CHAPTER 4: Understanding Plant Response to Grazing

By John Hendrickson and Bret Olson

John Hendrickson is a Rangeland Scientist at the USDA-Agricultural Research Service Northern Great Plains Research Laboratory, Mandan, ND. *Bret Olson* is Professor of Range Ecology in the Animal and Range Sciences Department at Montana State University, Bozeman, MT.

10 KEY POINTS

- The effects of targeted grazing on plants are difficult to predict because plants grow in complex ecosystems subject to change.
- Along with fire, grazing was the first tool humans used to manage vegetation.
- Plants have developed numerous defense mechanisms to protect them from grazing.
- A plant's ability to recover after grazing depends on its ability to reestablish leaves and renew photosynthesis.
- How plants interact with neighboring plants will influence their response to grazing.
- To determine a plant's response to grazing, it should be grazed during its growth stage.
- To be effective, targeted grazing must be applied with the right herbivore at the right time.
- Two or more grazing treatments may be needed during a growing season to suppress undesirable vegetation.
- Care must be taken to avoid overgrazing desirable species.
- The key to success is knowing the right herbivore, time, and amount of grazing for each vegetation situation.

Photo: Ron Daines, Logan, UT

INTRODUCTION

Natural and agricultural landscapes containing a wide diversity of plants. The effects of grazing on individual plants can be difficult to predict because plants grow in complex ecosystems that are subject to seasonal and yearly fluctuations in weather and natural disturbances. The degree of grazing on a plant is determined by its nutritive value, growth form, content of distasteful or harmful secondary compounds, and type of livestock that graze it. Plants also differ in their ability to tolerate or compensate for grazing. The ability of a plant to regrow after grazing depends on its age and physiological condition, stage of development, and carbohydrate allocation patterns. In addition, competition with other plants for space, soil nutrients, and water can influence how a plant responds to grazing.[2, 20]

Problems with vegetation composition are not quickly or easily solved. Understanding plant response to grazing is further complicated because these factors are constantly interacting. Still, some general principles that explain how plants respond to grazing can be used to select the right season and level of grazing to reduce weeds and, at the same time, favor or promote the growth of desirable plants. The key to a successful grazing prescription is for managers to have a good understanding of how plants respond to grazing and to know how to use and manipulate these responses to accomplish long-term vegetation management and landscape goals.

Plant Tolerance and Susceptibility

Grazing is a natural process that has influenced the evolution of plants for millennia. Along with fire, it was the first vegetation management tool ever applied by humans. Grazing, or herbivory, is a constant influence on all natural plant communities. Every plant species varies in its ability to survive and prosper in a grazed ecosystem. Most plants are not killed with a single grazing event that removes its foliage, flowers, and stems. Rather, plants have evolved mechanisms that reduce their likelihood of being grazed or promote their regrowth after grazing.[2]

Plant Defense Mechanisms

Plants low in forage value or containing potentially toxic compounds have lower palatability, and herbivores usually avoid them. Palatability is a collective term for the plant characteristics that influence whether an herbivore will prefer or avoid a plant. Many weeds have an acrid or bitter taste or “noxious” smell, at least to humans. Yet, sheep and goats readily consume the bitter-tasting spotted knapweed and leafy spurge. The high fiber and lignin in some weeds make it difficult for herbivores to tear full bites of foliage, reducing the plant’s palatability. Still, most weeds are quite palatable and have good forage value during some point in the growing season. Many weeds are similar in structure and digestibility to native grasses and forbs. In fact, some weeds, like leafy spurge, remain greener, more succulent, and more nutritious longer into the summer than neighboring native plants.[12]

All plants possess a variety of compounds that can reduce forage value or deter grazing. Some are innocuous and some have the potential to harm livestock. These plant chemicals, called secondary compounds, include tannins, terpenes, alkaloids, oxalates, and glycosides. Levels of these compounds vary seasonally in plants and among plant parts. They can deter grazing by reducing plant digestibility, producing toxic effects, or causing illness. Animals reduce their intake of chemical-laden plants by selecting among different species or grazing specific plant parts like leaves or flowers that may have lower concentrations of these compounds.

Many shrubs and succulent plants possess thorns or spines that deter herbivores. Animals may also avoid young tender plant shoots mixed among the skeletons of dead stems. Some bunchgrasses accumulate and maintain upright dead stems that can deter grazing – a growth form commonly called a “wolf plant.”[9, 21] Long-term grazing or mowing may cause plants to become decumbent – growing closer to the ground with a larger number of small shoots containing fewer, smaller leaves.[4] Plants that develop these characteristics, called grazing morphotypes, are less likely to be grazed or will lose less plant material if they are grazed.[1]

Plant Tolerance to Grazing

Plants have traits that increase their ability to regrow after grazing.[2] Some are simply better than others at replacing leaves or stems lost to grazing and producing new shoots to sustain growth and reproduction. A plant's ability to recover after grazing depends largely on its ability to reestablish leaves and renew photosynthesis. Plants do not maintain large stores of energy and nutrients, so they need carbohydrates gained from photosynthesis to survive, grow, and reproduce.

When plants are grazed, meristems at the base of the leaf blade, sheath, and stem internodes (called intercalary meristems) can be activated to provide regrowth. Plants can further regain plant material by lengthening stems and producing new leaves from apical meristems located at the tip of the shoots and branches. Plants can also grow new tillers or shoots from axillary buds at joints (nodes) along the branch or at the base of the plant. Plants tolerant of grazing generally have an abundant supply of viable meristems or buds that can be quickly activated to initiate regrowth[8] if water and nutrients are available.

Understanding the contribution of meristems to plant regrowth can show how plants regrow after they are defoliated and how to apply grazing to hasten the demise of target plants. Losing apical meristems is particularly damaging to a plant because regrowth must come from activation of axillary buds, a slow process that requires significant water and nutrients. While intercalary and apical meristems respond most rapidly after defoliation, most regrowth comes from new tillers or shoots produced by axillary or crown buds.[2]

Grasses are different from forbs and shrubs in how they respond to grazing because of where their growing points or meristems are located. Grasses maintain apical and axillary buds near the base of the plant until flowering is initiated.[2] This is why grasses are relatively tolerant of grazing before flowering and why they can regrow quickly when grazed in the young leafy stage. On the other hand, forbs and shrubs have axillary buds all along the stem and apical buds at the tips of branches. These meristems are readily available to herbivores and can be removed throughout the plant's life. Some forbs and shrubs have numerous growing points in the root crown at the base of the plant that can produce new shoots or underground runners called rhizomes.

Plant tolerance to grazing is also determined by physiological mechanisms like accelerated photosynthetic rates after grazing, an ability to quickly move energy and nutrients throughout the plant, and good root growth and function. It was once believed that carbohydrate reserves in roots determined whether a plant could recover from grazing. But plants also gain the energy needed for regrowth from existing leaves, not just from carbohydrates stored in the roots. So, depending on management goals, grazing activities should focus on either enhancing or suppressing the plants' ability to gather sunlight and photosynthesize. Heavy

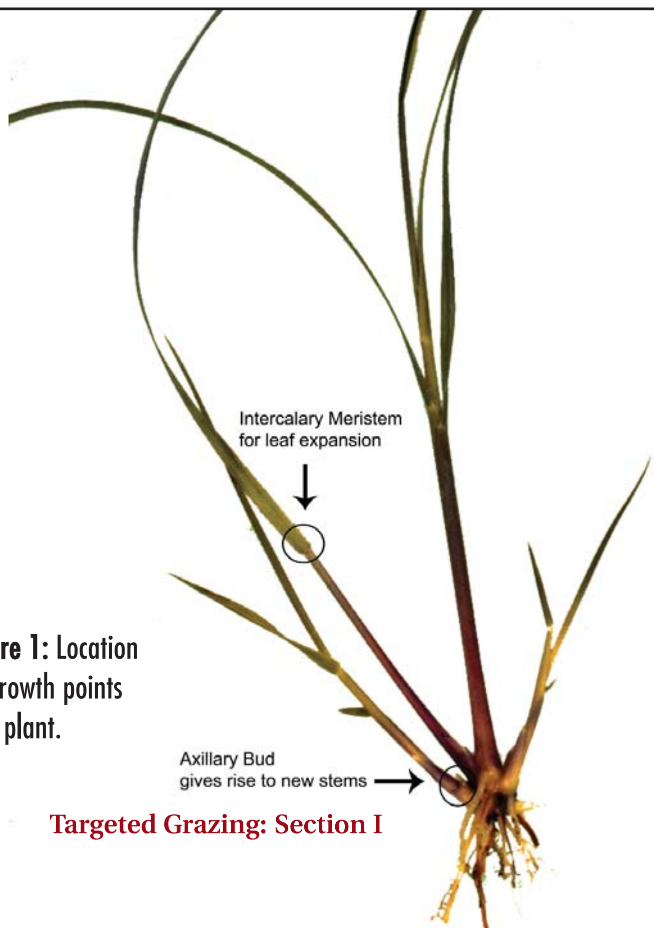

Figure 1: Location of growth points in a plant.

defoliation also reduces root growth, and thus a plant's ability to compete for water and nutrients, placing it at considerable disadvantage with neighboring plants.

Healthy and vigorous roots also help plants tolerate grazing. Grazing an actively growing plant above a certain level (about 50-60% utilization) will immediately curtail root growth because the plant no longer has the leaves to photosynthesize and produce carbohydrates needed to fuel root growth. Under favorable growing conditions, plants well adapted to grazing will resume root growth within a few days. Maintaining a leafy canopy for photosynthesis is therefore important for root growth and functioning.[4]

A good example of differences in grazing tolerance is how crested wheatgrass and bluebunch wheatgrass respond to defoliation. After being defoliated, crested wheatgrass sends more nitrogen and carbon to shoots than to roots compared with bluebunch wheatgrass.[6] Because crested wheatgrass allocates more resources to leaves and stems, it can regrow faster after grazing and reestablish leaves necessary for photosynthesis. This regrowth pattern gives crested wheatgrass its well-known ability to withstand and recover from grazing.

Competition Among Plants and Selective Grazing

A plant's response to grazing does not occur in isolation but as a member of a complex plant community. How plants interact with neighboring plants will influence how they respond to grazing. How severely a plant is defoliated may therefore be less important than how much a plant must compete with its neighbors for limited soil water and nutrients.[13] However, defoliation may not affect competitive interactions in the short term (less than three years) as strongly in drier regions as in wetter regions.[3]

Understanding which plants are likely to be grazed, and anticipating competitive interactions, forms the basis for effective targeted grazing strategies. Plants grazed more heavily are at a competitive disadvantage compared with those grazed less severely.[7] In simplest terms, grazing should be applied when the target plant is most palatable to livestock and most susceptible to damage through defoliation. Likewise, grazing should be applied when associated or desired plants are more tolerant to grazing. Such efforts can be enhanced by selecting animals that favor the plants targeted for control. It may be difficult for livestock producers or land managers to concentrate grazing during specific short periods when undesirable plants are most susceptible to damage, especially on vast rangelands where intensive management is more difficult. Still, the need to precisely apply grazing at specific times creates opportunities for livestock enterprises dedicated to vegetation management.

Selecting the Right Season to Maximize Grazing Effects

Plant phenology, or how plants grow through the season, should be considered when using grazing to manage vegetation. A plant's growth stage will determine how it responds to grazing. For example, most grasses and forbs tolerate early-season grazing, a time when soil moisture and nutrients needed for regrowth are abundant. Apical meristems are close to the soil surface at this time and less likely to be removed by herbivores, so leaf growth from stems or shoots can continue unabated after grazing.

Early in the growing season, plants need fewer nutrients because they are smaller with fewer leaves and stems. Losing leaves and reducing the ability to capture sunlight early in the season is less damaging than later in the growing season when energy demands are higher. For these reasons, grazing early in the season may have little effect on the plant community. However, many perennial plants have large root systems to support. Spring may be a poor time for controlling invasive herbaceous plants unless they grow and mature early in spring. The effects of early-spring browsing on shrubs are less well researched than for grasses and forbs. As with herbaceous plants, shrubs often tolerate early-season grazing because water and nutrients needed for regrowth are readily available.

Plants are most likely to be damaged by grazing at specific stages of development. Generally, a plant has the most difficulty recovering if it is grazed or browsed between the time when the flowerhead is ready to emerge (boot or bud stage) and full bloom.[22] Grasses are most susceptible to grazing in the boot stage when the developing, elongating flowerhead is causing the stem to swell, often bulging where the flowerhead is forming. For example, wheatgrasses grazed after the stem starts elongating and the flowerhead begins to emerge produced fewer new shoots the following year than when grazed earlier in the season, although the exact time when grazing is most detrimental varies by species.[10, 15] Likewise, forbs are most susceptible to grazing when stems are elongating and exposing the developing flowerhead – called the bolting stage.

Annual grasses require seeds to develop new plants. Defoliating grasses to limit seedstalk production can help reduce the numbers of seeds in the soil (the seedbank) and may decrease their density in the vegetative

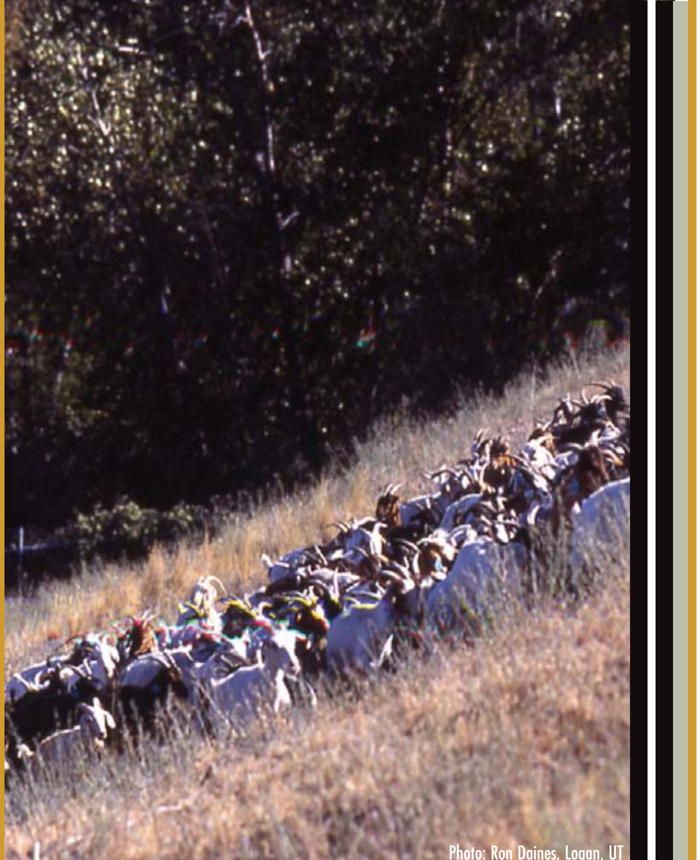
Photo: Ron Daines, Logan, UT

community. Biennial plants have a rosette stage in one year followed by a seed production stage the next year. As with annual plants, biennials need regular seed production to maintain populations. However, plants with a long-lived seedbank can be more difficult to control because the seeds can remain dormant in the soil until environmental conditions are favorable for emergence.

If the newly formed flowers and seeds are removed, the regrowth a plant needs to regain its ability to capture sunlight and synthesize carbohydrates must come from expansion of existing leaves or from new stems and leaves initiated by axillary buds. In many parts of the arid West, defoliation during the boot or bolting stage can damage plants because it coincides with a time in the growing season when water and nutrients required for regrowth are becoming limiting. This window of susceptibility for grazing target plants – generally in the boot stage for grasses and the bolting stage for forbs – typically occurs six to eight weeks before seed set.

Utilization levels during late summer or winter when a plant is dormant can be relatively high without impacting subsequent plant growth. Grazing dormant grasses and forbs generally has little effect on the plant because the leaves are not photosynthesizing and the plant will not attempt to replace lost plant material. However, browsing shrubs in the dormant season may hinder spring regrowth by removing axillary and apical buds. Shrub stems contain stored energy and nutrients a plant uses throughout dormancy, so losing stem material can harm the plant.

To be effective, grazing must be applied with the right species at the right time to suppress the target plant and leave the desired or native plants relatively intact. For example, Kentucky bluegrass is invading wetter sites in the Northern Great Plains. Because it starts growing relatively early in the season, Kentucky bluegrass may be suppressed by grazing early in spring when the native grasses are dormant. Annual grasses like cheatgrass are among the first plants to start growing in the spring. They begin flowering and elevating their seed-stalk when native grasses are still in the vegetative stage, for example, they have not started producing flowers. That opens an opportunity to graze such grasses early in the season to suppress them and favor growth of perennial grasses. In August 2005, sheep grazing a foothill bench in Montana avidly consumed flowerheads of spotted knapweed and avoided the native perennial grasses, most likely because the relatively green spotted knapweed had greater nutritive value than the dormant perennial grasses. Grasses were hardly used because they were dormant.

The Effects of Repeated Grazing

Two or more grazing treatments during a grazing season are often needed to suppress undesirable weedy plants simply because plants regrow. During the growing season, grazed areas should be rested for at least four weeks to allow desired plants to regrow leaf material and root mass. For example, weeds like spotted knapweed and yellow starthistle can be grazed as they begin bolting in the spring, which usually occurs before native grasses become vulnerable to defoliation. The weeds will generally respond by producing new shoots. Grazing can be reintroduced to the site when the native plants have completed seed production and the weeds are still bolting and flowering in response to the earlier grazing.

Weeds are susceptible to grazing at a certain stage of their development, but so are the desired species. The key in using repeated grazing is to avoid grazing desirable plants twice during the growing season, or at least ensure that enough time has elapsed for sufficient regrowth. Plant composition should be carefully monitored. The period of susceptibility of desirable species and weeds often coincide, but weeds often regrow more rapidly after grazing. For example, leafy spurge can be more tolerant of defoliation than the desired species.[18]

Repeated grazing can be very effective. In southwestern Montana, spotted knapweed-infested areas repeatedly grazed by sheep had lower densities of seedlings, rosettes, and mature spotted knapweed plants than ungrazed areas.[17] Further, grazed areas had fewer young spotted knapweed plants and spotted knapweed seed in the seedbank than ungrazed areas. These changes were evident after three summers of repeated sheep grazing with minimal impact on the native grass community even though the grasses were grazed at rates similar to those for spotted knapweed.[19] The density of mature leafy spurge stems was relatively unchanged, but the leafy spurge stems were shorter.[16] Other studies indicate that sheep must graze leafy spurge at least four years before it is noticeably reduced.[5, 11]

Grazing Effects on Flowering and Seed Production

Most sheep and goats relish bolting stems with their nutritious developing flowerheads.[14] Removing the developing flowerhead of biennial or perennial plants will likely prevent seed production, one of the most observable effects of carefully timed grazing. Three years of repeated sheep grazing in southwestern Montana reduced leafy spurge seed in the seedbank and seedling densities. The plant may send up new shoots from the base, but seed from these new shoots will rarely mature before the end of the growing season. Annual weeds are more likely to resprout and produce viable seeds. For example, grazing cheatgrass or yellow starthistle at flowering may trigger a regrowth of flower stalks yielding more seeds than ungrazed plants. In this case, repeated grazed may be needed to prevent further seed production.

Grazing Clonally Spreading Plants

Some weeds like leafy spurge, Canada thistle, reed canarygrass, and kudzu reproduce asexually, spreading by extensive lateral root systems or rhizomes that give rise to new plants. These species respond differently to grazing. While grazing can reduce seed production and may hinder the long-distance spread of seed via wind, water, or animals, these species can still spread across the landscape by their underground network of roots or rhizomes. Because of this, they are often more difficult to suppress.

CONCLUSIONS

Landscapes are collages of complex plant communities and site conditions. Within a plant community, competition for shared and often limited resources can be fierce. Prescription grazing managers must consider how the forage needs of their livestock can provide vegetation management solutions. To be successful, using grazing or browsing to control weeds requires a clear understanding of how both target and non-target plants respond to grazing, how plant communities can be modified by grazing pressure, and how grazing integrates with other management activities. Vegetation can often be effectively managed by simply grazing the right herbivore at the right time and intensity. The key is knowing the right herbivore, time, and amount of grazing for each vegetation situation.

Literature Cited

[1]Berdahl, J.D., A.C. Wilton, and A.B. Frank. 1989. Survival and agronomic performance of 25 alfalfa cultivars and strains interseeded into rangeland. *Journal of Range Management* 42:312-316.

[2]Briske, D.D. 1991. Developmental morphology and physiology of grasses. *In:* R.K. Heitschmidt and J.W. Stuth [EDS.], Grazing management: An ecological perspective. Portland, OR: Timber Press. p.109-139.

[3]Briske, D.D. and J.R. Hendrickson. 1998. Does selective defoliation mediate competitive interactions in a semiarid savanna? A demographic evaluation. *Journal of Vegetation Science* 9:611-622.

[4]Briske, D.D. and J.H. Richards. 1995. Plant responses to defoliation: A physiological, morphological and demographic evaluation. *In*: D.J. Bedunah and R.E. Sosebee [EDS.], Wildland plants: Physiological ecology and developmental morphology. Denver, CO: Society for Range Management. p. 635-710.

[5]Bowes G.G. and A.G. Thomas. 1978. Longevity of leafy spurge seeds in the soil following various control programs. *Journal of Range Management* 31:137-140.

[6]Caldwell, M.M., J.H. Richards, D.A. Johnson, R.S. Nowak, and R.S. Dzurec. 1981. Coping with herbivory: Photosynthetic capacity and resource allocation in two semiarid *Agropyron* bunchgrasses. *Oecologia* 50:14-24.

[7]Caldwell, M.M., J.H. Richards, J.H. Manwaring, and D.M. Eissenstat. 1987. Rapid shifts in phosphate acquisition show direct competition between neighboring plants. *Nature* 327:615-616.

[8]Dahl, B.E. 1995. Developmental morphology of grasses. *In:* D.J. Bedunah and R.E. Sosebee [EDS.], Wildland plants: Physiological ecology and developmental morphology. Denver, CO: Society for Range Management. p. 22-58.

[9]Ganskopp, D, R. Angell, and J. Rose. 1992. Response of cattle to cured reproductive stems in a caespitose grass. *Journal of Range Management* 45:401-404.

[10]Hendrickson, J.R., J.D. Berdahl, M.A. Liebig, and J.F. Karn. 2005. Tiller persistence of eight intermediate wheatgrass entries grazed at three morphological stages. *Agronomy Journal* 97:1390-1397.

[11]Johnston A. and R.W. Peake. 1960. Effect of selective grazing by sheep on the control of leafy spurge (*Euphor bia esula* L.). *Journal of Range Management* 13:192-195.

[12]Landgraf, B.K., P.K. Fay, and K.M. Havstad. 1984. Utilization of leafy spurge (*Euphorbia esula*) by sheep. *Weed Science* 32:348-352.

[13]Mueggler, W.F. 1972. Influence of competition on the response of bluebunch wheatgrass to clipping. *Journal of Range Management* 25:88-92.

[14]Olson B.E. and R.G. Kelsey.1997. Effect of Centaurea maculosa on sheep rumen microbial activity and mass in vitro. *Journal of Chemical Ecology* 23:1131-1144.

[15]Olson, B.E. and J.H. Richards. 1988. Annual replacement of the tillers of Agropyron desertorum following grazing. *Oecologia* 76:1-6.

[16]Olson B.E., R.T. Wallander, and R.W. Kott. 1997a. Recovery of leafy spurge seed from sheep. *Journal of Range Management* 50:10-15.

Literature Cited

[17]Olson B.E., R.T. Wallander, and J.R. Lacey. 1997b. Effects of sheep grazing on a spotted knapweed-infested Idaho fescue community. *Journal of Range Management* 50:386-390.

[18]Olson B.E. and R.T. Wallander. 1999. Carbon allocation in *Euphorbia esula* and neighbors after defoliation. *Canadian Journal of Botany* 77:1641-1647.

[19]Olson B.E. and R.T. Wallander. 2001. Sheep grazing of spotted knapweed and Idaho fescue. *Journal of Range Management* 54:25-30.

[20]Trilica, M.J. and L.R. Rittenhouse. 1993. Grazing and plant performance. *Ecological Applications* 3:21-23.

[21]Truscott, D.R. and P.O. Currie. 1989. Cattle preferences for a hybrid grass: Chemical and morphological relationships. *Journal of Range Management* 42:22-27.

[22]Vogel, W.G. and A.J. Bjugstad. 1968. Effects of clipping on yield and tillering of little bluestem, big bluestem and indiangrass. *Journal of Range Management* 21:136-140.