V.7 Beneficial Changes of Rangeland Through Proper Grazing

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Introduction

Grassland ecosystems are diverse and complex, a fact that makes developing management recommendations difficult. However, increasing knowledge of ecological principles and the intricacies of the numerous mechanisms that function in the grassland ecosystem have allowed for improvements in management strategies.

Several greenhouse and laboratory studies within the last 10 to 12 years have enabled scientists to begin to understand how grassland plants react to being grazed. Grassland plants and herbivores have evolved together for 20 million years. During this long period of coevolution, grassland plants have developed mechanisms to compensate for defoliation from herbivores and fire. These adaptive tolerance mechanisms can be separated into two main categories, but they do not function independently. The first mechanism involves numerous changes in the physiological growth processes within the grassland plant itself, and the second involves numerous changes in the activity levels of the symbiotic (mutually beneficial) soil organisms in the rhizosphere, which is the narrow zone of soil around perennial plant roots.

The physiological responses within the plant caused by defoliation have been reviewed and grouped into nine categories by McNaughton (1983). Physiological responses to defoliation do not occur at all times, and the intensity of the response varies. Grass plants have different physiological responses at various stages of growth. The key to ecological management by defoliation is to match the timing of defoliation events to the appropriate stage of growth that triggers the desired outcome.

All possible combinations of relationships between the physiological responses and the application of the defoliation-management treatment have not yet been quantitatively evaluated with scientific research. One of the main physiological effects of defoliation is the temporary reduction in the production of the blockage hormone auxin in young, developing leaves and within the meristem (the growth point where tissue is formed by cell division).

The reduction of plant auxin in the lead tiller allows either for the synthesis of cytokinin (a growth hormone) in the roots or crown or its utilization in axillary buds, which are growth points with potential to develop into vegetative tillers, resulting in the production of new plants (Murphy and Briske 1992). Partial defoliation of young leaf material reduces the hormonal effects of apical dominance (hormonal suppression of growth of other buds by the lead tiller) and allows secondary tillers to develop from the previous year's axillary buds. Secondary tillers can develop without defoliation manipulation after the lead tiller has reached the flowering growth stage. Usually, only one secondary tiller develops from the potential of five to eight buds because this secondary tiller also suppresses additional axillary bud development hormonally. When the lead tiller is partially defoliated between the third leaf stage and flowering, several axillary buds can develop subsequently into secondary tillers. No single secondary tiller is apparently capable of developing complete hormonal apical dominance following defoliation of the lead tiller at that time. Some level of hormonal control from the older axillary buds still suppresses development of some of the younger axillary buds. This mechanism is not completely understood, and scientists have not been able to manipulate the hormone levels so that all of the axillary buds develop into secondary tillers.

Besides encouraging grassland plants to tiller, defoliation also stimulates soil organism activity in the rhizosphere. The rhizosphere is that narrow zone of soil around living roots of perennial grassland plants where the exudation (leakage) of materials like sugars, amino acids, glycosides, and other compounds affects micro-organism activity. Bacterial growth in the rhizosphere is stimulated by the presence of carbon from the exuded material (Elliott 1978, Anderson et al. 1981). Protozoa and nematodes graze increasingly on the multiplying bacteria and accelerate the overall nutrient cycling process through the "fast" pathway of substrate decomposition proposed by Coleman et al. (1983). The activity of the microbes in the rhizosphere increases the amount of nitrogen available for plant growth (Ingham et al. 1985, Clarholm 1985). The presence of mycorrhizal fungi (those that live in association with plants) enhances the absorption of ammonia, phosphorus, other mineral nutrients, and water.

Rhizosphere activity can be manipulated by defoliation at early growth stages, when a higher percentage of the total nitrogen of the plant is in the aboveground parts and a higher percentage of the total carbon of the plant is in the belowground parts. At that time, partial defoliation disrupts the plant's relationship of carbon to nitrogen, leaving a relatively high level of carbon in the remaining plant. Some of this carbon is exuded through the roots into the rhizosphere in order to readjust the carbon–nitrogen ratio.

Because of limited access to simple carbon chains, bacteria in the rhizosphere are restricted in growth and activity levels under conditions when defoliation is absent. When defoliation management is used, rhizosphere bacteria increase in activity in response to the increase in exuded carbon. The increases in activity by the bacteria trigger increases in activity levels in the other micro-organisms that make up the nutritional food chain of the rhizosphere. These increases in activity levels ultimately increase available nutrients for the defoliated grass plant. The relationship between grassland plants and organisms in the rhizosphere is truly symbiotic with both entities receiving benefit from their association.

Rhizosphere activity can be stimulated by disrupting the carbon–nitrogen ratio through plant defoliation at early growth stages. During middle and late growth, carbon and nitrogen are distributed fairly evenly throughout the plant, and at these stages defoliation does not remove a disproportionate amount of nitrogen, and very little or no carbon is exuded into the rhizosphere. Also, water levels in the soil generally decrease during the middle and late portions of the grazing season and limit the activity levels of rhizosphere organisms.

The adaptive tolerance mechanisms that pertain to the changes in physiological growth processes within grassland plants, and to the changes in activity levels of the symbiotic organisms in the rhizosphere following defoliation, are the key to understanding the manipulation of beneficial effects from defoliation management under field conditions. Manipulation of these mechanisms by defoliation is also key to the development of ecologically sound recommendations for management of North America's grassland natural resources. Contributions to the development of biological and ecological foundations for grazing management recommendations were major goals of a research project developed to study the ecological effects of defoliation at the Dickinson Research Center in western North Dakota from 1984 to 1992. This study was expanded in 1990 to include sites in McKenzie County, ND.

The objectives of this study were to evaluate changes in plant-exuded material, soil organism activity and biomass, tiller development of grass plants, aboveground and belowground plant biomass, and livestock weight performance among twice-over rotation-grazing treatments, a 4.5-month seasonlong treatment, a 4-month deferred seasonlong treatment, a 6-month seasonlong treatment, and a long-term nongrazed treatment.

The Study Area and Methods

The long-term study site is located 20 miles north of Dickinson in southwestern North Dakota (lat. 47°14' N., long. 102°50' W.) on the Dickinson Research Center operated by North Dakota State University. The McKenzie County sites are located 21 miles west of Watford City (between lat. 47°35' and 47°50' N. and long. 104°00' and 103°45' W.) in the McKenzie County Grazing District of the Little Missouri National Grassland. The National Grassland is administered by the U.S. Department of Agriculture's Forest Service and managed in cooperation with the McKenzie County Grazing Association.

Soils are primarily dark in color and developed under grassland vegetation having cool, continental climate and moderate moisture levels. Average annual precipitation is 14 inches (356 mm) with 80 percent falling as rain between April and September. Temperatures in summer average 66 °F (19 °C) with average daily maximums of 80 °F (27 °C). Winter average daily temperatures are 13 °F (–11 °C) with average daily minimums of 2 °F (–17 °C). The vegetation is the wheatgrass–needlegrass type (Barker and Whitman 1988) of the mixed-grass prairie. The dominant native range species are western wheatgrass *(Agropyron smithii)*, needle-and-thread *(Stipa comata)*, blue grama *(Bouteloua gracilis)*, and threadleaved sedge *(Carex filifolia)*.

The treatments on native range were organized as a paired-plot design with two replications. The twice-over rotation grazing treatments at the Dickinson Research Center had three pastures with each grazed for 15 days between June 1 and July 15 and for 30 days after mid-July and prior to mid-October for a total of 4.5 months. Three seasonlong treatments were used: a 4.5-month seasonlong grazing between mid-June to early November, a 4-month deferred seasonlong grazing between mid-July to mid-November, and a 6-month seasonlong grazing between mid-May and mid-November. The long-term nongrazed treatment areas had not been grazed, mowed, or burned for more than 30 years prior to the start of data collection.

The McKenzie County sites had two grazing treatments. The rotation-grazing treatment had four pastures with each grazed for two periods. The other treatment had a traditional seasonlong grazing method. A long-term nongrazed exclosure was available for nondestructive sampling of control sites. Commercial crossbred cattle were used on all treatments in this trial.

Each of the treatments was stratified on the basis of three range sites (sandy, shallow, and silty). Samples from the grazed treatments were collected on both grazed and ungrazed (protected with cages) quadrats (plots). Aboveground plant biomass was collected on seven sampling dates from May to October. Belowground plant biomass and soil micro-organism data were collected on four sampling periods. Aboveground and belowground net primary productivity (NPP) were determined by methods outlined by Sala et al. (1981) and Bohm (1979), respectively. The major components sampled were live material (by species), standing dead material, and litter.

Plant materials were analyzed for nutrient content using standard procedures (Association of Official Analytical Chemists 1984). Plant species composition was determined between mid-July and mid-August using the 10-pin point frame method as described by Cook and Stubbendieck (1986). Root exudates were determined using procedures outlined by Haller and Stolp (1985). A standard paired-plot t-test (Mosteller and Rourke 1973) was used to analyze differences between means.

Individual animals were weighed on and off each treatment and on each rotation date. Mean weights of cows and calves were adjusted to the 8th and 23d day of each month of the grazing period. Biweekly live-weight performance periods of average daily gain and accumulated weight gain for cows and calves were used to evaluate each treatment. Response surface analysis (Kerlinger and Pedhazur 1973) with a repeated observation design was used to compare animal response curves among treatments and was reported by Manske et al. (1988).

Findings

Percent basal cover of grasses increased 25 percent (from 15 percent to 19 percent basal cover) on the rotation-grazing treatments compared to seasonlong treatments (table V.7–1). Basal cover of sedges and forbs decreased by 4 percent and 36 percent, respectively, on the rotation treatments compared to seasonlong treatments. Plant community relative percent composition changed, with grasses increasing by 14 percent, sedges decreasing by 14 percent, and forbs plus shrubs decreasing by 40 percent, on the rotation treatments compared to seasonlong treatments (table V.7–2).

The amount of herbage that remained standing on September 1 after the rotation treatments was greater than the amount of total current-year's growth on the long-term nongrazed treatments (table V.7–3). These data do not account for the amount of vegetation removed by livestock on the rotation treatments. During the entire grazing season, an average of 15 percent more herbage biomass was standing after each grazing period on the rotation treatments compared to long-term nongrazed treatments. Seasonlong treatments averaged 8 percent and 29 percent less herbage biomass standing after grazing than on the nongrazed and rotation treatments, respectively. The relatively greater amount of photosynthetic leaf area remaining on the rotation treatments at the end of the grazing season was beneficial for the continued development of the grassland ecosystem at a higher production level. This remaining herbage also provided a benefit as wildlife habitat.

Tiller development of grass plants and the resulting increase in aboveground herbage biomass were greater on the rotation treatments than on the nongrazed and seasonlong treatments. These increases in the vegetation suggest that removal by defoliation of some young leaf material early in the growth cycle has some effect on the

Table V.7–1—Mean percent basal cover, by vegetative growth form categories

	Treatments		
	Season-long	Rotation	Percent difference
Grass	14.7	18.6	+25.2
Sedge	7.7	7.6	–3.8
Forb	3.8	2.4	35.9
Shrub	0.1	0.1	—

Table V.7–2—Mean relative percent composition of plant communities

	Treatments		
	Season-long	Rotation	Percent difference
Grass	55.1	63.2	+14.1
Sedge	30.6	28.0	–13.6
Forb and shrub	14.5	8.7	–39.6

Table V.7–3—Mean monthly aboveground herbage biomass, in pounds per acre, remaining after grazing on three range sites

	Monthly sample periods				
Treatments	1June	1July	1Aug.	1Sept.	1Oct.
Nongrazed	822*a*	1,010*a*	1,144*a*	888*a*	—
Seasonlong	974*a*	1,017*a*	785*b*	717*a*	—
Rotation	990*a*	1,211*b*	1,231*a*	993*b*	987

Means of same column followed by the same letter are not significantly different (P<0.05).

reduction of auxin and the subsequent stimulation of cytokinin, which causes axillary buds to develop into secondary tillers. Thus, defoliation of grass plants at an early growth stage exerts beneficial effects on vegetative tiller development.

Preliminary interpretation of the rhizosphere data collected so far indicates that greater amounts of exuded material were released into the rhizosphere on the rotation treatments than on nongrazed or seasonlong treatments. These data also indicate that the biomass of soil mites was greater on the rotation treatments compared to the nongrazed or seasonlong treatments. This information suggests that removal of some young leaf material by defoliation at early growth stages has some effect on increasing exuded material, which in turn presumably stimulates activity of the bacteria. Greater bacterial activity stimulates activity of subsequent organisms in the nutritional food chain of the rhizosphere. Activity levels were increased in protozoa, nematodes, and mites. Increasing the activity levels of organisms in the rhizosphere increases the amount of nitrogen available for plant growth. Thus, defoliation of grass plants at an early growth stage has beneficial effects on symbiotic rhizosphere organism activity and results in greater amounts of nutrients available for growth by those plants.

The period when defoliation of grass plants showed beneficial effects on the increases in vegetative tillers and symbiotic rhizosphere organism activity occurred between the third leaf stage and the flowering period during this study.

The increase in grass tiller development and symbiotic rhizosphere activity on the twice-over rotation treatments allowed a mean increase in stocking rate of 40 percent greater than on the 4.5-month seasonlong treatments, 96 percent greater than on 6-month seasonlong treatments, and 9 percent greater than the 4-month deferred seasonlong treatments.

Accumulated weight performance of individual cows and calves (table V.7–4), their average daily gain (table V.7–5), and weight gain per acre (table V.7–6), were greater on the rotation treatments compared to the seasonlong and deferred seasonlong treatments. Weight performance of cows and calves on the three grazing treatments was

Table V.7–4—Mean annual accumulated weight gain in pounds for cows and calves

	Treatments		
	Deferred season-long	Season-long	Rotation
		Pounds	
Cows	34	40	107
Calves	204	284	309

Table V.7–5—Mean annual average daily weight gain in pounds for cows and calves

	Treatments		
	Deferred season-long	Season-long	Rotation
		Pounds	
Cows	0.32*a*	0.34*a*	0.62*b*
Calves	1.80*a*	2.09*a*	2.21*b*

Means of same row followed by the same letter are not significantly different (P<0.05).

Table V.7–6—Mean annual weight gain in pounds per acre for cows and calves

	Treatments		
	Deferred season-long	Season-long	Rotation
		Pounds per acre	
Cows	2.6*a*	2.9*a*	8.1*b*
Calves	20.4*a*	20.5*a*	28.5*b*

Means of same row followed by the same letter are not significantly different (P<0.05).

generally not significantly different during the first grazing period of June and July. During the second grazing period, after early August, the animal weight performance on the rotation treatments was significantly greater than on the seasonlong and deferred seasonlong treatments (Manske et al. 1988). Individual animal performance improved on the twice-over rotation-grazing system with an increase in calf average daily gain of 6 percent greater than 4.5-month seasonlong and 23 percent greater than deferred seasonlong grazing treatments. Average daily weight gain of cows improved on the twice-over rotation system by 82 percent greater than 4.5-month seasonlong and 94 percent greater than deferred seasonlong grazing treatments.

The combination of increases in stocking rate and individual animal performance gave the twice-over rotation system a considerable increase in animal weight gain per acre over the other grazing treatments. Calf weight gain per acre on the twice-over rotation system was 39 percent greater than 4.5-month seasonlong and 40 percent greater than deferred seasonlong treatments. Cow weight gain per acre on the twice-over rotation system was 179 percent greater than 4.5-month seasonlong and 212 percent greater than deferred seasonlong grazing treatments.

The improved livestock weight performance during the later portion of the grazing season on the rotation treatments was primarily attributed to the increase in available nutrients from the addition of secondary tillers. These tillers had developed from axillary buds and were at an early growth stage during the second rotation period. Generally, the available herbage on the rotation treatments was 1.5 and 2.5 percentage points greater in crude protein content than the herbage on the seasonlong and deferred seasonlong treatments during the later portion of the grazing season.

The grassland plant community can be changed beneficially when grazing defoliation is properly timed to coincide with the appropriate growth stage of the grass plants (fig. V.7–1). Grass plant density is increased, and total herbage production is increased when defoliation by grazing is timed to occur between the third leaf stage and the flowering stage. A greater amount of vegetation can remain at the end of the grazing season, which causes a noticeable change in the vegetation canopy cover. There

Figure V.7–1—Land managers and ranchers can create beneficial changes on rangeland by using proper and timely grazing systems. Changes in turn can affect the habitat for some grasshopper species, offering another possible tool for long-term grasshopper management.

is a decrease in the amount of bare ground present in the pastures. These changes in plant structure and density should be unfavorable for most troublesome rangeland grasshopper species. Most rangeland pest grasshopper species are favored by open vegetation canopy and bare areas. These open areas in the vegetation structure are used by the grasshoppers to provide access to solar radiation during nymphal development for body temperature regulation and by some species for egg-laying sites.

Grassland areas that have higher percentages of open canopy should have relatively higher grasshopper populations. Grassland areas that have had beneficial changes in the structure and density of the vegetation as a result of the manipulation of the adaptive tolerance mechanisms of the grass plants by the twice-over rotation treatment should show negative effects on grasshopper populations. The changes in vegetation structure and density should lower air and soil temperatures, raise relative humidity, and reduce the level of irradiation within the grasshopper microhabitat. These changes in grasshopper microhabitat should lengthen the time required for nymphal development, exposing the nymphs to numerous causes of death, which would raise the average daily mortality rate and reduce the density of individuals. Lowering the number of nymphs will reduce the number of grasshoppers that develop into adults. This, in turn, will reduce the number of eggs laid. All of these factors should cause an overall reduction in the population of grasshoppers on grassland areas managed with twice-over rotation treatments.

The other characteristic of the twice-over rotation treatment that would negatively affect grasshopper populations is that the sequence of grazing periods on the rotation-system pastures is never the same in consecutive years. This variation should alter the vegetation growth patterns enough so that no single pest grasshopper species would consistently be favored.

Conclusions

Additional research would help quantify exuded material, soil organism activity and biomass, axillary bud development into tillers, and nitrogen, carbon, and phosphorus cyclic flows. These additional findings would allow scientists to understand more completely the adaptive tolerance mechanisms developed by grassland plants to compensate for defoliation. Grassland managers then could manipulate these mechanisms more precisely and be able to use the beneficial defoliation effects on a finer level and further improve the grassland ecosystem. Additional research also needs to document relationships between the changes in vegetation structure and density and the effects on grasshopper population dynamics.

Data collected to date have shown that defoliation of grass plants between the third leaf stage and flowering stage has beneficial effects on the physiological responses within the plant. These effects allow for greater tiller development and beneficial effects on the symbiotic rhizosphere organism activity, which is believed to increase the amount of nitrogen available for plant growth. Deliberate and precise manipulation of these adaptive tolerance mechanisms can increase secondary tiller development and total herbage biomass. The secondary tillers increase the nutrient content of the herbage, and that increase enhances individual animal weight performance during the latter portion of the grazing season.

The increase in herbage biomass permits an increase in stocking rate and leaves a greater amount of herbage after grazing. This increase in residual herbage is beneficial for grassland wildlife habitat. Plant density, canopy cover, and litter cover increase as a result of increased tiller growth, which in turn, reduces the impact of raindrops, reduces and slows runoff, reduces erosion, and increases water infiltration. These improvements in the vegetation density and canopy cover should have negative impacts on grasshopper populations. Grazing management recommendations of systematically rotating 7- to 15-day periods of defoliation between the third leaf stage and flowering growth stage (June 1–July 15 in western North Dakota) on each pasture should maximize beneficial effects on the adaptive tolerance mechanisms of grassland plants.

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