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Effects of grazing management on standing crop dynamics in tallgrass prairie

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Abstract

Grazing system and stocking rate effects on forage standing crop of tallgrass prairies in north-central Oklahoma were evaluated from 1989 to 1993. Twelve experimental units, consisting of pastures dominated by big bluestem [*Andropogon gerardii* Vitman], little bluestem [*Schizachyrium scoparium* (Michx.) Nash], indiangrass [*Sorghastrum nutans* (L.) Nash], and switchgrass [*Panicum virgatum* L.], were arranged in a completely randomized design with either a short duration rotation or continuous grazing system and stocking rates ranging from 127 kg animal live-weight/ha to 222 kg live-weight/ha. Yearling steers grazed the units from late April to late September. Herbage standing crop was sampled in July and September. Total, live, and dead standing crops did not differ significantly between the 2 grazing systems in July. Total standing crop was significantly higher in the rotation units in September (3,600 versus 3,020 kg/ha, $P<0.05$). Dead standing crop was also higher in the rotation units in September (1,950 versus 1,570 kg/ha, $P<0.05$). Evidence suggests the difference in standing crop between systems is due, in part, to reduced forage intake by the livestock. Grazing system did not interact with either stocking rate or year. Stocking rate had significant effects on total, live and dead standing crops at both sample dates. The slope of the total standing crop-stocking rate relationship varied over years and ranged from -12 to -36 kg/ha per kg live-weight/ha in July and from -12 to -27 kg/ha per kg live-weight/ha in September. Higher standing crop at the end of the grazing season in the rotation units would mean greater soil protection and higher fuel loading for prescribed burning, and would suggest a lower impact on plant vigor. However, if the higher standing crop is a result of lower forage intake, we would expect livestock weight gains to decline.

Keywords: continuous grazing, rotation grazing, tallgrass prairie, forage production

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Short duration rotational grazing has been suggested as a method for increasing livestock numbers while maintaining range condition (Booysen and Tainton 1978, Savory 1978). However, research results comparing rotational grazing to continuous grazing at equal stocking rates have not shown dramatic increases in herbage standing crop with rotation grazing. Gammon and Roberts (1978), Hart et al. (1988), and White et al. (1991) found no differences in caged standing crop on continuous and rotational systems.

Observation and a large body of research indicate that standing crop decreases with increasing stocking rate (Herbel and Anderson 1959, Van Poollen and Lacey 1979, Brummer et al. 1988, Heitschmidt et al. 1989). Some authors have suggested that stocking rate affects standing crop more than grazing system (Van Poollen and Lacey 1979, Wilson 1986). Possible interactions between grazing system and stocking rate have been hypothesized but seldom completely studied. Most research has compared continuous grazing at a moderate stocking rate with rotation grazing at stocking rates 50 to 100% higher. Results from such studies confound grazing system with stocking rate and make interpretation open to question.

Tallgrass prairie response to less intensive grazing systems is well documented (Owensby et al. 1973, Owensby and Smith 1978, Owensby et al. 1988) but less research is available concerning short duration rotation grazing (Gillen et al. 1991, Brummer et al. 1988). Studies of stocking rate effects on tallgrass prairie are limited (Herbel and Anderson 1959, Owensby et al. 1988). The purpose of this study was to evaluate the effects of continuous and rotational grazing systems at several stocking rates on standing crop dynamics of tallgrass prairie.

Study Area

The study was conducted from 1989 to 1993 at the Oklahoma State University Research Range, located approximately 21 km southwest of Stillwater, Okla. (36°04' N, 99°13' W). The climate is continental with an average frost-free growing period of 204 days, extending from April to October. Average annual precipitation for the area is 831 mm with 65% falling as rain from May to October. The mean annual temperature is 15°C, and ranges from an average daily minimum of -4.3°C in January to an average daily maximum of 34°C in August (Myers 1982).

Major range sites found on the area are shallow prairie (33%), loamy prairie (25%), and eroded prairie (22%). Sandy savannah dominates the remaining area. The shallow prairie sites have

Grainola series soils (fine, mixed, thermic Vertic Haplustalf), which have a loam surface with silty clay subsoil. Coyle series soils (fine-loamy, siliceous, thermic Udic Argiustoll) comprise the loamy prairie sites. These soils have fine sandy loam surfaces with sandy clay loam subsoils. The eroded prairie sites are on old fields and have Renfrow (fine, mixed, thermic Udertic Paleustoll), Mulhall (fine-loamy, siliceous, thermic Udic Paleustoll), and Coyle series soils.

Vegetation on the experimental units was in a high seral state during the course of the study. Vegetation composition on a dry weight basis, determined by the dry weight rank method in August 1991, consisted of 28% little bluestem [*Schizachyrium scoparium* (Michx.) Nash], 25% combined big bluestem [*Andropogon gerardii* Vitman] and indiangrass [*Sorghastrum nutans* (L.) Nash], 25% midgrasses, 13% forbs, 5% switchgrass [*Panicum virgatum* L.], and 4% shortgrasses and annual grasses. All units had been moderately grazed and burned 1 or 2 times in the 5 years previous to initiation of the study.

Methods

The experimental design consisted of a completely randomized design with grazing system and stocking rate as treatments. Six of 12 experimental units were randomly assigned to a rotational grazing system, and the remaining 6 units were assigned to a continuous grazing system. Experimental units ranged in size from 14 to 26 ha. The rotation units were subdivided into 8 pastures. Within each grazing system the units were randomly allocated to 1 of 6 levels of stocking rate. Stocking rates ranged from 127 kg animal live-weight/ha to 222 kg live-weight/ha, which represent moderate to very heavy rates for this range type. The experimental animals were mixed-breed yearling beef cattle with average initial weights of 200-225 kg. Cattle numbers per unit ranged from 10 to 22. The yearlings grazed the units from early April until late September. Cattle in the rotational units remained in a single herd and were moved between pastures every 3 to 7 days. We lengthened the grazing periods as the growing season progressed. Cattle in the continuous units were not moved during the grazing season. All units were burned 1 Apr. 1990 and 20 Mar.1993.

Herbage standing crop was measured in July and September by clipping the total standing crop at ground level in 0.1-m^2 quadrats. Forty-five quadrats were located systematically in a grid pattern in each pasture. The live:dead herbage ratio was determined according to the technique of Gillen and Tate (1993).

Dependent variables of interest were total, live, and dead standing crop. We analyzed the data as a repeated measures experimental design. Main plot factors were grazing system and stocking rate with year as the repeated factor. Grazing system and year were qualitative variables. Stocking rate was a quantitative variable. Both linear and quadratic effects of stocking rate were included in the statistical model. Because stocking rate was not replicated, Type I sums of squares were used for hypothesis testing (SAS Institute 1985). July and September sampling dates were analyzed separately. When year effects were declared significant, the least significant difference was used for mean separation. When stocking rate interactions with grazing system or year were declared significant, slopes of standing crop versus stocking rate were tested using indicator regression methods (Neter and Wasserman 1974).

Results and Discussion

November-April precipitation was above normal in 4 of the 5 study years (Table 1). May-August precipitation was more than 50% above normal in 2 years, 1989 and 1992. Spring-summer temperatures for these 2 years were relatively cool. May-August precipitation was close to average in 2 other years, 1991 and 1993, and 22% below normal in 1990. Overall weather conditions were favorable during the study period with cumulative precipitation well above average and spring-summer temperatures slightly below average. May-August precipitation correlated well with total standing crop in September (Tables 1, 3).

Year

Year had a significant effect on all standing crop parameters (Table 2). July standing crops were highest in 1991 while September standing crops were highest in 1989 and 1992 (Table 3). Standing crops were lowest in 1990. From minimum to maximum, the data varied over years by a factor greater than 2 for total and live standing crops and a factor of 3.5-4.5 for dead standing crop.

Spring burning probably contributed to lower total standing crops in 1990 and 1993 by removing dead herbage. Burning may have caused a higher proportion of live standing crop in July of 1993. Low early-season precipitation may have masked the effect on live standing crop in July 1990. Precipitation was 38% below normal in May-June but 50% above normal in July-August for 1990. By September, both burn years had higher proportions of live standing crop.

Table 1. Precipitation (mm) and average maximum daily temperature (°C) at the Oklahoma State University Research Range, Payne County, 1989-1993.

Year	Precipitation Nov.-Apr.	Precipitation May-Aug.	Max Daily Temperature May-Aug.
	(mm)	(mm)	(°C)
1989	307	608	29.5
1990	497	281	31.1
1991	204	343	31.9
1992	305	536	28.6
1993	542	361	30.8
Study Average	371	426	30.4
Long-term Average	268	360	31.3

Grazing System

Grazing system did not interact with stocking rate or year for any standing crop parameter (Table 2). There were no significant differences between grazing systems for any standing crop parameter in July (Fig. 1). Total and dead standing crop were significantly higher in the rotation units in September (Fig. 2). The relative difference in total standing crop between grazing systems was 9.5% in July and 19% in September, suggesting the effect of grazing system on standing crop was cumulative over the season. The proportion of live standing crop in July was similar between grazing systems (0.68 versus 0.70 for continuous and rotation, $P>0.05$). The proportion of live standing crop was lower in September but still similar between grazing systems (0.48 versus 0.46 for continuous and rotation, $P>0.05$).

Possible explanations for increased herbage biomass in September in the rotational systems include: (1) enhanced growth due to timing and pattern of defoliation; (2) lower forage intake by cattle; or (3) lower non-consumptive losses. Simple standing crop measurements cannot test these alternative hypotheses. Timing and pattern of defoliation were affected by grazing system with a lower frequency of defoliation on little bluestem in the rotational units (Derner et al. 1994). Additional research will be necessary to fully explain the increased herbage biomass in September in the rotational systems.

Working in tallgrass prairie, Owensby et al. (1973) reported total herbage production was 17% higher under a deferred grazing system compared to continuous grazing. This is similar to the outcome of the current study although the deferred grazing system used only 3 pastures and cattle were moved once or twice during the grazing season.

Table 2. *P*-values from analyses of variance of herbage standing crop as affected by grazing system, stocking rate, and year.

Source of Variation	df	July Standing Crop				September Standing Crop			
		Total	Live	Dead	% Live	Total	Live	Dead	% Live
(%)									
Grazing System	1	0.32	0.31	0.67	0.39	0.03	0.13	0.03	0.38
Stocking Rate[a]	1	0.01	0.01	0.02	0.16	0.01	0.01	0.01	0.62
GSxSR	1	0.77	0.67	0.75	0.60	0.46	0.68	0.38	0.74
Stocking Rate²	1	0.93	0.71	0.39	0.39	0.98	0.73	0.77	0.53
GSxSR²	1	0.65	0.41	0.30	0.12	0.96	0.85	0.82	0.83
Year	4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
YearxGS	4	0.61	0.89	0.32	0.35	0.47	0.90	0.18	0.84
YearxSR	4	0.01	0.04	0.01	0.63	0.02	0.37	0.01	0.08
YxGSxSR	4	0.99	0.99	0.78	0.87	0.38	0.52	0.34	0.61
YxSR²	4	0.25	0.57	0.36	0.76	0.40	0.46	0.30	0.68
YxGSxSR²	4	0.99	0.93	0.70	0.83	0.56	0.75	0.29	0.16

[a]Stocking Rate denotes linear effect, Stocking Rate² denotes quadratic effect.

Other researchers have seldom reported higher herbage standing crop with rotation grazing. Jung et al. (1985), Pitts and Bryant (1987), Anderson (1988), and Thurow et al. (1988) reported no differences in end-of-season standing crop between continuous and rotation grazing when the systems were stocked at similar rates. Rotation and continuous grazing had equal peak standing crops in exclosures (Gammon and Roberts 1978, Hart et al. 1988, and White et al. 1991) suggesting rotation grazing had little influence on plant vigor. In the study of White et al. (1991), the rotation system was stocked 10-100% higher than the continuous unit while stocking rates were equal between systems in the other studies. Exclosures were moved to new locations each year.

Stocking Rate

Stocking rate was inversely related ($P<0.05$) to total, live, and dead standing crop (Table 2, Fig. 2). More animals per unit area increase total forage demand, so the lower standing crop at the heavier stocking rates was an expected result (Van Poollen and Lacey 1979, Brummer et al. 1988). All standing crop-stocking rate relationships were linear (Table 2). Ralphs et al. (1990) also reported a linear decline in standing crop as stocking rate increased under rotation grazing. They felt the rest periods helped compensate for heavy forage removal at high stocking rates so that the rate of decline in standing crop was lower than expected based on the increase in stocking rate. Stocking rate did not interact with grazing system in this study (Table 2).

Stocking rate interacted ($P<0.05$) with year in 5 of 6 comparisons (Table 2). The slope of total standing crop versus stocking rate varied from -12 to -36 kg/ha per kg live-weight/ha in July and from -12 to -27 kg/ha per kg live-weight/ha in September (Fig 2). The steepest slopes were associated with 1991 and 1992 and were not clearly tied to weather or total forage production for the year. Ralphs et al. (1990) also reported annual variability in slopes, attributing part of the variability to declining vigor at the higher stocking rates because the slopes became more negative over time. Such an effect was not apparent in our study. Additional research is needed to quantify the factors affecting these slopes since intake, trampling, decomposition, or consumption by other animals appeared to vary widely from year to year.

Stocking rate did not affect the proportion of live standing crop in

Table 3. Herbage standing crop averaged over grazing system and stocking rate, 1989-1993.

Year	July Standing Crop				September Standing Crop			
	Total	Live	Dead	% Live	Total	Live	Dead	% Live
	———kg/ha———				———kg/ha———			
1989	3490	2510	980	72.0	4470	2340	2130	52.3
1990	1760	1130	630	64.1	1970	1290	680	65.5
1991	4330	2710	1620	62.7	3160	1230	1930	38.9
1992	3320	2300	1020	69.2	4380	1320	3060	30.2
1993	2550	2070	480	81.3	2580	1580	1000	61.1
$LSD_{.05}$	370	370	200	6.6	360	180	280	4.5

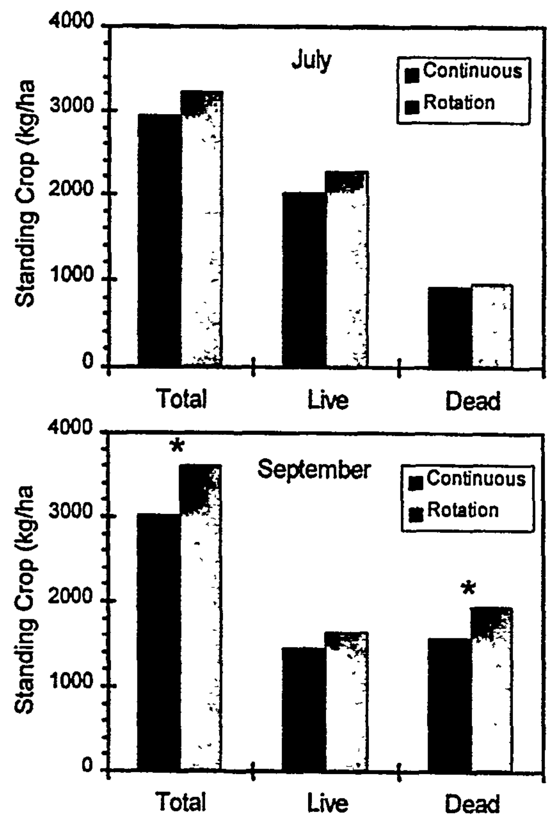

Fig. 1. Herbage standing crop as affected by grazing system averaged over stocking rate and year. Asterisks indicate significant differences ($P<0.05$) between continuous and rotation grazing.

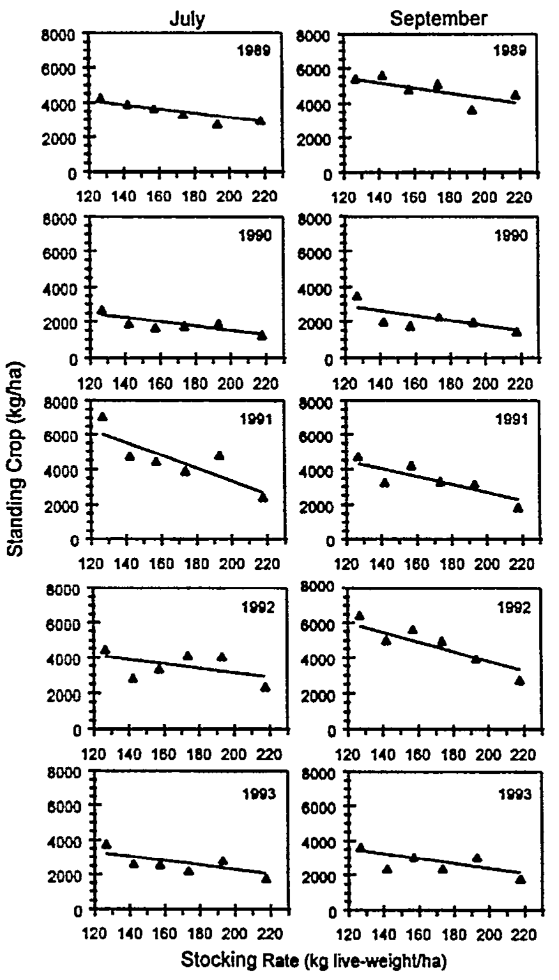

Fig. 2. Total standing crop as affected by stocking rate averaged over grazing system. All lines within sample date are significantly different ($P<0.05$).

July (Table 2). For September , the proportion of live standing crop decreased as stocking rate increased in 1990 and 1992 while the opposite effect occurred in 1989, 1991, and 1993. Under year-round grazing, Heitschmidt et al. (1989) reported a higher proportion of live herbage as stocking rates increased even though total standing crop was lower. Effects may have been variable in our study because of periodic burning and because dead herbage was not consumed during the dormant season (grazing was confined to the growing season).

Conclusions

Weather conditions were generally favorable during the study period. Results could be different under more stressful precipitation patterns. Herbage standing crop in September was about 20% higher in rotation units than in continuous units regardless of stocking rate. Higher total standing crop at the end of the grazing season would mean more forage for winter grazing and higher fuel loading for prescribed burning, and would suggest a lower impact of grazing on plant vigor. However, higher herbage standing crop does not necessarily indicate higher livestock production (Owensby et al. 1973). Livestock gains per head and per acre averaged 13% lower under rotational grazing compared to continuous grazing in this study (Gillen et al. 1992).

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