the crowns of perennial grass species between mid August and the end of the active growing season, remain viable over the winter. They continue growth as lead tillers the following spring, producing a high proportion of that season's herbage.

During the later portion of the growing season, the grass plant population consists of mature lead tillers, secondary tillers, and fall tillers. Mature lead tillers that are near the completion of their life cycle and early secondary tillers that were exposed to the photoperiods triggering sexual reproduction and have developed seed heads will not overwinter but will progress through a natural aging process called senescence. During this aging process, the cell components of the aboveground structures are translocated to belowground structures. The translocation of cell contents reduces the nutritional quality and the weight of the herbage. The nutritional quality of mature herbage during fall is about 4.8% crude protein, about half the mid summer quality. The weight of the herbage is about 40% to 60% of the herbage weight during mid summer.

Secondary tillers and fall tillers that will overwinter have active leaf material until the end of the growing season, when the chlorophyll fades and the leaves lose their green color, appearing brown like the lead tillers that have completed their growth cycle. Perennial grasses remain alive and maintain physiological processes throughout the year, even during the winter. Winter dormancy for perennial grasses is not a period of total inactivity but a period of reduced biological activity. The crown, some portions of the root system, and some leaf tissue remain active by using stored carbohydrates. Survival and spring regrowth of secondary tillers and fall tillers depend on the plant's having adequate carbohydrate reserves.

The quantity of carbohydrates stored during the winter hardening process is closely related to the amount of active leaf material on each tiller. Tillers with abundant leaf area during late summer and early fall can store adequate quantities of carbohydrates to survive the winter and produce robust leaves the following spring. Generally, the greater the number of active leaves on a tiller during the late summer and fall, the more robust the plants will be the following spring.

Treating young fall tillers of grasses as a source of bonus late-season forage for grazing livestock can be costly. Heavy grazing of grasslands during August to mid October removes sufficient leaf material from secondary and fall tillers that quantities of carbohydrates stored will be low. Tillers with low carbohydrate reserves may not survive until spring. Researchers suspect that fall tillers with fewer than one and a half leaves may be unable to store adequate carbohydrate reserves to survive the winter. Plants that have low carbohydrate reserves and survive the dormancy period produce tillers with reduced height and weight.

The rate at which plants respire, or use, stored carbohydrates during the winter is affected by the amount of insulation that standing plant material and snow provide from the cold winter air temperatures. The greater the amount of insulation, the more slowly the plant draws on its carbohydrate reserves. When the standing herbage on a grassland is grazed short and most of the snow is blown off, very rapid respiration can occur and deplete carbohydrate reserves before spring, causing plant death called "winter kill".

On tillers that have overwintered, the leaf portions with intact cell walls can regreen early in the spring. The leaf portions with ruptured cell walls remain brown. The surviving leaves, with their brown tops and green bases, are most obvious soon after the snow melts. The cells in the green portion of the overwintered leaves conduct photosynthesis and provide nourishment for the plant. In combination with the remaining stored carbohydrates, the products of photosynthesis support the development and growth of new leaves and roots, so the robustness of spring growth in plants that overwinter is dependent on the amount of surviving leaf area.

Removal of the leaf area of the overwintering tillers by grazing during fall or winter deprives developing tillers of a major source of nutrients, increases the demand on low levels of carbohydrate reserves, and results in reduced leaf production. Reductions in leaf height for the major grasses during the succeeding growing season range from 17% to 43%, and the contribution of herbage weight to the ecosystem biomass is greatly reduced.

The popular belief that grazing perennial grasses after they turn brown following a hard frost will not harm grass plants is not consistent with the biology of grass growth and should not be used as a foundation for grazing management decisions because of the resulting reductions in grass production and increases in pasture-forage costs the following year. Although it's commonly accepted as an innocuous practice, fall grazing has the potential to degrade grassland ecosystems because it can remove or damage fall growth and other leaf material that the grass plant depends on to survive the winter and resume growth the next spring.

Summary of Biologically Effective Grazing Management Recommendations

Developing biologically effective grazing management strategies that meet the biological requirements of the plants and enhance plant health status is the long-term solution to management-caused herbage reduction problems. Three effective management practices that improve plant health are recommended:

- Begin grazing in the spring only after plants reach the third-leaf stage (early May for crested wheatgrass and smooth bromegrass and early June for native rangeland).
- Coordinate grazing rotation dates with grass growth stages. Plant density increases when secondary tiller growth is stimulated by grazing for 7 to 17 days during the period between the third-leaf and flowering growth stages (early June to mid July for native rangeland).
- Do not graze spring and summer pastures or haylands during the fall. Fall grazing decreases the carryover secondary tillers and the new fall growth tillers and reduces the amount of herbage biomass produced the following season.

Management Implications

Biologically effective grazing management strategies place priorities on meeting the biological requirements of plants and facilitating the operation of ecological processes. The result is sustained high performance levels of healthy grassland ecosystems. The twice-over rotation system, a biologically effective grazing management strategy developed for use in the Northern Plains, was designed to manipulate processes that result in beneficial changes to plant growth, soil organisms, and biogeochemical cycles in the ecosystem. The twice-over rotation system on native rangeland with complementary domesticated grass spring and fall pastures coordinates defoliation with grass phenological growth stages to enhance vegetation, livestock, and wildlife performance.

The twice-over rotation system begins grazing in May, on a spring pasture of crested wheatgrass or other early growing domesticated cool-season grass that has reached the third-leaf stage, the earliest plant-growth stage at which grasses can be grazed without damage. Native grasses begin seasonal development more slowly, and the use of domesticated grass pastures in May protects native pastures by delaying grazing on them until the plants have reached the third-leaf stage.

A 3- to 6-pasture native range rotation system is used from early June until mid October, with each pasture grazed for two periods. Each native rangeland pasture is grazed for 7 to 17 days during the first period, the 45-day interval from 1 June to 15 July. The number of days each pasture is grazed during the first period is the same percentage of 45 days as the percentage of the total season's grazeable forage each pasture contributes.

During the first period, grasses are between the third-leaf stage and flowering phenophase, the stages of plant development at which grazing stimulates both tillering from axillary buds and enhanced activity of rhizosphere organisms. Increased vegetative reproduction by tillering contributes to the production of greater herbage weight and nutrient quality, and increased activity of the symbiotic soil organisms supplies the plants with greater quantities of nutrients to support additional grass tiller growth.

During the second period, after mid July and before mid October, each pasture is grazed for double the number of days it was grazed during the first period. Increasing secondary tillers improves herbage quality and extends the period of improved livestock performance two to two and a half months, until late September or mid October. The biology of native grass plants does not permit extending these conditions beyond mid October, when native rangeland herbage quality is insufficient to meet the nutritional requirements of lactating cows.

Cows and calves graze a fall pasture of Altai wildrye or other type of wildrye from mid October until weaning in early or mid November. Wildryes are the only perennial grasses that retain nutrient quality in the aboveground portions of the plant later than mid October. Removing livestock from native rangeland pastures at the end of the perennial-plant growing season allows native grasses to conserve stored nutrients that will maintain plant processes over the winter and early spring and to retain the leaf area of secondary tillers and the fall vegetative growth that will become next season's lead tillers. This practice ensures healthy plants in the spring and greater herbage production during the following growing season.

The twice-over rotation system's elevation of plant health and stimulation of beneficial ecosystem processes result in increased plant basal cover and aboveground herbage biomass and improved nutritional quality of forage. The twice-over rotation grazing management system with complementary domesticated grass pastures has a grazing season of more than 6.5 months, with the available herbage above, at, or only slightly below the nutritional requirements for a lactating cow for the entire grazing season. The increase in quantity and quality of herbage on the twice-over rotation system results in improved animal performance. Cow and calf accumulated weight gain, weight gain per acre, and weight gain per day are greater on the twice-over rotation system than on traditionally managed systems.

The greater herbage production per acre permits higher stocking rates on the twice-over rotation system than on traditional management systems. In western North Dakota, the twice-over rotation system requires fewer than 12 acres per animal unit for the entire 6.5-month grazing season. This is half the land area that a 6.0-month seasonlong grazing system requires when properly stocked at 24 acres per animal unit. The lower acreage required to carry a cow-calf pair for the season reduces pasture-forage costs.

Effective management practices meet the biological requirements of the plants and help the ecosystem processes function at their full potential. These management practices improve the performance levels of all grassland ecosystem components, elevate plant health status, and increase productivity of grassland ecosystems. The result is sustained greater herbage weight production, higher quality habitat for wildlife, and stronger livestock weight gain performance.

Conclusion

The twice-over rotation grazing management system applies defoliation treatment to grass plants at the appropriate phenological growth stages to stimulate the defoliation resistance mechanisms: the vegetative reproduction of tillers from axillary buds and the activity of the symbiotic rhizosphere microorganisms. This stimulation increases both secondary tiller development of grasses and nutrient flow in the rhizosphere, resulting in increased plant density and herbage production and improved herbage nutrient quality.

The increase in quantity and quality of herbage permits an increase in stocking rate levels, improves individual animal performance, increases total accumulated weight gain, reduces acreage required to carry a cow-calf pair for the season, improves net return per cow-calf pair, and improves net return per acre. The increase in basal cover and herbage biomass reduces the number and size of bare soil areas and increases the quantity of residual vegetation. These changes in vegetation produce conditions favorable to the limitation of grasshopper pestiferous species populations. The increase in plant density, herbage production, residual vegetation, and ecosystem health improves the habitat for prairie grouse, ducks, and other waterfowl and ground nesting birds.

The benefits of biologically effective grazing practices are both ecological and economic. By implementing the twice-over rotation grazing management strategy, producers protect rangeland health, increase their profits, and help to ensure that the grassland will sustain their cow-calf operation for years to come.

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