Seasonal Growth Rates of Tallgrass Prairie after Clipping

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Abstract

Intensive rotation grazing is dependent on the proper timing of livestock movement for success. The timing of livestock movement is in turn dependent on the rate of forage growth, but quantitative information on growth rates of tallgrass prairie is limited. The objective of this study was to develop information on seasonal growth parameters of tallgrass prairie following uniform clipping. Plots were mowed to 10 cm on various starting dates during the growing season and sampled weekly for live standing crop for 10 weeks following mowing. Four and five regrowth trials were completed in 1984 and 1985, respectively. Regrowth trials were analyzed by fitting second degree polynomial regression models to the weekly standing crop data and calculating several growth parameters from the fitted models. The maximum standing crop of forage regrowth declined significantly as the time of initial clipping was delayed (2,300–280 kg ha^{-1}, 1984; 2,400–1,130 kg ha^{-1}, 1985). The maximum net growth rate also declined significantly with season (52–0 kg ha^{-1}d^{-1}, 1984; 36–16 kg ha^{-1}d^{-1}, 1985). The time required to reach maximum regrowth standing crop or maximum net growth rate did not vary significantly with season. If livestock movement under rotation grazing was based strictly on the time to reach maximum net growth rate, the length of the rest period for a given pasture would remain constant or even decrease slightly with season. The attainment of a given level of forage in a pasture as a criterion for livestock movement would result in a better balance between forage livestock production than the use of the time to maximum net growth rate.

Key Words: rotatation grazing, growth analysis

Considerable interest in intensive rotation grazing on rangelands in the United States has developed over the past 10 years. These grazing methods generally involve the development of 8–16 pasture grazing cells and the movement of a single herd of livestock among the pastures. Grazing and resting periods on any given pasture are 1–14 days and 20–60 days, respectively (Savory 1978, Kothmann 1980). Proper timing of livestock movement is essential for the success of these grazing methods, but published guidelines have been rather general. Proper length of the rest period for a given pasture has been described as being long enough to allow recovery of the major forage species from grazing (Booysen and Tainton 1978, Howell 1978, Savory 1978, Kothmann 1980). However, specific guidelines on how recovery from grazing should be judged are not stated. Another criterion for timing the length of the rest period was given by Voisin (1959) and Morley (1968). These authors suggested that a pasture should be grazed at the point where forage growth rate reaches a maximum. Grazing at this point maintains the forage on the rapid accumulation phase of the sigmoid growth curve and maximizes forage production over the growing season. Most sources agree that the length of the rest period should be adjusted seasonally as forage growth rates change (Voisin 1959, Morley 1968, Savory 1978, Kothmann 1980). As forage growth slows, recovery from grazing requires more time, and rest periods should be lengthened.

Rational application of intensive rotation grazing should require quantitative information on forage growth rates following grazing and how these growth rates vary with season. Such information is limited for tallgrass prairie ranges and was usually based on full-season growth of ungrazed plants (Dwyer and Hutcheson 1965, Sims and Singh 1978, Gilbert et al. 1979). The objective of this study was to develop information on growth parameters of tallgrass prairie following uniform clipping and to determine how these parameters vary seasonally.

Methods and Materials

The study was conducted on the Stillwater Research Station of the Oklahoma Agricultural Experiment Station in northcentral Oklahoma. Average annual precipitation totals 831 mm with 75% falling during the April–October growing season. Mean annual temperature is 15.5° C with average monthly temperatures of 2.3° C in January and 27.6° C in July.

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The study site was located on a Renfrow silt loam with a 3–5% west-facing slope. The Renfrow soil is a member of the fine, mixed, thermic Udertic Paleustolls; has a clay subsoil at 30–40 cm; and is classified as a Claypan Prairie range site. Vegetation composition by weight on the study site was approximately 20% big bluestem (*Andropogon gerardii* Vitman); 30% little bluestem (*Schizachyrium scoparium* (Michx.) Nash); 10% switchgrass (*Panicum virgatum* L.); 35% other grasses including indiangrass (*Sorghastrum nutans* (L.) Nash), tall dropseed (*Sporobolus asper* (Michx.) Kunth), and Scribner's panicum (*Dichanthelium oligosanthes* (J.A. Schultes) Gould); and 5% forbs, principally western ragweed (*Ambrosia psilostachya* DC.) and slimflower scurfpea (*Psoralea tenuiflora* Pursh). Peak ungrazed standing crop of current year's growth on the site measured in August was 4,060 and 4,740 kg ha^{-1} in 1984 and 1985, respectively. The site had been intermittently harvested for hay for several years, including the year just prior to initiation of the study.

Four regrowth cycles were measured in 1984 and 5 cycles were measured in 1985. Different plot areas were used for study each year. At the initiation of a given cycle a 30 × 30-m macroplot was mowed to a 10 cm height to approximate a moderate to heavy level of utilization and the cut material removed. The macroplot was then divided into 55, 2.5 × 6-m microplots. Five random microplots were sampled every 7 days from day 0 to day 70. Sampling consisted of harvesting a 0.5 × 5-m strip to a 5 cm height with a rotary mower through the center of each microplot. The total weight of the harvested material was measured in the field. Subsamples (100 g) of the harvested material were bagged, oven-dried, and hand-separated to determine dry weight and live herbage conversion factors. Each microplot was sampled once during a regrowth cycle. Regrowth cycles were initiated on 18 May, 9 June, 30 June, and 21 July in 1984 and 24 April, 15 May, 12 June, 26 June, and 18 July in 1985.

All growth analyses were based on live herbage only to avoid confounding with standing dead herbage present from previous year or growth periods. Because a of pronounced lag in growth from day 0 through day 7 for several trials, only data from day 7 through day 70 were included in the analyses. The standing crop data for live herbage were fitted to polynomial regression models after transformation to logarithms to stabilize the variance of the dependent variable over dates (Hunt 1982). First, second, and third-degree polynomials were compared for best fit using R^2, mean square residual, and significance of individual regression parameters as selection criteria. Regression models using the logistic function were also fitted to the transformed primary data. The logistic models were virtually identical to the polynomial models in terms of accuracy, precision, and ability to describe the data. The polynomial models were chosen for further analysis because they could be calculated using linear regression procedures. Six of the 9 trials were best described by second-order polynomials; 1 was best described by a third-order polynomial; and 2 could not be fitted with significant regressions. For uniform comparison purposes the following model was fit to all trials:

$$\mathrm{Ln}(W) = b_0 + b_1{*}T + b_2{*}T^2 \qquad \text{where,}$$

$\mathrm{Ln}(W)$ = natural logarithm of aboveground live standing crop, kg ha^{-1}
T = time from clipping, days
b_0, b_1, b_2 = regression coefficients

Standing crop curves and net growth rate curves (rate of change of standing crop) were plotted in the original units of measurement by retransforming the fitted regression models. For standing crop, this resulted in:

$$W = \mathrm{EXP}(b_0 + b_1{*}T + b_2{*}T^2) \qquad \text{where,}$$

W = estimated aboveground standing crop, kg ha^{-1}
EXP = exponential function

The equation for net growth rate was:

$$G = (b_0 + 2{*}b_2{*}T){*}W \qquad \text{where,}$$

G = estimated net growth rate, kg ha^{-1}d^{-1}

Maximum live standing crop of regrowth (WMAX, kg ha^{-1}), time to WMAX after clipping (TWMAX, days), maximum net growth rate (GMAX, kg ha^{-1}d^{-1}), and time to GMAX (TGMAX, days) were calculated in the original units of measurement from the fitted regression models (Table 1). Because these estimates are nonlinear functions of the regression coefficients, a method for obtaining approximate variances must be used. The method used is referred to as the "delta method" (Bishop et al. 1975) and results in z-test comparisons between trials within years.

Results

Winter-spring precipitation through June, 1984, was about average, but the July–August period was dry with only 35% of the long-term average precipitation received. This resulted in poor growing conditions in the late growing season of 1984. Precipitation through June of 1985 was 65% above normal and late-season precipitation was about average, so that 1985 was considered an excellent year for forage growth.

The regression models accounted for 68–90% of the variation in the logarithm of live standing crop (Table 2). All regression models were highly significant (P<0.001), except for Trials 3 and 4 in 1984 when little regrowth occurred and regression models were not useful (R<0.15).

WMAX decreased with season in both years, but TWMAX was stable over season within years (Table 3, Fig. 1 and 2). Net growth rates followed a similar pattern with GMAX decreasing with season, while TGMAX remained relatively constant (Table 3, Figs. 3 and 4). Net growth rates peaked within 33 days of clipping in all regrowth trials and were negative by the conclusion of 6 out of 7 of the trials in which significant regrowth occurred.

Discussion

Defoliation by clipping is not equal to defoliation by grazing.

Table 1. Formulas used to calculate growth parameters and variances in original units of measurement. See text for parameter abbreviations.

Parameter[1]	Variance of Parameter
$WMAX = EXP[b_0{-}b_1^2/(4{*}b_2)]$	$VWMAX = WMAX^{2}{*}[V(b_0){+}TWMAX^{2}{*}V(b_1){+}TWMAX^{4}{*}V(b_2){+}2{*}TWMAX{*}Cov(b_0,b_1){+}2{*}TWMAX^{2}{*}Cov(b_0,b_2){+}2{*}TWMAX^{3}{*}Cov(b_1,b_2)]$
$TWMAX = -b_1/(2{*}b_2)$	$VTWMAX = TWMAX^{2}{*}[V(b_1)/b_1^2{+}V(b_2)/b_2^2{-}2{*}Cov(b_1,b_2)/(b_1{*}b_2)]$
$GMAX = SQR(-2{*}b_2){*}EXP[b_0{-}b_1^2/(4{*}b_2){-}0.5]$	$VGMAX = GMAX^{2}{*}[V(b_0){+}TWMAX^{2}{*}V(b_1){+}(TWMAX^2{+}(TWMAX{-}TGMAX)^2)^2{*}V(b_2){+}2{*}TWMAX{*}Cov(b_0,b_1){+}2{*}(TWMAX^2{+}(TWMAX{-}TGMAX)^2){*}Cov(b_0,b_2){+}2{*}TWMAX{*}(TWMAX^2{+}(TWMAX{-}TGMAX)^2){*}Cov(b_1,b_2)]$
$TGMAX = -b_1/(2{*}b_2){-}1/SQR(-2{*}b_2)$	$VTGMAX = 1/(4{*}b_2^2){*}V(b_1){+}[b_1{+}SQR(-2{*}b_2))/(2{*}b_2^2)]^2{*}V(b_2){+}(b_1{+}SQR(-2{*}b_2))/(2{*}b_2^3){*}Cov(b_1,b_2)$

[1]EXP() denotes exponential function, SQR () denotes square root, V () denotes variance, and Cov () denotes covariance of quantity in parentheses.

Table 2. Sample size (N), coefficient of determination (R^2), standard error of estimate (Sy.x), and regression coefficients (b_0, b_1, b_2) for regression models of tallgrass prairie regrowth following uniform clipping, 1984 and 1985. Models fitted to transformed data.

Year	Start date	N	R^2	$S_{y.x}$	b_0	$b_1(x\ 10^{-2})$	$b_2(x\ 10^{-4})$
1984	19 May	50	0.78	0.272	5.65(±0.29)[1]	8.08(±1.72)	-7.81(±2.18)
	9 June	50	0.70	0.193	6.35(±0.20)	4.59(±1.22)	-4.42(±1.55)
1985	26 Apr.	45	0.90	0.162	6.11(±0.17)	4.57(±1.09)	-3.12(±1.43)
	16 May	45	0.78	0.205	6.26(±0.22)	4.72(±1.33)	-3.99(±1.73)
	12 June	50	0.77	0.199	6.06(±0.21)	4.62(±1.25)	-3.89(±1.57)
	26 June	50	0.72	0.195	5.99(±0.21)	3.29(±1.24)	-2.37(±1.57)
	18 July	50	0.68	0.217	5.91(±0.22)	3.52(±1.29)	-2.76(±1.63)

[1]95% confidence intervals.

Table 3. Maximum regrowth standing crop (WMAX, kg ha^{-1}), time to WMAX (TWMAX, days), maximum net growth rate (GMAX, kg $ha^{-1}d^{-1}$), and time to GMAX (TGMAX, days) for tallgrass prairie regrowth following uniform clipping, 1984 and 1985.

Year	Start date	WMAX	TWMAX	GMAX	TGMAX
1984	19 May	2300^{a}[1]	52^{NS}	55^{a}	26^{NS}
	9 June	1870^{b}	52	34^{b}	18
	30 June	820^{c}	—	—	—
	21 July	280^{d}	—	—	—
1985	26 Apr.	2400^{a}	73^{NS}	36^{a}	33^{NS}
	16 May	2130^{a}	59	36^{a}	24
	12 June	1690^{b}	59	29^{a}	24
	26 June	1260^{c}	69	17^{b}	23
	18 July	1130^{c}	64	16^{b}	21

[1]Means within year and column followed by the same letter are not significantly different at the 5% probability level; NS denotes significant differences within a set of means.

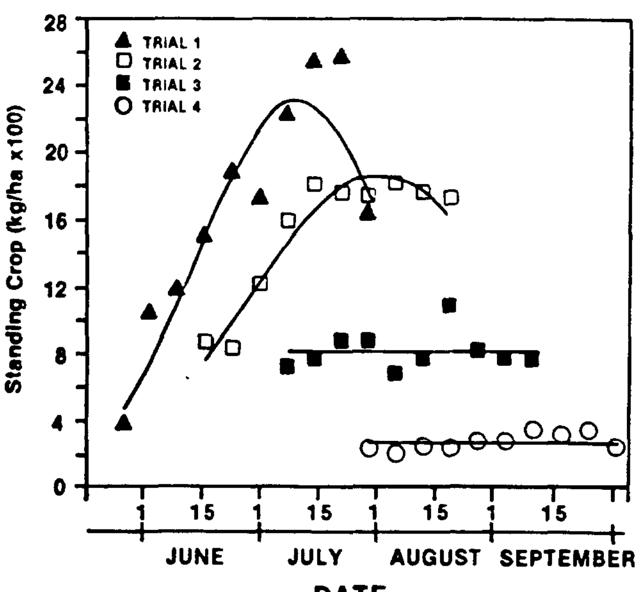

Fig. 1. *Tallgrass prairie regrowth following uniform clipping, 1984. Symbols denote means of five samples per date. Trial start dates: 1 = 19 May, 2 = 9 June, 3 = 30 June, 4 = 21 July.*

Clipping does not incorporate the selectivity of the grazing animal for plant species or plant part (White 1973, Watkin and Clements 1978). Clipping also removes the effects of trampling and nutrient recycling by the grazing animal (Watkin and Clements 1978). The divergence between clipping and grazing would be greatest when comparing plant response to one or a few annual clippings versus

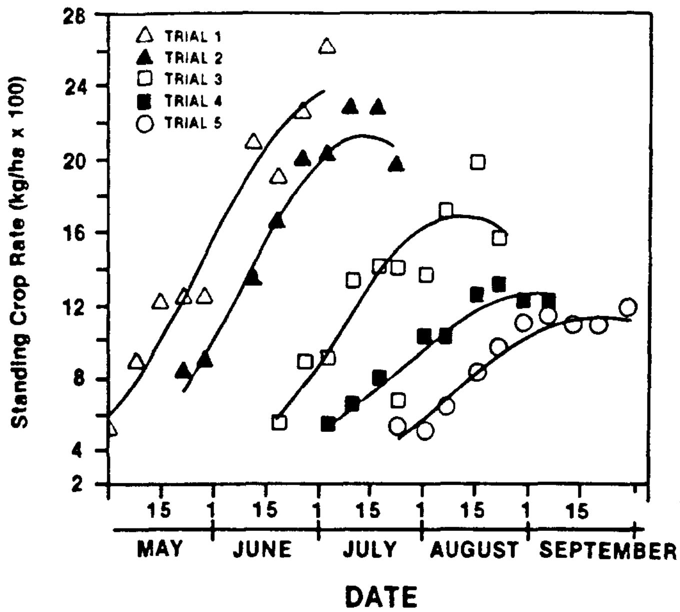

Fig. 2. *Tallgrass prairie regrowth following uniform clipping, 1985. Symbols denote means of 5 samples per date. Trial start dates: 1 = 26 Apr., 2 = 16 May, 3 = 12 June, 4 = 26 June, 5 = 18 July.*

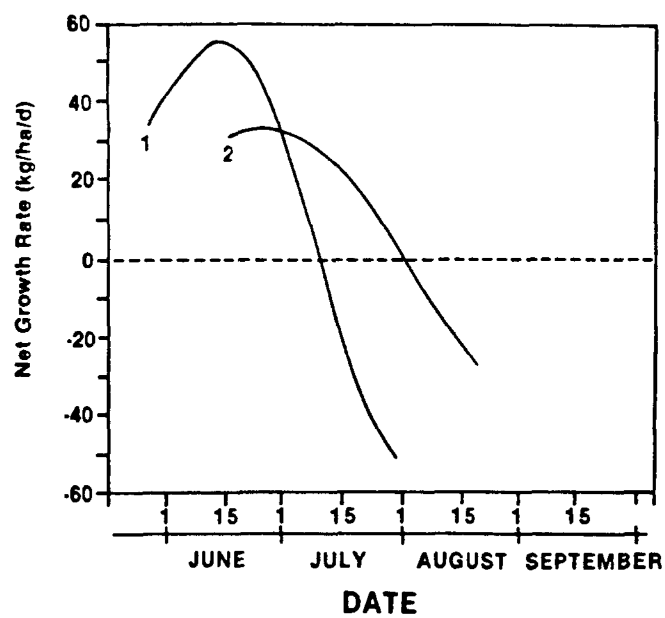

Fig. 3. *Growth rates of tallgrass prairie following uniform clipping, 1984. Trial start dates: 1 = 19 May, 2 = 9 June.*

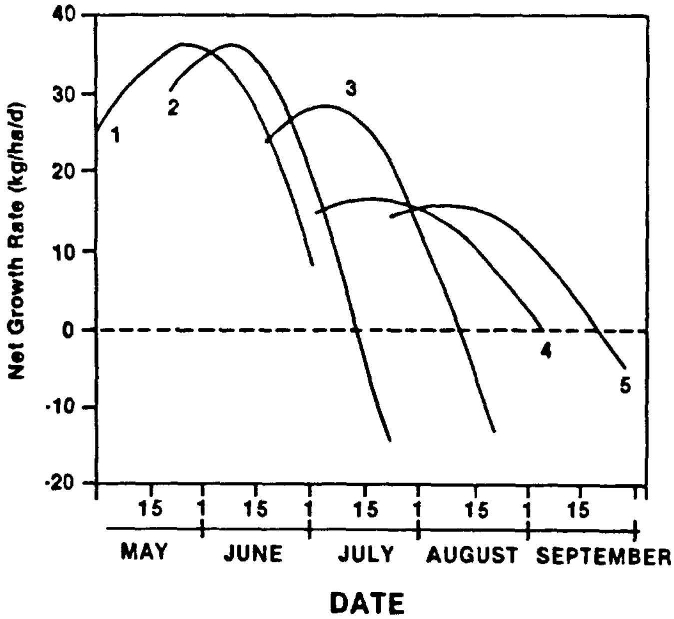

Fig. 4. *Growth rates of tallgrass prairie following uniform clipping, 1985. Trial start dates: 1 = 26 Apr., 2 = 16 May, 3 = 12 June, 4 = 26 June, 5 = 18 July.*

continuous grazing over a period of years. Such a situation would illustrate the maximum effect of animal selectivity, trampling, and nutrient cycling on plant production and species composition. This study used clipping to simulate rotation grazing that incorporates moderate to heavy forage utilization within a short period. In this situation, clipping and grazing would impose more similar defoliation regimes with short-term responses (immediate regrowth rates) being evaluated. While responses following grazing as opposed to clipping in this situation might be quantitatively different, the qualitative responses (shape and position of response curves) would be expected to be similar.

Total forage regrowth and net growth rate declined with season as soil moisture was depleted and daily temperatures increased in July and August. The duration of regrowth was much less affected by season. Morely (1968) found similar results for improved temperate pastures during the summer as TGMAX only varied between 35 and 49 days. The model presented by Voisin (1959) in which WMAX remains constant and TGMAX increases with season is not supported in this experiment. If livestock movement was based as TGMAX alone, the rest period would not lengthen with season but would remain constant. However, with lower WMAX, less herbage would be available for grazing during each subsequent rotation resulting in depressed animal performance and higher forage utilization.

Grazing management should be based on both animal and plant requirements (Savory 1978, Kothmann 1980). Another criterion for livestock movement that might address both components more evenly would be the attainment of a given level of forage in a pasture before regrazing. A target forage level would be reached more rapidly in the early season when growth rates are higher than in the later season when growth rates decline. Such a criterion would result in a lengthening of the rest period as season progressed as is currently recommended but would not match grazing with the occurrence of TGMAX.

What constitutes 'adequate recovery from grazing' has not been determined from this study, but it appears that TGMAX is not a useful criterion for managing livestock movement under intensive rotation grazing in the tallgrass prairie. The potential for significantly influencing the growth curves of tallgrass prairie forage also appears to be limited. Growth rates decline rapidly from mid-May through June. Growth rates are low on defoliated tallgrass prairie after July 1 even in favorable precipitation years and are virtually zero in unfavorable years. While the frost-free period in this region averages 204 days, the period of major forage growth of native warm-season grasses is limited to 75–100 days. Finally, as suggested by Morley's work (1968) on improved temperate pastures, growth parameter estimates presented here should be useful in further quantitative analyses of the impact of different grazing management practices on the tallgrass prairie.

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