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Early summer grazing effects on defoliation and tiller demography of prairie sandreed

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Abstract

Grazing strategies should be designed to maintain vigorous populations of plant species critical for livestock production, wildlife habitat, and/or ecosystem functions. Treatments consisting of 5- to 7-day, mid-month grazing periods in June or July at 16, 32, or 48 animal unit days (AUD) per ha, were replicated 3 times and applied to the same pastures in 1995 and 1996 to quantify cattle use and tiller recruitment and mortality of prairie sandreed [*Calamovilfa longifolia* (Hook) Scribn.], a rhizomatous species characterized by dispersed populations of tillers. Cumulative grazing pressure (AUD Mg^{-1}) was used to quantify treatments because of differences in phytomass among pastures and dates. Grazing pressure ranged from 10 to 90 AUD Mg^{-1} and accounted for 69, 61, and 77% of the variation in percentage of tillers grazed, mean defoliation of grazed tillers, and use of prairie sandreed, respectively. As grazing pressure increased from 10 AUD Mg^{-1}, percentage of tillers grazed increased from 48 to 90%; defoliation of grazed tillers increased from 54 to 74%; and utilization of prairie sandreed increased from 27 to 67% at plateaus beginning at 50 to 60 AUD Mg^{-1}. When spring precipitation was above average, 45 to 55% use in June or July increased tiller densities, however, these increases were not sustained or repeated in the following year with average precipitation. Utilization was 50% at 28 AUD Mg^{-1} and 60% at 40 AUD Mg^{-1}. Relatively large increases in utilization per-unit-change of grazing pressure below 20 AUD Mg^{-1} indicated that yearling cattle selectively grazed prairie sandreed. The high degree of correlation between percentage of prairie sandreed tillers grazed and use of prairie sandreed (R^2 = 0.91 in June and 0.90 in July) suggests that percentage of grazed tillers can be used to monitor early-summer use of this species in the Nebraska Sandhills.

Key Words: stocking rate, grazing pressure, tiller recruitment and mortality, *Calamovilfa longifolia*

Resumen

Las estrategias de apacentamiento deben diseñarse para mantener poblaciones vigorosas de las especies de plantas que son críticas para el ganado, hábitat de la fauna silvestre y/o funciones del ecosistema. Los tratamientos consistieron en períodos de apacentamiento de 5 a 7 días a mediados de mes durante Junio y Julio, con cargas animal de 16, 32 o 48 unidades animal día (UAD) por hectárea. Los tratamientos se repitieron 3 veces y se aplicaron en los mismos potreros durante 1995 y 1996 para cuantificar el uso del ganado y el restablecimiento y mortalidad de hijuelos del zacate "Prairie sandreed" [Calamovilfa longifolia (Hook) Scribn], una especie rizomatosa caracterizada por poblaciones dispersas de hijuelos. Debido a las diferencias de fitomasa entre potreros y fechas, la presión de apacentamiento acumulativa (UAD Mg^{-1}) se utilizó para cuantificar los tratamientos. La presión de apacentamiento vario de 10 a 90 UAD Mg^{-1} y contribuyo con el 69, 61 y 77% de la variación de las variables: porcentaje de hijuelos apacentados, promedio de defoliación de los hijuelos apacentados y uso del "Prairie sandreed" respectivamente. Conforme la presión de apacentamiento se incremento de 10 UAD Mg^{-1}, el porcentaje de hijuelos apacentados se incremento de 48 a 90%; la defoliación de hijuelos apacentados incremento de 54 a 74% y la utilización del "Prairie sandreed" se aumento de 27 a 67% iniciando la estabilización de la curva entre 50 a 60 UAD Mg-1. Cuando la precipitación de primavera fue mayor que el promedio, el uso entre el 45 a 55% en Junio o Julio incremento las densidades de hijuelos, sin embargo, estos incrementos no se sostuvieron o repitieron en el siguiente año con la precipitación promedio. Con 28 UAD Mg^{-1} la utilización fue del 50% y del 60% con 40 UAD Mg^{-1}. El incremento relativamente grande en la utilización por unidad de cambio de la presión de apacentamiento abajo de 20 UAD Mg^{-1} indico que el ganado de año apacentó selectivamente el "Prairie sandreed". El alto grado de correlación entre el porcentaje de hijuelos del "Prairie sandreed" apacentados y el uso del "Prairie sandreed" (R^2 = 0.91 en Junio y 0.90 en Julio) sugiere que el porcentaje de hijuelos apacentados puede ser utilizado para monitorear el uso de esta especie a inicios del verano en el Nebraska Sandhills.

Effects of stocking rate, grazing pressure, and/or date of grazing on defoliation of individual species in native plant communities have been investigated extensively (Butler and

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Briske 1988, Gillen et al. 1990, Jensen et al. 1990, Hart et al. 1993, Allen and Marlow 1994, Derner et al. 1994). However, most grazing systems used on semi-arid rangelands are not designed for specific plant species. Successful systems use moderate stocking rates and/or growing-season deferment of adequate length and frequency to minimize and compensate for grazing damage to vegetation (Heady 1984, Ralphs et al. 1990). Knowledge of critical grazing pressure and critical grazing dates for key plant species should be incorporated into grazing systems (Zhang and Romo 1995, Reece et al. 1996). Additionally, efficient methods are needed for monitoring livestock use of key forage species to optimize grazing strategies (Manley et al. 1997, Ortega et al. 1997, Taylor et al. 1997).

Effects of early-summer stocking rates on livestock use and tiller dynamics have not been reported for prairie sandreed [*Calamovilfa longifolia* (Hook) Scribn.], a key forage species throughout the 4.9 million ha of Nebraska Sandhills and the sandy prairie soils of the northern and central Great Plains (Lodge 1963, Welch 1968, Aase and Wight 1973, GPFA 1986). In the Nebraska Sandhills, prairie sandreed can provide 25 to 40% of the herbage produced on upland range sites in good to excellent condition (Nichols et al. 1984). Tillering response of grasses to defoliation is affected by selective herbivory, environment, phenological stage, and severity and frequency of defoliation (Briske and Richards 1995); therefore, it is often necessary to evaluate species responses to grazing within given ecosystems.

In Nebraska, length of time that cattle are on rangeland during the summer grazing season has declined to avoid reduced gains and/or reduced cow condition when forage quality declines with advanced plant maturity. Additionally, interest in placing relatively heavy yearlings on high-quality, early-summer forage for 1 to 3 months before they enter feedlots has increased. In contrast to the ability of tallgrasses in humid environments to tolerate intensive early-season stocking (Smith and Owensby 1978, McCollum et al. 1990), heavy grazing (1.5X) in June or July causes measurable reductions in total organic reserves in prairie sandreed (Reece et al. 1996). Our objective was to quantify defoliation processes and effects on tiller demography of prairie sandreed over a wide range of grazing pressure to supplement an ecological data base for the development of grazing strategies in the Nebraska Sandhills. Three stocking rates and 2 grazing dates were used to produce an array of grazing pressures. We hypothesized that (1) use of prairie sandreed would increase at a constant rate as grazing pressure increased, and (2) tiller recruitment and mortality would increase as defoliation increased.

Materials and Methods

The study was conducted on sands range sites in good to excellent condition at the University of Nebraska, Gudmundsen Sandhills Laboratory (GSL) located near Whitman, Nebr. Prairie sandreed, sand bluestem (*Andropogon hallii* Hack), and little bluestem (*Andropogon scoparius* Michx.) were co-dominant species on these sites (Great Plains Flora Association 1986). Long-term average annual precipitation is 560 mm (National Oceanic and Atmospheric Administration 1996). Soils are Valentine fine sands (mixed, mesic Typic Ustipsamments).

Experimental units were individual 1.0-ha pastures. Twenty-one pastures were separated into 3 blocks based on frequency of occurrence of species in fifty, 50 × 50-cm quadrats randomly located on stratified transects in each pasture in May 1995. Six stocking rate by grazing date treatments and an ungrazed control were randomly allotted to pastures within each block. Grazing treatments consisted of 1, 5- to 7-day, mid-month grazing period in June or July at 16, 32, or 48 AUD ha^{-1}, representing light (0.5X), moderate (1.0X), and heavy (1.5X) seasonal stocking rates. Yearling cattle were weighed after an overnight stand without food and water and allocated to treatments by weight to provide equal total weights of cattle for replications within stocking rate treatments. Animal weights were divided by 454 kg to estimate animal unit (AU) equivalents. The number of yearlings per pasture ranged from 4 to 12. Grazing treatments were applied to the same pastures during 1995 and 1996. Pastures in this study were used for grazing research from 1988 to 1991 (Reece et al. 1996). All pastures were rested in 1992 and 1994. Pastures were stocked at 49 AUD ha^{-1} from June to October 1993.

Twenty, 20 × 50-cm quadrats were located systematically in each pasture over a 20 × 20-m grid in late-May 1995. A quadrat was placed near each grid point where a minimum of 7 current-year prairie sandreed tillers occurred. Quadrats were marked permanently with landscaping staples and numbered aluminum tags. Survival of current-year tillers with 1 or more fully expanded leaf blades was censused in early June, early July, early August, late August, and early October. The base of new tillers was loosely wrapped with a different color-coded telephone wire for each sampling date. Dead tillers were marked with latex paint and the wire was removed after initial census date was recorded. All wires were removed from 1995 tillers in late May 1996, and biennial tillers were counted. The census procedure was repeated in 1996. A data set of demographic differences was generated by subtracting mean responses for ungrazed control pastures from mean responses for grazed treatments within each block.

Before grazing treatments were applied, current-year standing herbage was estimated by clipping all vegetation at ground level in ten, 25 × 100-cm randomly located quadrats per pasture. Previous years growth and plant species not grazed by cattle were discarded. Species not grazed by cattle in June or July included six weeks fescue, (*Festuca octoflora* Walt.), green sagewort (*Artemisia dracunculus* L.), western ragweed (*Ambrosia psilostachya* DC.), prickly pears (*Opuntia* spp. P. Mill.), pincushion cactus [(*Corypanthia vivipara* (Nutt.) Britt. & Rose], and prairie wild rose (*Rosa arkansana* Porter) (Northup 1993). Palatable herbage was oven dried at 60°C for 48 hours and weighed to the nearest 0.1 g to determine dry matter yield. Grazing pressure was expressed as animal unit days per metric ton of current-year palatable herbage measured at the beginning of grazing periods (AUD Mg^{-1}).

Defoliation was estimated from marked tillers in 10 quadrats randomly selected from the 20 permanently marked 20 × 50-cm quadrats in each pasture used to monitor tiller demography. Distribution of tiller biomass over tiller height was measured in June and July to estimate percentage defoliation based on stem-diameter class and remaining stem height. About 100 ungrazed tillers were randomly selected and clipped at ground level at each of 20 sample areas outside the pastures during each grazing period and sorted into 5 stem-diameter classes: <1 mm, 1–2 mm, 2–3 mm, 3–4 mm, and >4 mm. For each sample area, tillers within stem-diameter classes were tied into bundles, with stem bases flush at one end. Bundles were balanced on a narrow edge to determine average remaining height at which 50% of the herbage would be removed. The bundle was cut in half at the balance point. Top and bottom half bundles were balanced and measured to determine average remaining stem heights for 25 and 75% defoliation. Equations fit to these data with regression analysis ($R^2 \geq 0.90$) were used to estimate defoliation of each grazed prairie sandreed tiller in each quadrat when yearlings were removed from pastures. Height-weight relations were similar for defoliated and nondefoliated prairie sandreed tillers because the upright growth habit and distance among the dispersed tillers of this species resulted in top-down defoliation when cattle grazed prairie sandreed. The summation of tiller numbers in each stem-diameter class multiplied by mean tiller weight for respective stem-diameter classes was used to estimate current-year prairie sandreed herbage in each quadrat. Percentage defoliation of each grazed tiller multiplied by mean tiller weight for the respective stem-diameter class was summed and divided by current-year prairie sandreed herbage to estimate utilization of prairie sandreed populations in each quadrat.

Data were analyzed as a split-plot in time with the General Linear Models Procedure (SAS 1985). Pre-planned contrasts were used to test for differences between control and grazed treatments, for differences between grazing dates, and to test for linear and quadratic effects of grazing pressure (Cullan 1998). Treatment effects were considered significant at $P \leq 0.05$. When significant grazing pressure effects occurred, regression analysis was used to fit equations to 36 grazed pasture-by-year means for percentage tillers grazed, percentage defoliation of grazed tillers, and use of prairie sandreed populations. All 3 defoliation characteristics plateaued. Data within the plateau were fit with a non-significant line estimated by the mean of values within the plateau. Regression analysis also was used to fit equations to 18 grazed pasture-by-year means for the relationship between use of prairie sandreed populations (dependent variable) and percentage of prairie sandreed tillers grazed (independent variable) in June and in July.

Results and Discussion

Available Herbage

When grazing treatments began in mid-June, yield of current-year, palatable herbage was 48% greater in 1995 than in 1996 (860 compared to 580 kg ha^{-1}), which was associated with 87% more precipitation during March to June 1995 than in 1996. Mean air temperatures during April to May 1995 were 5 to 6°C below 30-year averages while temperatures and precipitation in 1996 were similar to long-term averages. Mean current-year herbage when grazing started in July pastures was about 1,360 kg ha^{-1} in both years. Current-year herbage in pastures ranged from 360 kg ha^{-1} in mid-June to 1,630 kg ha^{-1} in mid-July. A correspondingly wide range of cumulative grazing pressure (10 to 90 AUD Mg^{-1}) resulted from the different combinations of pastures, grazing dates, and stocking rates.

Among the 3 co-dominant grass species, prairie sandreed was the most uniformly distributed within pastures with a mean frequency of occurrence ≥ 78% in all pastures and a frequency of 90 to 100% in 18 of 21 pastures (Fig. 1). Prairie sandreed produces populations of dispersed tillers in which rhizome tillers may emerge more than 30 cm from parent tillers (Maun 1985). In contrast, rhizomes of sand bluestem are intermediate in length and little bluestem is a bunchgrass (Weaver 1965). The frequency distribution of sand bluestem for pastures was intermediate between prairie sandreed and little bluestem and the distribution of both bluestems varied measurably among pastures (Fig. 1). Additionally, the presence of 20 other species of native graminoids and 45 species of native perennial forbs in these pastures (Northup 1993) provided the opportunity for a measurable diversity of species to be associated with prairie sandreed, within and among pastures. In

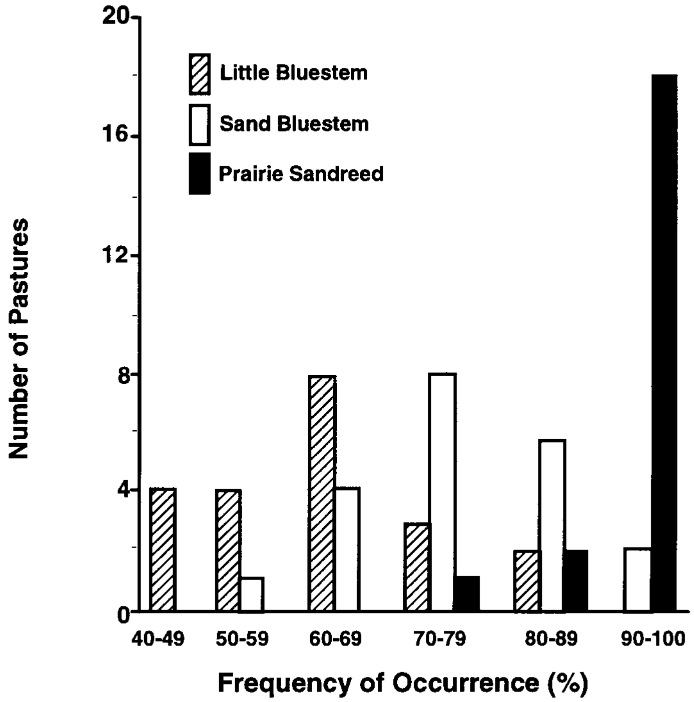

Fig. 1. Distribution of mean frequencies of occurrence for pastures for little bluestem, sandbluestem, and prairie sandreed in 50, 0.25-m^2 quadrats per pasture at the Gudmundsen Sandhills Laboratory, near Whitman, Nebr., in May 1995.

a preceding, 3-year study in these pastures, prairie sandreed produced about 20% of the current-year herbage available in June and July each year while sand bluestem and little bluestem collectively produced 23 to 50% of the herbage available in June or July (Northup 1993).

Defoliation of Prairie Sandreed

Prairie sandreed tiller populations are predominantly vegetative throughout the growing season at The Gudmundsen Laboratory (GSL) (Hendrickson et al. 1997). Percentage of tillers grazed increased rapidly from about 48% at 10 AUD Mg^{-1} to 78% at 30 AUD Mg^{-1} (Fig. 2a). Above 50 AUD Mg^{-1}, cattle consistently grazed about 90% of the prairie sandreed tillers. Grazing pressure accounted for 69% of the variation in percentage of tillers grazed in the 18 pastures during 2 years. While grazing pressure accounted for only a small amount of variation in occurrence of defoliation of key species in a tallgrass prairie in Oklahoma, Gillen et al. (1990) reported relatively wide ranges in percentage of tillers grazed over a narrow range in grazing pressure. Percentage of tillers grazed increased from 35 to 100% for big bluestem (*Andropogon gerardii* Vitman) and from 20 to 80% for little bluestem when grazing pressure increased from 7 to 33 AUD Mg^{-1}.

Mean defoliation of grazed tillers increased about 2% for each 5 AUD Mg^{-1} increase in grazing pressure, from 54% at 10 AUD Mg^{-1} to a plateau of about 74% from 58 to 90 AUD Mg^{-1} (Fig. 2b). Grazing pressure accounted for 61% of the variation in mean defoliation of grazed tillers among pastures. Part of the remaining variation may have been caused by the top-down grazing of this species that resulted in relatively small variation in grazed height within grazing treatments (Northup 1993, Cullan 1998) regardless of stem-diameter class. Tiller height was directly proportional to stem diameter (Cullan 1998). Consequently, percentage defoliation of grazed tillers with stem diameters > 4 mm was greater than defoliation of tillers with 1 to 2 mm stem diameters when plants were grazed to the same remaining height.

Grazing pressure accounted for 77% of the variation in utilization of prairie sandreed populations among pastures (Fig. 2c). The average rate at which utilization increased was about 5% per 4 AUD Mg^{-1} from 10 to 30 AUD Mg^{-1} compared to about 5% per 10 AUD Mg^{-1} from 30 to 60 AUD Mg^{-1} (Fig. 2c). Consequently, 50% use of prairie sandreed occurred relatively rapidly at 28 AUD Mg^{-1} during early-summer grazing, although 60% use required an additional 12 AUD Mg^{-1} or a 43% increase in cumulative grazing pressure. We reject our hypothesis that use of prairie sandreed increases at a constant rate as cumulative grazing pressure increases and conclude that cattle preferentially graze this species in June and July.

The potential for plant growth during grazing periods to cause errors in cumulative grazing pressure calculations was greater in June compared to July because of lower amounts of current-year herbage and relatively higher rates of plant growth. However, comparable levels of dry-matter intake by cattle at equal stocking rates would have reduced leaf area more rapidly in June than in July and may have limited the potential of plant growth in June to effect grazing pressure estimates. Average growth rates in July (Northup 1993) would cause less than 5% error in cumulative grazing pressure calculations for 5-to 7-day periods. The relatively high correlation of data from June and July during 2 years with measurable differences in precipitation suggests standing crop estimates at the beginning of short grazing periods are adequate for estimating cumulative grazing pressure in this ecosystem.

Physiologically, damage to growing grasses is generally stated to be minimal until defoliation exceeds 50 to 60% (Crider 1955, Launchbaugh 1967, Ryle and Powell 1975). Mean use of prairie sandreed plateaued at about 67% from 60 to 90 AUD Mg^{-1} which is measurably

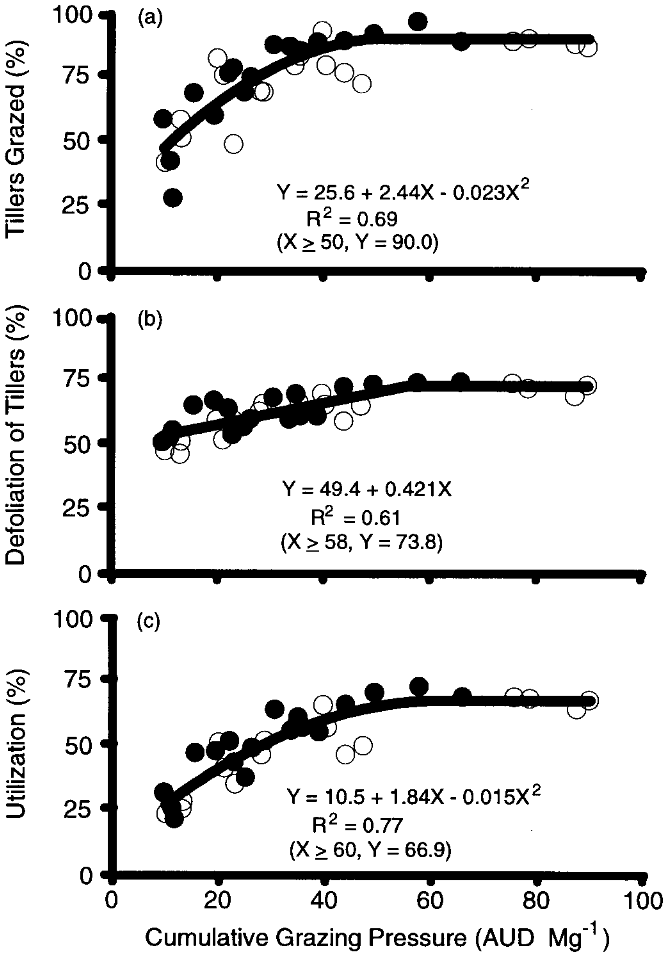

Fig. 2. Effects of cumulative grazing pressure on percentage of tillers grazed (a), percentage defoliation of grazed tillers (b), and utilization of prairie sandreed in pastures at the Gudmundsen Sandhills Laboratory, near Whitman, Nebr., after grazing in mid-June or mid-July in 1995 (°) and 1996 (•).

higher than reported for grazing use of key management species in other Great Plains range ecosystems (Hart and Balla 1982, Gillen et al. 1990). Translocation of nutrients through rhizomes from ungrazed to grazed tillers may be an important mechanism of grazing tolerance in prairie sandreed because mean defoliation of grazed tillers was greater than 50% over the entire range of grazing pressure in this study. If tolerance of prairie sandreed to grazing is primarily clonal (Stout and Brooke 1985) compared to an individual tiller response, measurable effects of grazing may occur between 50 and 60% use when the ratio of ungrazed to grazed tillers decreases from 1:4 to less than 1:7. When use of prairie sandreed plateaued at 67% the ratio of ungrazed to grazed tillers was 1:10.

Given the large differences in herbage that can occur among pastures and years, and the pronounced effect of cumulative grazing pressure on utilization, stocking rate is a poor criterion for effective early-summer grazing management decisions for prairie sandreed. It is also unlikely that animal condition could be used as an index for proper use of prairie sandreed because relatively high levels of forage quality during early summer (Hendrickson et al. 1997, Northup and Nichols 1998) could result in high levels of animal performance at relatively high grazing pressures (Hart et al. 1983).

An efficient method of monitoring utilization of prairie sandreed is needed when the potential for high grazing pressure occurs in June or July. Utilization of prairie sandreed was highly correlated (R^2 = 0.91 in June and 0.90 in July) with percentage of prairie sandreed tillers grazed over a wide range in species composition and grazing pressures (Fig. 3). Percentage defoliation of grazed tillers was greater in June compared to July (Cullan 1998) because of higher grazing pressure (Fig. 2b). Consequently, when utilization of prairie sandreed populations was below 40%, fewer tillers were grazed at comparable levels of use in June compared to July, i.e., 42% of tillers grazed at 35% use in June compared to 62% of tillers grazed at 35% use in July. However, the percentage of tillers grazed in each month converged rapidly to 72% in June and 78% in July at 50% use. It should be possible to estimate use of prairie sandreed in June or July from percentage of tillers grazed with a high degree of repeatability. Grazing pressure can be used to select dates at which monitoring should begin.

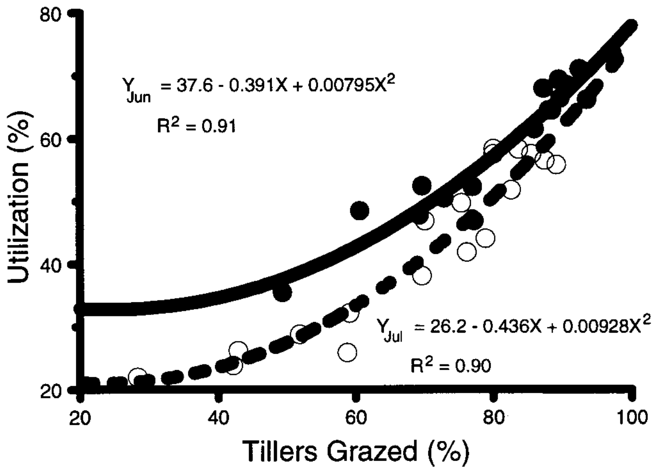

Fig. 3. Relationship between percentage of prairie sandreed tillers grazed and utilization of prairie sandreed in pastures at the Gudmundsen Sandhills Laboratory, near Whitman, Nebr., after grazing in mid-June (•) or mid-July (❍) in 1995 and 1996.

Tiller Demography

Total end-of-season tiller recruitment averaged over stocking rates was about 10% higher after grazing in July compared to June in both years, 277 compared to 250 m^{-2} in 1995 and 211 compared to 193 m^{-2} in 1996. Availability of photosynthates for tiller development may have been higher in July because of a 30-day delay in grazing and consistently less use of prairie sandreed in July than in June (Cullan 1998). Mean tiller recruitment for grazed pastures was about 30% greater in 1995 (264 m^{-2}) compared to 1996 (202 m^{-2}) and 40% greater in control pastures in 1995 (278 m^{-2}) than in 1996 (198 m^{-2}). Differences in recruitment between years corresponded to 87% more precipitation from March to June in 1995 than in 1996 and concur with positive correlations between soil moisture and tiller recruitment for other species (Zhang and Romo 1995).

In 1995, increasing stocking rate from 16 to 48 AUD ha^{-1} in June reduced tiller recruitment whereas increasing stocking rate in July increased recruitment compared to ungrazed control pastures (Fig. 4). Measurable reductions in tiller recruitment occurred in June pastures when average use of prairie sandreed increased from 49% at 16 AUD ha^{-1} to 65% at 32 AUD ha^{-1}. Reductions in tiller recruitment were similar after moderate (32 AUD ha^{-1}) and heavy (48 AUD ha^{-1}) stocking rates because high grazing pressures resulted in near maximum utilization of 65 and 71%, respectively. Total end-of-season tiller recruitment in July pastures increased by about 21 m^{-2} for each 10 AUD ha^{-1} increase from 16 to 48 AUD ha^{-1}. This pattern corresponded to an increase in defoliation of about 9% for each 10 AUD ha^{-1} from 27% at 16 AUD ha^{-1} to 57% at 48 AUD ha^{-1}. Stocking rate effects on tiller recruitment in 1995 were not repeated or sustained in the following year, when average precipitation occurred, regardless of degree of use. Mullahey et al. (1991) reported similar findings at the same research location in a 3-year clipping study. We reject our hypothesis that recruitment of prairie sandreed tillers increases as cumulative grazing pressure increases and conclude that the effects of grazing on tiller recruitment in this species are inconsistent and limited by environmental variables.

It is unlikely that micro-environmental light conditions were different between years because grazing treatments produced a similar array of remaining herbage and foliar architecture each year (Volesky et al. 1999). Above-average precipitation and concurrently below average spring air temperatures may be important variables for recruitment of prairie sandreed tillers. Measurably higher prairie sandreed herbage in late spring 1995 compared to 1996 indicated that spring air temperatures did not limit

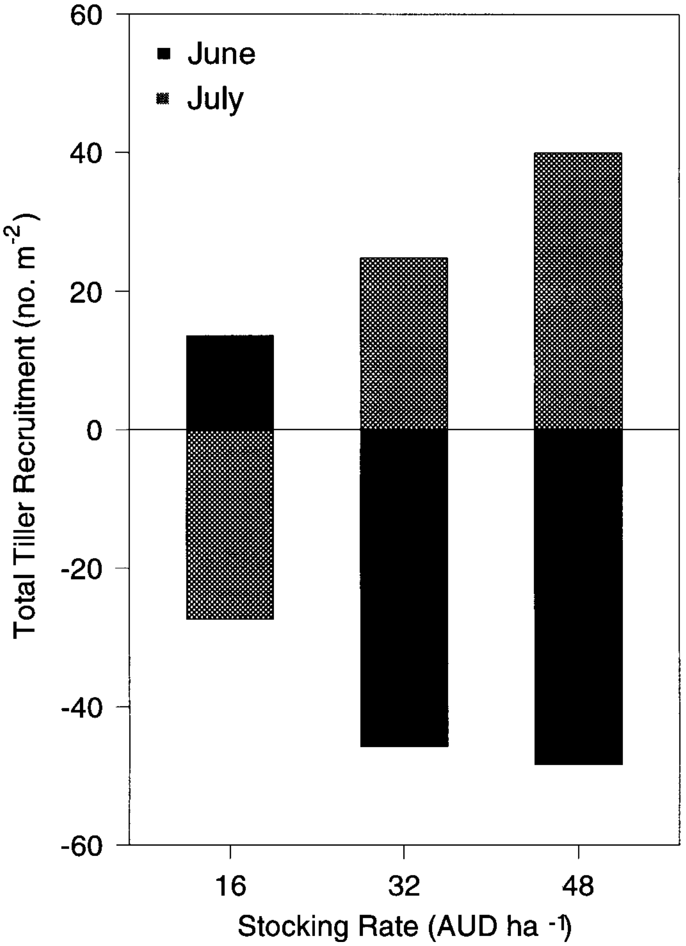

Fig. 4. Stocking rate effects on the difference (grazed-control) in total end-of-season recruitment of prairie sandreed tillers for pastures grazed in June (■) or (▒) July during 1995 compared to ungrazed control.

growth or that above-average precipitation allowed plants to compensate by mid-June in 1995. Larger differences in recruitment between years for control compared to grazed pastures may reflect differences in infiltration rates and/or depth and extent of roots. Heavy defoliation reduces root growth and nutrient uptake (Crider 1955, Engel et al. 1998). Tiller recruitment was reduced after grazing in June in both years when utilization exceeded 60% at 32 and 48 AUD ha^{-1} (Fig. 4). Consequently, we hypothesize that availability of soil moisture and ability of plants to absorb soil moisture appear to be the critical variables in prairie sandreed tiller recruitment.

Tiller mortality was generally less than 1% of the tiller population for all treatments in both years. Severely defoliated tillers remained green and succulent until killing frost, even when growing points were removed in July. In contrast to other species, reproductive growth in parental tillers had no effect on tiller mortality (Briske and Richards 1995). Mortality of prairie sandreed tillers occurred only when tillers were completely removed by grazing. Therefore, we reject our hypothesis that tiller mortality increases as cumulative grazing pressure increases and conclude that grazing pressure has no measurable effect on tiller mortality within years.

About 24% of the 1995 tiller populations in control pastures survived into the following growing season. These biennial tillers accounted for 33% of the 1996 tiller population. Tillers that had emerged and fully expanded 1 leaf blade by early June 1995 accounted for 82% of the biennial tillers in 1996 which is comparable to the year-to-year survival of northern wheatgrass *[Agropyron dasystachyum* (Hook.) Scribn.] tillers (Zhang and Romo 1995).

Management Implications

The high degree of correlation between percentage of prairie sandreed tillers grazed and utilization of prairie sandreed suggests that percentage of grazed tillers can be used to monitor early-summer use of this grass in the Nebraska Sandhills. Additional research is needed to develop efficient sampling procedures that can be used for monitoring and to determine if utilization of other species is related to use of prairie sandreed.

The effect of grazing on prairie sandreed tiller recruitment is limited by environmental variables. While soil moisture appears to be important, the specific variables and mechanisms have not been determined. Annual differences in this study indicate that increases in tiller density are inconsistent and may not be sustained in the following year. Managers can use equations in this paper and estimates of cumulative grazing pressure or percentage of grazed tillers as tools to achieve target levels of use of this species.

Relatively large increases in use per-unit-change of cumulative grazing pressure below 20 AUD Mg^{-1} indicate that cattle selectively graze prairie sandreed in June and July. Additionally, yield of current-year herbage in June may only be 20 to 50% of peak-standing crop when cattle are turned out in June, causing a 2 to 5-fold increase in cumulative grazing pressure. While grazing strategies would appear to have a limited effect on use of prairie sandreed, some strategies would produce predictably low or high cumulative grazing pressure in June or July. When grazing periods are < 2 months, initiating grazing in June at stocking rates recommended by the Natural Resources Conservation Service for 4 to 6-month summer grazing seasons, will result in relatively high early-summer grazing pressure and cause use of prairie sandreed to exceed 65% nearly every year. In contrast, stocking rangeland for near maximum average daily gains in cattle (Willms et al. 1986, Hart et al. 1988a, 1988b) under continuous season-long grazing for 4 to 6 months would result in relatively low monthly grazing pressures and nearly eliminate the potential for use of prairie sandreed to exceed 50% in June or July. Use of prairie sandreed should be monitored when the potential for high cumulative grazing pressure occurs in early summer.

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