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Prairie Sandreed Response to Preceding-Year Defoliation and Precipitation Regime

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PRAIRIE SANDREED RESPONSE TO PRECEDING-YEAR DEFOLIATION AND PRECIPITATION REGIME

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ABSTRACT—Knowledge of how current-year grazing and drought stress affect subsequent-year herbage production is needed to enhance the management of semiarid Sandhills prairies. This study quantifies subsequent-year effects of defoliation and precipitation on prairie sandreed (*Calamovilfa longifolia*), a high-seral, warm-season tallgrass, and total graminoid herbage production in the Nebraska Sandhills. Mainplots (9.0 m^2) received either ambient precipitation (noncovered) or precipitation was excluded during April-May, June-July, or August-September, resulting in 66% to 135% of the long-term average (434 mm) precipitation. All species in 1.0 m^2 defoliated subplots were clipped in early July at the stubble height required for 30%, 60%, or 90%

defoliation of *C. longifolia*. Measurements were made during July of the following year. Yield of *C. longifolia* declined about 5% for each 10 percentage points of defoliation compared to 3% yield declines for all graminoids (grasses and sedges) combined, regardless of precipitation regime. Additionally, excluding precipitation during June-July reduced tiller density by about 44% and yield and percent composition of *C. longifolia* by about 25% compared to ambient precipitation. Periodic full growing-season deferment may be necessary to maintain high-seral species dominance in these grassland communities, particularly in pastures where overgrazing and drought stress occur concurrently during June or July.

Key Words: herbage response, prairie sandreed, seasonal water stress, tallgrasses, tiller demography

INTRODUCTION

Sands and sandy range sites are widely distributed throughout the Great Plains, with large contiguous areas of Sandhills prairie occurring in north-central Nebraska and south-central South Dakota. The Nebraska Sandhills encompass about 4.9 million ha of predominantly upland sites (i.e., water table >1 m below the soil surface throughout the growing season). This region is one of the major livestock production areas in the United States (Burzlaff 1962) and it consistently supports about one-third of the beef cattle production in Nebraska, primarily in cow-calf ranching operations (Miller 1998).

Prairie plant communities are characterized by diverse species groups that vary in their response to precipitation and defoliation (Olson et al. 1985; Fuhlendorf et al. 2001; Skinner et al. 2002). Tiller demography and herbage production of graminoids (grasses and sedges) are generally integrated responses to preceding-year and current-year precipitation and defoliation regimes (Olson et al. 1985; Smoliak 1986; Westoby et al. 1989; O'Connor et al. 2001). Furthermore, selective herbivory and season of defoliation can profoundly affect the ability of high-seral graminoids to dominate prairies (Ganskopp 1988; Reece et al. 1996; Engel et al. 1998).

As the most uniformly distributed and abundant species on upland sites, prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.] is the characteristic grass of Sandhills prairie in high-seral stages in the central and northern Great Plains (Rydberg 1895; Burzlaff 1962; Kaul 1998) and a primary forage species for livestock production (Frolik and Shepherd 1940; Stubbendieck 1998). It is preferentially grazed by cattle (Northup 1993; Cullan et al. 1999) and declines under prolonged heavy grazing.

The Nebraska Sandhills region is a fragile ecosystem that is highly susceptible to wind erosion when the vegetative cover is disturbed or destroyed (Tolstead 1942; Burzlaff 1962; Stubbendieck 1998). Wind can create or enlarge blowouts in disturbed areas and cover other areas with sand deposits (Tolstead 1942). Prairie sandreed's vigorous rhizome production enables this species to help stabilize the Sandhills and colonize denuded areas (Frolik and Shepherd 1940; Brejda et al. 1989).

In order to sustain livestock production, Sandhills ranchers must balance the needs and impacts of livestock with the growth and development of key components of the plant community such as prairie sandreed. This includes decisions about stocking rates, season of grazing, grazing systems, and pasture-use sequences (Brinegar and Keim 1942; Stubbendieck 1998; Reece et al. 2001). This task is complicated by variable precipitation patterns, including periods of drought.

A greater understanding of how the timing and amount of precipitation and the timing and intensity of defoliation affect subsequent-year production in semiarid Sandhills prairie is needed. We explored these relationships using rainout shelters and clipping treatments. We focused on prairie sandreed, a high-seral, warm-season tallgrass, as the key management species for this ecosystem. We hypothesized that (1) subsequent-year herbage production would not decline until a critical level of defoliation was exceeded, (2) such declines would be linear, and (3) the effects of defoliation would be greater when available moisture was restricted. To help interpret herbage production patterns, we also determined prairie sandreed tiller density and mean tiller weight. Secondarily we evaluated total graminoid herbage production, the sum of all perennial grass and sedge species.

METHODS

Study Site

This study was conducted at the University of Nebraska's Gudmundsen Sandhills Laboratory (GSL) near Whitman, NE (latitude 42°07′N, longitude 101°43′W, elevation 1,049 m). All sites were in pastures previously used

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for summer grazing (June-October) at moderate stocking rates (32 AUD ha^{-1}) since 1985. Soils are Valentine fine sands (mixed, mesic typic Ustipsamments). Site topography ranged from nearly level to 5% slope. Precipitation and air temperature were recorded by an automated weather station at GSL headquarters, ≤1.6 km from the study sites. We determined plant-year precipitation, the precipitation received during the preceding dormant season (October-March) plus that received during the current growing season (April-September). Plant-year is identified by the year of the active growing season. The 21-year average plant-year precipitation at GSL was 434 mm.

We selected four sites dominated by prairie sandreed (35% to 44% of total graminoid herbage) in July. Other common species included sand bluestem (*Andropogon hallii* Hack.), blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Griffiths.], Scribner panicum [*Dichanthelium oligosanthes* (Shult.) Gould var. *scribnerianum* (Nash) Gould], needle-and-thread (*Stipa comata* Trin and Rupr.], switchgrass (*Panicum virgatum* L.), and sun sedge (*Carex eleocharis* Baily). Two sites were randomly selected for treatment in 2001 and two for treatment in 2002. Cattle were excluded from each site with electric fence exclosures.

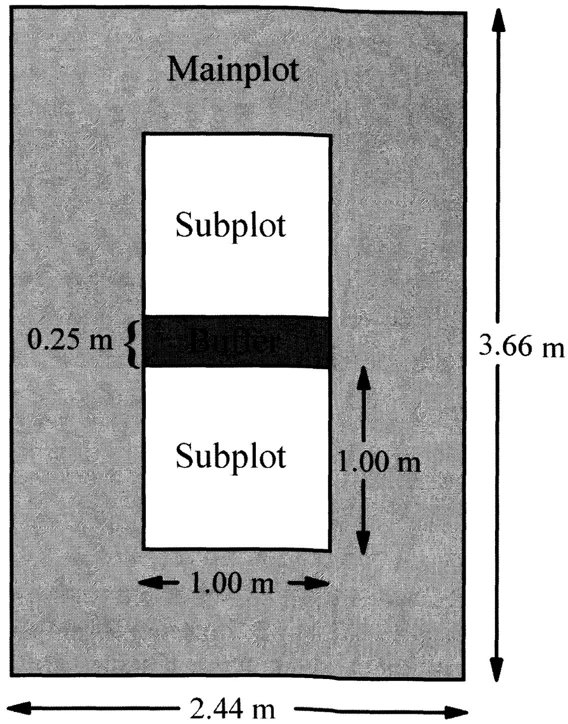

Figure 1. Diagram of plot arrangement. Precipitation treatments (ambient precipitation or exclusion of precipitation during April-May, June-July, or August-September) were applied to the 9.0 m^2 mainplots. Defoliation treatments were applied to the 1 m^2 subplots. One subplot was randomly selected as a nonclipped control, and the other subplot was randomly assigned a clipping treatment (30%, 60%, 90% defoliation). Level of defoliation of the graminoid community was determined in the 0.25 m^2 buffer.

Experimental Design

This study was arranged in a randomized complete-block, split-plot design with precipitation treatments applied to mainplots and defoliation treatments applied to subplots. Twenty-four 9.0 m^2 mainplots were located within each exclosure. Each mainplot was selected based on the uniformity of prairie sandreed distribution and vigor within the plot area. A pair of 1.0 m^2 subplots separated by a 25 cm buffer strip was centered within each mainplot (Fig. 1). Visual estimates of the degree of slope and similarity of community composition were used to separate mainplots into two blocks in each exclosure. All mainplots, subplots, and sampling areas were permanently marked. Data were collected within the entire subplot unless otherwise specified.

Mainplot Treatments

Four precipitation treatments—ambient precipitation (noncovered control) and exclusion of precipitation during April-May, June-July, or August-September—were randomly assigned to mainplots within each block, resulting in six replications of each precipitation treatment in each exclosure. Precipitation was excluded using 2.5 × 3.7 m rainout shelters composed of 3.7 m × 5.0 cm × 10.0 cm rafters and end walls of 1.3 cm exterior plywood and 5.0 × 10.0 cm studs with screened peaks (Fig. 2). Each end wall had about 0.2 m^2 of 9.0 mm^2 screening. End walls had a peak height of 1.2 m and the sides, defined by the lowest rafters, were 0.6 m high. The lower 0.5 m of each side was open to allow air movement. During each treatment year, clear 1.5 mm polyethylene covers were installed on the shelters prior to April-May rainout treatments and replaced prior to August-September rainout treatments to avoid using covers that were excessively weathered. We verified that relative humidity and air temperatures were similar inside and outside the shelters using HOBO sensors (Onset Computer Corporation, Bourne, MA, USA) installed 60 cm above the soil surface. Measurements were recorded inside and outside two shelters at each site at 30 min intervals from June 3 to July 31, 2001.

We monitored soil water using the TRIME FM soil moisture assessing system (Imko Corporation, Karlsruhe,

Figure 2. Wood-framed 2.5 × 3.7 × 1.2 m rainout shelters. Peaks on each end wall were covered with screening and the frame was covered with 1.5 mm polyethylene. Shelters were anchored at each corner with steel T-bar posts. These low-profile rainout shelters withstood wind in excess of 100 km hr^{-1}.

Germany) to evaluate effects of precipitation treatments. Soil water was measured weekly, from mid-May to mid-August 2001, in 1 m plexiglass access tubes installed in 12 mainplots (one block) at each site.

Subplot Treatments

Within each mainplot, one subplot was randomly selected for defoliation and the other was used as a nonclipped control. Level of defoliation (30%, 60%, or 90%) was randomly assigned to each clipped subplot, resulting in eight replications of each clipping treatment and 24 replications of the nonclipped treatment in each exclosure. Prior to every clipping event, we estimated prairie sandreed tiller density in each subplot by counting the number of tillers within a 0.24 m^2 sample area. Herbage samples were dried in a forced-air oven at 55°C to a constant weight.

Stubble-height clipping treatments corresponding to 30%, 60%, or 90% defoliation of prairie sandreed were applied to all species in defoliated subplots during July 8-11 of the treatment year (2001 or 2002). We selected these treatments because, although prairie sandreed has shown susceptibility to grazing in July (Reece et al. 1996; Engel et al. 1998; Cullan et al. 1999), little was known about how prairie sandreed responds to different levels of defoliation or how this response might be influenced by different moisture regimes. Each year we determined clipping heights using site-specific regression equations developed from independently collected samples. Shortly before applying the treatments we randomly located ten 0.25 × 1.0 m quadrats at each site in plant communities with an abundance of prairie sandreed, clipped all prairie sandreed tillers at ground level, and tied them into bundles with stem bases flush. Bundles were balanced to estimate the stubble height at which 50% of the herbage would be removed. Bundles were cut at the point of balance, and the resulting two bundle portions were balanced and measured to estimate stubble height for 25% and 75% defoliation. We fit regression equations to these data and used the equations to determine clipping heights.

We estimated corresponding levels of total graminoid defoliation using data collected in a 0.25 × 1.0 m quadrat centered in the buffer strip (Fig. 1) of each mainplot. All graminoids within the quadrat were clipped to the same height as the corresponding defoliated subplot. The resulting stubble was clipped at ground level to determine the dry weight of the remaining herbage. Using these values we calculated the percentage of defoliation = herbage removed/(herbage removed + herbage remaining).

All response variables were measured during mid-July the year following treatment (2002 or 2003). Herbage was clipped at ground level and separated into current-year prairie sandreed, other graminoids, forbs, and residual herbage. For each subplot, mean prairie sandreed tiller weight was calculated using herbage weight and tiller density data.

Just prior to the 2002 harvest, cattle breached the exclosure at site 2. Because of trampling and/or grazing damage, reliable data were not available for all plots at this site; therefore, 2002 site 2 data were excluded from analysis. Data analyzed in this study are from replicated treatments at a single site in 2002 and two sites in 2003.

Statistical Analysis

Data were analyzed using the Mixed Model Procedure (SAS 2002) with years and defoliation treatments as fixed effects and precipitation treatments as random effects. When significant effects were detected the least-squares means procedure (SAS 2002) was used to separate means. Differences among means were significant at $P \leq 0.10$ unless otherwise stated. Regression analysis (SAS 2002) was used to fit equations to data when defoliation effects were detected.

RESULTS AND DISCUSSION

Precipitation Regimes

The combination of 60-day rainout treatments and differences in ambient rainfall between the two treatment years resulted in eight precipitation regimes (Fig. 3),

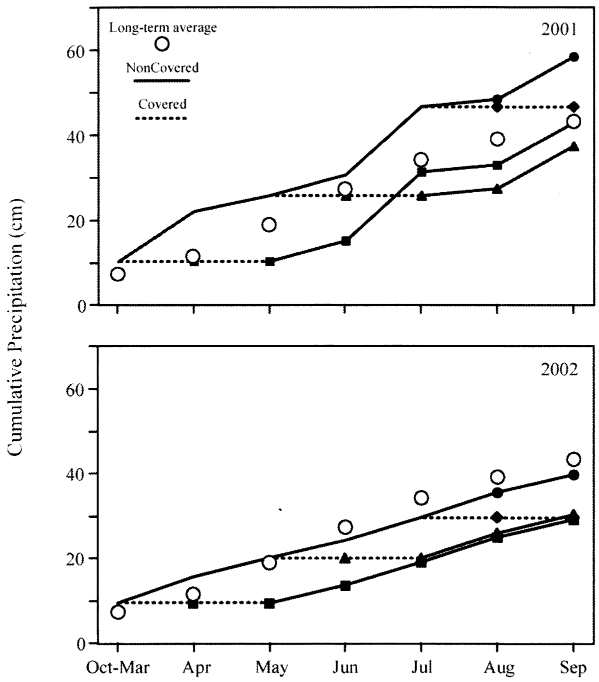

Figure 3. Cumulative plant-year (October-September) precipitation for each treatment in 2001 and 2002 and the long-term average (○) at the University of Nebraska-Lincoln, Gudmundsen Sandhills Laboratory near Whitman, NE. Cumulative precipitation for rainout treatments was the same as cumulative precipitation for ambient precipitation until the rain exclusion periods. Symbols designate where the lines for each treatment differ from each other [noncovered ambient (●) and rainout treatments in April-May (■), June-July (▲), and August-September (♦)]. Solid lines indicate noncovered periods. Dotted lines indicate periods when rainout shelters were in place.

TABLE 1
RESPONSE OF PRAIRIE SANDREED TO SEASON-LONG AMBIENT PRECIPITATION OR EXCLUSION OF PRECIPITATION DURING APRIL-MAY, JUNE-JULY, OR AUGUST-SEPTEMBER OF THE PRECEDING GROWING SEASON

Response variable	Precipitation treatment	Mean*	(± SE)
Yield (g m^{-2})	Ambient	47a	(4)
	April-May	44a	(4)
	June-July	35b	(4)
	August-September	38ab	(3)
Tiller density (no. m^{-2})	Ambient	158a	(18)
	April-May	133a	(16)
	June-July	89b	(10)
	August-September	129a	(16)
Species composition (%)	Ambient	36a	(2)
	April-May	32b	(2)
	June-July	27c	(2)
	August-September	31b	(2)

*Within response variables, means followed by the same letter are not significantly different ($P > 0.10$) based on differences of least squares means.

ranging from 66% to 135% of the long-term plant-year average. In 2001, cumulative ambient precipitation was above average during much of the growing season (April-September). As a result, total precipitation was near the long-term average for each of the rainout treatments (Fig. 3). In contrast, in 2002 cumulative ambient precipitation was similar to the long-term average throughout the growing season and all three rainout treatments resulted in drought precipitation regimes (Fig. 3). Subsequent-year (2002 or 2003) cumulative ambient precipitation was similar to the long-term average.

Interaction Effects

No interactions between defoliation and precipitation treatments were observed for any of the variables measured ($P > 0.10$). Thus, there was no support for the hypothesis that restricting moisture would increase the impact of defoliation. Apparently a single 60-day interval of water exclusion was insufficient to alter the effects of defoliation under the precipitation regimes experienced in this study. Ambient precipitation varied among treatment years, and only rainout treatments applied during 2002 resulted in drought levels of plant-year precipitation. Near-average precipitation occurred through July of each subsequent year (2002 or 2003), which may have moderated precipitation regime effects on response to defoliation. We suspect that interaction effects may occur under more extreme conditions, particularly multiyear droughts.

Precipitation Treatment Effects

April-May and August-September rainout treatments had no measurable effect on prairie sandreed yield or tiller density (Table 1). In contrast, excluding precipitation during June and July caused a 25% reduction in subsequent-year yields ($P = 0.09$) and a 44% reduction in tiller density ($P = 0.007$). Precipitation regime did not affect the mean weight of prairie sandreed tillers ($P = 0.81$),

TABLE 2
COMPARISON OF SOIL-WATER LEVELS AMONG ALL DEPTH INCREMENTS WITHIN AMBIENT AND THE RESPECTIVE RAINOUT TREATMENT AT THE END OF EACH 60-DAY INTERVAL

Soil depth (cm)	Soil water (%)*	
	April-May	Ambient
0-18	2.8e	5.3d
18-36	6.0d	7.8c
36-54	8.5c	9.8b
54-72	10.2ab	10.5ab
72-90	11.3a	10.6a
	June-July	Ambient
0-18	0.0f	3.0d
18-36	0.6ef	6.7c
36-54	1.3ef	8.7b
54-72	1.9de	9.5ab
72-90	2.4de	9.9a

Note: Soil water was measured in nonclipped control subplots at the end of April-May 2001 or June-July 2001 rainout treatments.
*Means with the same letter are not different ($P > 0.05$). Standard errors ranged from 0.4 to 1.1 for soil-depth increments below 54 cm, and from 0.1 to 0.4 for increments above 54 cm. Field capacity was near 11% for all depth increments.

indicating that drought-induced reductions in tiller density may help to maintain the potential rhizome and bud development of surviving tillers (Reece et al. 2002). Differences in soil-water content were observed to a depth of 54 cm following the April-May rainout treatment and to 1 m following the June-July rainout treatment (Table 2). These depths correspond to the rooting depth of cool-season (C_3) and warm-season (C_4) species, respectively (Weaver 1965), and likely reflect the combined effects of excluding precipitation and increased evapotranspiration as air temperature and the amount of current-year herbage (particularly C_4 grasses) increased from April through July.

Prairie sandreed herbage production and tiller density are primarily determined by tillers emerging during the current growing season (Hendrickson et al. 2000). The majority of new tillers emerge early in the growing season during May and June (Hendrickson et al. 2000), coinciding with portions of two of the rainout treatments. In the Nebraska Sandhills, prairie sandreed has a unimodal pattern of emergence with >50% of the tillers emerging by mid-May and 80% by mid-June (Hendrickson et al. 2000). Prairie sandreed tillers must generally reach the four- to five-leaf stage before new rhizomes develop (Brejda et al. 1989). Subsequent elongation of rhizomes is positively correlated with the amount of live herbage (Reece et al. 2002).

Like many of the dominant species in semiarid grasslands (Weaver 1930), prairie sandreed propagates almost exclusively by rhizomes (Tolstead 1942; Brejda et al. 1989). The advantage of this form of propagation is that parent plants help supply water and nutrients to distant tillers (Weaver 1930); therefore, stresses to parent plants during critical periods of rhizome development may impair emergence and growth of tillers from buds on the distal ends of rhizomes.

Precise information about the relationship between rhizome and tiller development is limited. However, Reece et al. (2002) reported that tiller density, herbage, and density of buds that could form rhizomes were positively correlated with length of old rhizomes (>1 year old). This suggests that factors affecting rhizome development during one growing season could potentially impact tiller development during the following year. Although not evaluating subsequent-year effects, Hendrickson et al. (2000) observed a 25% decline in prairie sandreed tiller density in the 1991 growing season following 24% below long-term average precipitation in 1990. In contrast, they found no correlation between tiller recruitment and precipitation during 14- or 30-day intervals prior to sampling (Hendrickson et al. 2000).

All rainout treatments reduced the percentage of total graminoid herbage accounted for by prairie sandreed (Table 1). Excluding precipitation in June-July, when prairie sandreed normally grows most rapidly, reduced the subsequent-year composition of prairie sandreed to 27% compared to 36% for ambient precipitation ($P = 0.005$). Changes of this magnitude could impact range-condition scores, which are visual estimates of the quality of the plant community (Nichols and Jensen 2001), and therefore influence decisions about the timing and level of stocking.

Prairie grasses produce 50% to 80% of their current-year herbage during a 30-day interval (Reece et al. 2007). The timing of these rapid-growth intervals is often different among species. Declines of four to five percentage points in prairie sandreed composition after April-May and August-September rainout treatments (Table 1) are likely the result of soil-water stress on prairie sandreed, as total graminoid yield was not affected by the rainout treatments ($P = 0.66$).

Defoliation Treatment Effects

Defoliation treatments were applied in mid-July, when prairie sandreed is susceptible to defoliation. However, subsequent-year declines in prairie sandreed herbage (Fig. 4A) accounted for only 60% of the decline in total graminoid yield (Fig. 5), indicating that other species are susceptible to defoliation at this time.

Based on the regression equation, prairie sandreed herbage production declined about 5% for each 10 percentage points of defoliation compared to nondefoliated control ($P = 0.0005$; Fig. 4A). Ecologically, the relative effects of overgrazing are likely to increase as the initial composition of prairie sandreed declines because the constant rate of yield reduction per hectare represents a larger percentage of the herbage produced by smaller populations. In contrast to drought-induced declines in herbage, defoliation did not reduce tiller density ($P = 0.21$); however, mean tiller weight declined at an increasing rate as defoliation increased ($P = 0.03$; Fig. 4B). Severe (90%) defoliation reduced tiller weight by about 30%. The decline in prairie sandreed composition ($P = 0.03$; Fig. 4C) suggests prairie sandreed is more susceptible to defoliation in mid-July than associated species over a wide range of precipitation regimes (Fig. 3).

Based on the regression equation, herbage production from all graminoids combined declined ($P < 0.0001$) about 3% for each 10 percentage points of defoliation (Fig. 5). Although our study sites were relatively small (<1.0 ha), total graminoid yield varied substantially (Fig. 5). Some variation likely arose because of our focus on a key species. Mainplots were selected on the basis of the presence, distribution, and vigor of prairie sandreed; characteristics of the overall graminoid community likely varied. Applying treatments on the basis of defoliation level of prairie sandreed resulted in a broad range of defoliation levels for the graminoid community (Fig. 5). As the severity of total graminoid defoliation increased, variation in yield values declined.

Both prairie sandreed and total graminoid herbage production declined at constant rates, which is consistent with our hypothesis that yield declines linearly as level of defoliation increases. There was no evidence for a critical level of defoliation beyond which yield declined (Fig. 4A); however, it appears that a threshold may exist for prairie sandreed mean tiller weight (Fig. 4B) and composition (Fig. 4C) on the basis of numerical values and standard

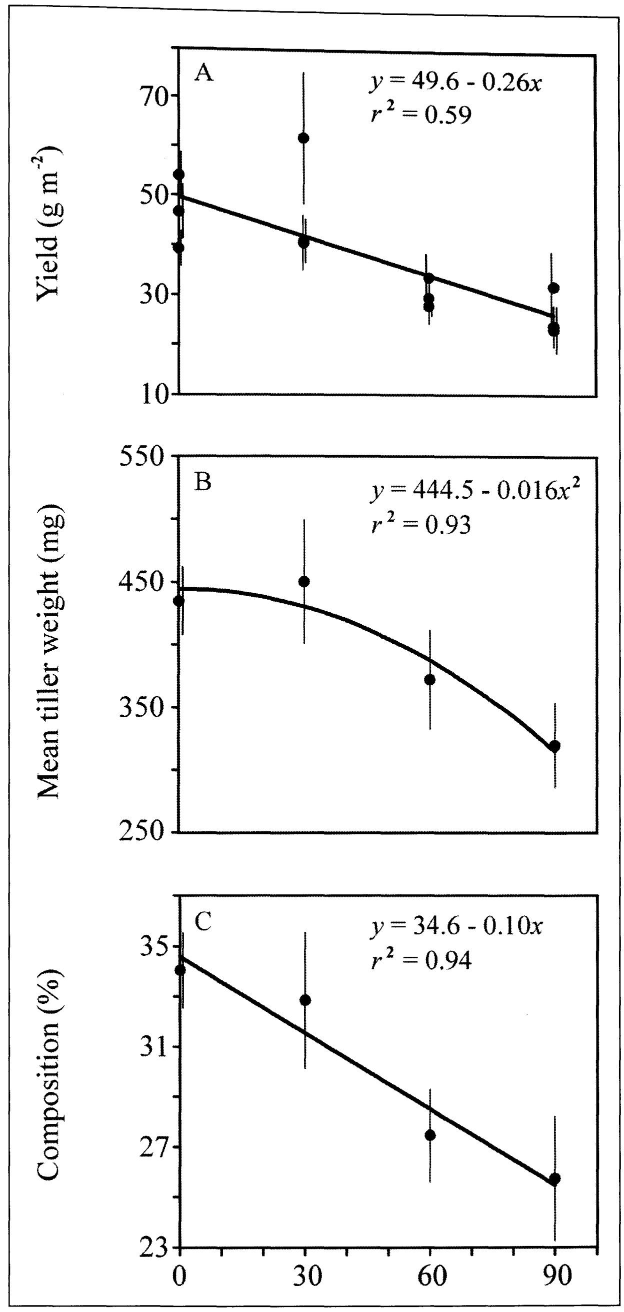

Figure 4. (A) Defoliation effects on the subsequent-year yield of prairie sandreed. Data points are site by defoliation treatment means ± SE. (B) Effects of defoliation on the mean weight of prairie sandreed tillers in the subsequent year. Data are defoliation treatment means ± SE. (C) Defoliation effects on the percentage of subsequent-year total graminoid yield composed of prairie sandreed. Data points are defoliation treatment means ± SE.

errors of means for defoliation levels. The clipping treatments included in this study were selected to represent sustainable to severe levels of defoliation. More thorough evaluation of possible thresholds and inflection points

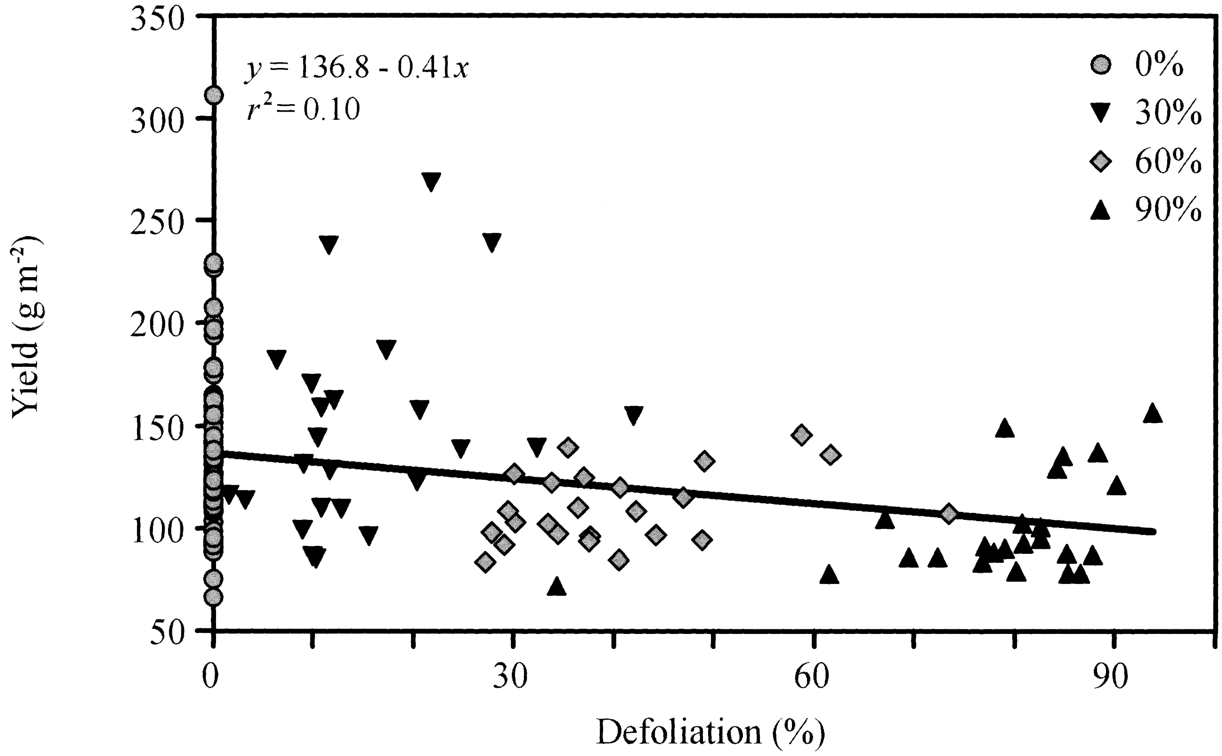

Figure 5. Effects of defoliation on the subsequent-year yield of all graminoids combined. Data points represent the total yield and level of defoliation for individual subplots. Symbol shapes represent the corresponding defoliation treatment, stubble heights selected to remove 0%, 30%, 60%, or 90% of the herbage from prairie sandreed.

would require evaluating a greater number and more closely spaced levels of defoliation. Greater control over community composition and microsite characteristics should strengthen such efforts.

CONCLUSIONS

Sandhills ranchers face the challenge of meeting the nutritional needs of livestock throughout the year while managing their grassland resources for long-term sustainability. This involves decisions about stocking rates, season of grazing, grazing systems, pasture-use sequences, and how to respond to changing precipitation patterns. We conducted this study to better understand how the timing and amount of precipitation and defoliation affect subsequent-year production in semiarid Sandhills prairie, using prairie sandreed as an indicator species.

Managing season of grazing is critical to optimizing herbage production on mid- to late-seral, semiarid Sandhills prairie. Our results indicate that prairie sandreed was sensitive to reduced soil water during June and July when it normally grows most rapidly. Additionally, both prairie sandreed and the total graminoid community were susceptible to defoliation in mid-July. The level of defoliation during such periods of vulnerability is key and is influenced by season of grazing (Reece et al. 1996) and grazing pressure (Cullan 1999). Within the Great Plains ranching community, the adage "take half and leave half" is widely considered a prescription for sustainable grazing. The adage is nearly always linked to the long-term success of moderate stocking rates. However, 50% defoliation in mid-July would result in a 26% decline in yield of prairie sandreed and a 15% decline in the yield of total graminoids (see equations in Figs. 4A and 5). Thus, it is likely that repeatedly "taking half" of the herbage from pastures during early summer will result in the demise of prairie sandreed, potentially reducing sustainable stocking rates and affecting ecosystem functions.

On the basis of previous research in the Nebraska Sandhills (Northup 1993; Cullen et al. 1999; Reece et al. 2004), livestock use of current-year total graminoid herbage is generally <30% when moderate stocking rates are used. This would limit the impact of grazing in July if livestock were nonselective herbivores. However, cattle preferentially graze prairie sandreed during much of the summer (Northup 1993), and defoliation of this species often exceeds 60% as cumulative grazing pressure increases during June and July (Northup 1993; Cullan et al. 1999).

Choice of grazing system is also likely to influence the patterns of defoliation. Average cumulative grazing pressure tends to be low during early summer under season-long continuous grazing. However, grazing pressure can be high near livestock water and other preferred sites, resulting in the demise of prairie sandreed in such areas. Use of moderate to heavy stocking rates during June or July in deferred-rotation grazing systems (one herd ≥ 4 pastures) will likely result in the periodic overgrazing of prairie sandreed on a pasture scale. Year-to-year changes in the order in which pastures are grazed are critical decisions for successful use of deferred-rotation grazing on Sandhills prairie. Pastures should not be grazed during June or July in consecutive years. Managers must also consider that drought-induced reductions in herbage production can increase grazing pressure if stocking rates are not reduced from predrought levels.

Clearly, grazing management decisions and precipitation patterns can affect prairie sandreed. Defoliation impacts mean tiller weight, and precipitation impacts tiller density. Either overgrazing or drought stress could adversely affect the viability of prairie sandreed. These effects are additive. Therefore, it may be necessary to periodically defer grazing until after killing frost to maintain vigorous prairie sandreed populations, particularly in pastures where overgrazing and drought stress occurred concurrently in June or July of the preceding year.

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