Defoliation applied at some phenological growth stages negatively affects grass plants

Llewellyn L. Manske PhD
Range Scientist
North Dakota State University
Dickinson Research Extension Center

Abstract

Timing grazing according to phenological growth stages of grass plants is important. Grazing applied at some phenological growth stages can have detrimental effects on grass growth and herbage production. These stages occur during early spring growth before plants have reached the third-leaf stage and during the period after secondary tillers have been stimulated to grow and before they reach the third-leaf stage. Selective heavy fall and winter grazing of late-stimulated secondary tillers and of fall-initiated lead tillers of cool-season grasses also negatively affects plant growth and herbage production. Grazing applied at some phenological growth stages can produce positive effects on grass growth and herbage production by beneficially manipulating the biological processes grass plants have developed as defoliation resistance mechanisms: light defoliation of grass plants between the third-leaf and flowering phenophases stimulates growth of secondary tillers from axillary buds and stimulates activity levels of symbiotic organisms in the rhizosphere (Manske 1998).

Grass Leaf Development

Young grass leaves develop from leaf bud primordia produced in the apical meristem. Almost all cells of the leaf are formed while the leaf is a minute bud (Langer 1972). Growth of the leaf results from expansion in cell size (Esau 1960, Dahl 1995) and increase in weight (Coyne et al. 1995). The new growing leaf draws carbohydrates from roots, stems, or older leaves until its maintenance and growth requirements can be met by assimilates produced by the new leaves (Langer 1972, Coyne et al. 1995). Defoliation of leaf material before the tiller has reached the third-leaf stage has the potential to disrupt the formation of leaf bud primordia for the tiller. When the tiller is between the 3.0 and 3.5 leaf stage, the apical meristem ceases to produce leaf bud primordia and begins to produce flower bud primordia (Frank 1996, Frank et al. 1997). The previously formed leaf bud primordia continue to grow and develop (Esau 1960, Langer 1972), with the oldest cells at the tip (Langer 1972, Dahl 1995) and the oldest leaf outermost (Rechenthin 1956, Beard 1973). In the Northern Great Plains, most native cool-season grasses reach the third-leaf stage around early June, and most native warm-season grasses reach the third-leaf stage around mid June. Many domesticated cool-season grasses reach the third-leaf stage around late April and early to mid May.

Grazing before Third-Leaf Stage

Cool-season grasses initiate lead tiller growth during the fall and resume active growth the next spring. Spring growth of cool-season grass leaves depends both on carbohydrate reserves and on photosynthetic products from the portions of fall-initiated tiller leaves that have overwintered and regreened. Spring growth of warm-season grass leaves depends initially on carbohydrate reserves and later both on carbohydrate reserves and on photosynthetic product from young leaves. Grass plant growth and development depend on adequate carbohydrate reserves in early spring because the amount of photosynthetic product synthesized by early growing leaves is insufficient to meet the requirements for leaf growth (Heady 1975, Coyne et al. 1995). Grass growth also requires that the plant have adequate leaf area to provide photosynthetic product for early growing leaves. The total nonstructural carbohydrates of a grass plant are at low levels following the reduction of reserves during the winter respiration period, and the carbohydrate reserves remaining in the roots and stems are needed for both root growth and initial leaf growth during early spring. The low quantity of reserve carbohydrates may not be adequate to supply the entire amount required to support root growth and also support leaf growth until sufficient leaf area is produced to provide the photosynthetic assimilates required for plant growth and other processes (Coyne et al. 1995). Removal of aboveground material from grass plants not yet at the third-leaf stage deprives plants of foliage needed for photosynthesis and increases the demand upon already low levels of carbohydrate reserves when sequential leaves grow. The quantity of herbage produced by a grass plant after it has been grazed is dependent on the levels of carbohydrates present in the remaining herbage at the time of defoliation (Coyne et al. 1995). Defoliation of the tiller before the third-leaf stage, when the plant is low in carbohydrates, results in reduced growth rates of herbage production (Coyne et al. 1995) and negatively affects the peak herbage biomass production later in the year (Manske 1994).

Grazing after Third-Leaf Stage

Defoliation of leaf material after the third-leaf stage affects herbage biomass production in relation to the amount of leaf material removed. The amount of leaf area capable of conducting photosynthesis that remains after defoliation is an important factor affecting the quantity of herbage produced by the grazed grass plants. Severely defoliated plants depend upon stored carbohydrates for new plant growth (Briske and Richards 1995). There is an additional cost to the plant when the photosynthetic system needs to be replaced from stored carbohydrates. This implied reduction in efficiency results in low growth rates and reduced quantities of herbage biomass produced (Coyne et al. 1995). Additional restrictions inhibit herbage production when the stored carbohydrates are at low levels (Coyne et al. 1995). Plants with sufficient leaf area remaining after defoliation utilize some stored carbohydrates for development of new leaf tissue (Briske and Richards 1995, Coyne et al. 1995), but the source of carbohydrates for most new growth is current photosynthates, which are preferentially allocated to areas of active shoot growth (Richards and Caldwell 1985, Briske and Richards 1995). Replacement of leaf tissue from current assimilates has a lower cost to the plant than growth from stored carbohydrates and results in higher growth rates and increased production of herbage biomass (Coyne et al. 1995).

Defoliation after the third-leaf stage stimulates vegetative reproduction from axillary buds by reducing apical dominance (Manske 1998). Light defoliation of grass plants between the third-leaf and flowering stages stimulates growth of secondary tillers and stimulates rhizosphere organism activity (Manske 1998). The presence of higher levels of carbohydrate reserves before defoliation increases the number of stimulated tillers that grow (Coyne et al. 1995), and the resulting development of secondary tillers increases herbage biomass. Rate of growth of secondary tillers is variable depending on the growing season periods during which axillary bud growth is stimulated.

Early stimulated secondary tillers require less time to reach the third-leaf stage than do late-stimulated tillers. Grazing periods should be synchronized with the growth rate of the stimulated secondary tillers so that defoliation is applied only after they reach the third-leaf stage.

Grazing during Late Season

In the fall, cool-season grass species initiate lead tillers, which overwinter. The following spring, the tiller leaf cells with intact cell walls regreen, resume active growth, and provide photosynthetic product for new leaf growth (Briske and Richards 1995, Manske 1998). Late-stimulated secondary tillers that start development during late June or early July usually do not produce flower heads and also frequently overwinter, resuming active growth the subsequent growing season (Briske and Richards 1995, Manske 1998). Selective severe fall and winter defoliation of late-stimulated secondary tillers and cool-season fall-initiated lead tillers reduces their contribution to the ecosystem and results in greatly reduced grass density and herbage production the following year (Manske 1998) because with late-season defoliation plants are unable to replenish adequate amounts of reserve carbohydrates to support active growth (Coyne et al. 1995).

Time of Grazing Affects Herbage Biomass

Grazing early in the spring greatly affects the percentage of the potential peak aboveground herbage biomass produced. Studies conducted in the Northern Great Plains have evaluated starting dates for seasonlong grazing management (Campbell 1952, Rogler et al. 1962, Manske 1994). The data from three locations show that if seasonlong grazing is started in mid May on native range, 45-60% of the potential peak herbage biomass will be lost and will never be available to grazing livestock. If the starting date of seasonlong grazing is delayed until early or mid July, nearly all the potential peak herbage biomass will grow and be available to the grazing livestock, but the nutritional quality will be at or below the crude protein levels required for a lactating cow. If the starting date is deferred until after mid July, less than peak herbage biomass will be available to grazing livestock and nutritional quality will be low because of senescence and the translocation of cell material to belowground structures. Data from the studies indicate that a starting date between early June and early July results in the fewest negative effects on herbage biomass production and nutritional quality of the available forage. The dates at which native range grasses reach the third-leaf stage indicate that seasonlong grazing management should delay grazing until mid June, but rotation systems could begin grazing on native range in early June. Domesticated cool-season grasses such as crested wheatgrass and smooth bromegrass reach their third-leaf stage in late April or early May and can serve as complementary pastures before native range pastures are ready for grazing in the spring. Numerous domesticated wildrye varieties translocate their aboveground cell material to belowground structures later in the fall than do other grasses. These varieties of wildrye can serve as complementary pastures for grazing in the fall.

Time of Grazing Affects Animal Performance

The physical damage grass plants sustain from early spring grazing applied before the third-leaf stage and from selective heavy fall and winter grazing of late-stimulated secondary tillers and fall-initiated lead tillers reduces herbage production and negatively affects animal performance and production (Manske 1996, Manske and Sedivec 1999). Stocking rate, animal gains, net return per cow/calf pair, and net return per acre are reduced and pasture costs and costs per pound of calf gain are increased on management strategies that heavily graze native range fall and winter and/or graze during early spring before the third-leaf stage.

Grazing Readiness

The 3.0 to 3.5 leaf phenological growth stage is the best indicator of the grass plants' grazing readiness. Grazing grass plants prior to the third-leaf stage negatively affects grass growth, herbage production, and animal production and exerts a negligible stimulatory effect on tillering (Olson and Richards 1988, Vogel and Bjugstad 1968). Starting grazing after the third-leaf stage allows plants to establish sufficient leaf area to produce adequate amounts of photosynthetic assimilate to meet leaf-growth requirements and allows leaf bud primordia in the apical meristem to develop completely. Defoliation after the third-leaf stage stimulates secondary tiller development and rhizosphere organism activity. Secondary tillers should be allowed to reach the third-leaf stage before grazing. Late-stimulated secondary tillers and fall-initiated lead tillers should be managed in the fall and winter so that they retain adequate leaf material to produce sufficient carbohydrate reserves for winter respiration and to regreen and contribute sufficient photosynthate for active root and leaf growth in the spring.

Management Implications

The grazing management strategy that times grazing periods according to phenological growth stages of grasses is the twice-over rotation system with 3 to 6 native range pastures and spring and fall domesticated cool-season complementary pastures. The grazing periods of this management system are synchronized with the phenological growth stages of grasses so that the negative effects of grazing are minimized and the beneficial effects of grazing are enhanced.

Summary

Effective grazing management strategies are based on the phenological growth stage of grasses. Grazing early spring growth before grass plants reach the third-leaf stage and grazing stimulated secondary tillers during periods before they reach the third-leaf stage negatively affect grass growth and result in reduced herbage production. Native cool-season grasses reach the third-leaf stage around early June, and native warm-season grasses reach the third-leaf stage around mid June. Many domesticated cool-season grasses reach the third-leaf stage four to five weeks ahead of native range grasses. Secondary tillers reach the third-leaf stage at variable times, depending on the growing season period during which tiller development is initiated. Early stimulated secondary tillers require less time to reach the third-leaf stage than do late-stimulated tillers. Late-stimulated secondary tillers and cool-season fall-initiated lead tillers can overwinter and resume active growth the next growing season. Selective severe fall and winter grazing of late-stimulated secondary tillers and of fall-initiated lead tillers of cool-season grasses negatively affects grass growth and herbage production.

Acknowledgment

The subject matter of this paper was problematical and difficult to present in a concise and logical sequence because of its complexities. I am grateful to Amy M. Kraus for assistance in sorting this complex material by providing constructive suggestions for changes in sentence structure and organization which simplified and clarified the explanations of the information and I thank her for her perseverance during the development of the numerous versions of this manuscript. I am grateful to Sheri Schneider for assistance in processing the numerous changes of this manuscript.

Literature Cited

Beard, J.B. 1973. Turfgrass: science and culture. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Briske, D.D., and J.H. Richards. 1995. Plant responses to defoliation: a physiological, morphological and demographic evaluation. p.635-710. *in* D.J. Bedunah and R.E. Sosebee (eds.), Wildland plants: physiological ecology and developmental morphology. Soc. for Range Manage., Denver, CO.

Campbell, J.B. 1952. Farming range pastures. J. Range Manage. 5:252-258.

Coyne, P.I., M.J. Trlica, and C.E. Owensby. 1995. Carbon and nitrogen dynamics in range plants. p. 59-167. *in* D.J. Bedunah and R.E. Sosebee (eds.), Wildland plants: physiological ecology and developmental morphology. Soc. for Range Manage., Denver, CO.

Dahl, B.E. 1995. Developmental morphology of plants. p. 22-58. *in* D.J. Bedunah and R.E. Sosebee (eds.), Wildland plants: physiological ecology and developmental morphology. Soc. for Range Manage., Denver, CO.

Esau, K. 1960. Anatomy of seed plants. Wiley and Sons, New York, NY.

Frank, A.B. 1996. Evaluating grass development for grazing management. Rangelands 18:106-109.

Frank, A.B., J.D. Berdahl, and J.F. Karn. 1997. Phyllochron development in cool-season grasses. XVIII International Grassland Congress Poster.

Heady, H.F. 1975. Rangeland management. McGraw-Hill Book Company, New York, NY.

Langer, R.H.M. 1972. How grasses grow. Edward Arnold Ltd., London**.**

Manske, L.L. 1994. Problems to consider when implementing grazing management practices in the Northern Great Plains. NDSU Dickinson Research Extension Center. Range Management Report DREC 94-1005. Dickinson, ND. 11p.

Manske, L.L. 1996. Economic returns as affected by grazing strategies. pages 43-55. *in* Z. Abouguendia, ed. Total Ranch Management in the northern Great Plains. Grazing and Pasture Technology Program, Saskatchewan Agriculture and Food. Regina, Saskatchewan, Canada.

Manske, L.L. 1998. General description of grass growth and development and defoliation resistance mechanisms. NDSU Dickinson Research Extension Center. Range Management Report DREC 98-1022. Dickinson, ND. 12p.

Manske, L.L. and K.K. Sedivec. 1999. Early grazing strategies. North Dakota State University Extension Service. Circular

R-1167.

Olson, B.E., and J.H. Richards. 1988. Spatial arrangement of tiller replacement in *Agropyron desertorum* following grazing. Oecologia 76:7-10.

Rechenthin, C.A. 1956. Elementary morphology of grass growth and how it affects utilization. J. Range Manage. 9:167-170.

Richards, J.H., and M.M. Caldwell. 1985. Soluble carbohydrates, concurrent photosynthesis and efficiency in regrowth following defoliation: a field study with *Agropyron* species. J. Appl. Ecol. 22:907-920.

Rogler, G.A., R.J. Lorenz, and H.M. Schaaf. 1962. Progress with grass. ND Agr. Exp. Sta. Bull. 439. 15p.

Vogel, W.G., and A.J. Bjugstad. 1968. Effects of clipping on yield and tillering of little bluestem, big bluestem, and Indiangrass. J. Range Manage. 21:136-140.
