EFFECTS OF GRAZING PRESSURE
ON DEFOLIATION PATTERNS
OF TALLGRASS PRAIRIE

By

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ABSTRACT

Few studies have dealt with measuring individual plant defoliations in the context of intensive grazing management. In May, July, and August of 1987, grazing trials were conducted to quantify the effects of cattle grazing pressure on defoliation patterns of little bluestem (Schizachyrium scoparium (Michx.) Nash), big bluestem (Andropogon gerardii Vitman), and indiangrass (Sorghastrum nutans (L.) Nash). Grazing pressures of 10, 20, 30, and 40 kg AUD^{-1} were replicated twice per trial. Treatment pastures contained 30 marked tillers of each species. Standing crop was measured before and after grazing. Tiller height, relative leaf area removed, and frequency of defoliation were measured every 2 days over 10 day trials. The frequency and intensity of tiller defoliation was highly dependent on species and grazing pressure. Tiller height decreased more rapidly as grazing pressure increased, and leaf area removed increased as grazing pressure increased. Height and leaf area removed were similar for grazing pressures of 30 and 40 kg AUD^{-1}. Indiangrass was the most preferred species in all trials. Tillers were spread among at least three defoliation frequency classes for all species and grazing pressures. Trial 1 had the greatest proportion of undefoliated tillers regardless of species. Under most grazing pressures, indiangrass and big bluestem had more tillers defoliated 3 times in a trial. Tillers were moderately defoliated the first time and severely defoliated afterwards. Defoliating all tillers once in a rangeland community is virtually impossible to achieve without severe defoliation on some species. Planning livestock movements based on a target defoliation intensity and regulating grazing pressure to reduce the risk of severe defoliation can be useful strategies for

intensive grazing management.

INTRODUCTION

Range management and research have focused much attention on intensive grazing management during the last ten years. Much of this research involved comparisons between grazing systems from a vegetation production and animal performance aspect (Denny and Barnes 1977, Hart and Balla 1982, Ralphs et al. 1986, Heitschmidt et al. 1987a, 1987b). Studies of this nature have clearly illustrated the complexity of plant-animal interactions. However, few studies have addressed the impact of intensive grazing management on individual plant defoliations.

Defoliation patterns can be partially characterized by the frequency and intensity of individual plant defoliation. Researchers in Africa and Europe have found defoliation patterns are dependent on factors such as grazing pressure, season of use, tiller morphology and phenology, species selection, and length of the grazing period (Hodgson and Ollerenshaw 1969, Gammon and Roberts 1980, Curll and Wilkins 1982, Barthram and Grant 1984, Tallowin et al. 1986). These studies were conducted with cattle or sheep on native grass or improved pastures. In the U.S., similar studies have been conducted on rangelands in Wyoming, Utah, Texas and Washington (Hart and Balla 1982, Norton and Johnson 1983, Brown and Stuth 1984, Pierson and Scarnecchia 1987).

Potentially, intensive grazing management can be an effective method of optimizing forage use by manipulating grazing pressure, and controlling the frequency and intensity of plant defoliation (Kothmann 1984). Results from short duration grazing (SDG) studies have been mixed. For instance, how much stocking rate can be safely increased as a result of implementing an SDG system is a controversial subject. Because defoliation patterns reflect animal behavior, measuring defoliation patterns in different geographical areas, may explain variable plant and animal responses under intensive grazing management.

The objective of this study was to quantify defoliation patterns by beef cattle on native tallgrass prairie during the growing season over a range of grazing pressures.

STUDY AREA

The research was conducted in northcentral Oklahoma, 3 km northwest of Oklahoma State University, Stillwater. The average annual precipitation is 84 cm with 75% falling during the April to October growing season. This region of Oklahoma has a temperate climate with moderately cold winters and hot, relatively dry summers.

The study site was located on a Renfrow silt loam soil with a 3 to 5% west-facing slope. Renfrow silt loam soil is a fine, mixed, thermic Udertic Paleustoll with a clay subsoil at 30-40 cm and is classified as a Claypan Prairie range site.

During the summer of 1987, the vegetation composition by weight on the study site consisted of 35% big bluestem (Andropogon gerardii Vitman), 22% little bluestem (Schizachyrium scoparium (Michx.) Nash), 22% indiangrass (Sorghastrum nutans (L.) Nash), 10% switchgrass (Panicum virgatum L.), and 11% other perennial grasses, annual grasses and forbs. For several years before the study began, the vegetation was harvested for hay in early July. Six weeks before the study began, the site was burned to ensure a uniform level of spring growth.

MATERIALS AND METHODS

Three grazing trials, each lasting 10 days, were conducted during the 1987 growing season on the following dates: 15-25 May (Trial 1), 2-

12 July (Trial 2), 12-22 August (Trial 3). Four grazing pressures, 10, 20, 30, and 40 kg AUD^{-1}, were replicated twice for a total of eight pastures per trial. These grazing pressures are similar to those used by Allison et al. (1982), who concluded that increases in grazing pressure improved forage harvest efficiency and may be linked to the successes of short duration grazing systems. Grazing pressures were calculated based on standing crop before the trial started. Fifty 0.1 m^2 plots were clipped at random, over the entire study area, samples were oven dried to a constant weight and averaged. Pasture size was calculated based on forage demand for three steers of similar weight (Table 1) for 10 days of grazing, divided by the initial standing crop (Hodgson 1979). Pastures were constructed using temporary electric fencing materials. Target grazing pressures for Trial 2 were the same as the other trials, but miscalculations of initial standing crop caused the actual pressures to be adjusted downward (Table 1). At the end of each trial, standing crop was estimated using 15 0.1 m^2 plots per pasture. Samples were oven dried, weighed and averaged for each pasture.

Tiller measurements were taken every 2 days during each trial. Three permanent 30 m transects were located in each pasture and 10 tillers of little bluestem, big bluestem, and indiangrass per transect were marked using color-coded wire rings (Gammon and Roberts 1978). Tiller height and the proportion of leaf area removed were used as relative measures of defoliation intensity. Tiller height was measured from the ground to the highest point on a tiller as it was extended upright. A numerical defoliation intensity code, based on a visual estimate of leaf area removed, was recorded with the following scale: 1) no evidence of defoliation; 2) tiller lightly defoliated, majority of leaf area intact;

3) tiller moderately defoliated, about half of leaf area removed; 4) tiller severely defoliated, little or no leaf area left. With a short period of practice before a trial was initiated, a high level of consistency among observers was obtained (i.e. variation was low). The frequency of tiller defoliation was monitored by marking the cut edges of defoliated tillers with latex paint on each day of measurement.

Pastures were arranged in a randomized complete block design with trial and grazing pressure as whole plots and repeated measures on species, day, and trial. Statistical analysis included standard analysis of variance (AOV) procedures for intensity of defoliation. Prediction models, using additive polynomial regression equations, were developed to include linear, quadratic, and all interactions within a trial and species. Grazing pressure and day of grazing were used as independent variables. Chi-square analysis was used for defoliation frequency distributions. Analysis of variance was used to analyze the combined effects of intensity and frequency of defoliation.

RESULTS AND DISCUSSION

Standing Crop

Final standing crop was affected least by grazing pressures in the spring than later in the season, except at excessive grazing pressure (10 kg AUD^{-1}, Table 2). Most likely, this was a result of the rapid growth rate of tillers in May. Final standing crop decreased as grazing pressure increased during Trials 2 and 3. Reece (1986) reported similar results in Nebraska.

Intensity of Defoliation

Coefficients of determination for the polynomial regression equations predicting grazing intensity were relatively high with few exceptions (Table 3). The intensity of tiller defoliation (tiller height or proportion of leaf area removed) was highly dependent on the linear effects of grazing pressure and day of grazing. In all cases, tiller height decreased over time as grazing pressure increased and the severity of grazing with respect to leaf area increased over time as grazing pressure increased. The quadratic effects due to grazing pressure and day on defoliation intensity were less important than linear effects but still significant (Table 3). Among the quadratic effects, day of grazing was significant more often than grazing pressure. Interactions between grazing pressure and day, linearly and quadratically, were also significant. Again, the quadratic effect of grazing pressure as it interacted with day was less important.

During Trial 1, initial tiller height was 10 cm and 7 cm greater for indiangrass than little bluestem and big bluestem, respectively (Fig. 1). When grazing pressure was 40 kg AUD^{-1}, all species had small reductions in tiller height. As grazing pressure increased, tiller height decreased more rapidly and tended to do so curvilinearly for big bluestem and indiangrass. Among all grazing pressures, tiller height for little bluestem was reduced less than the other species.

During Trial 2, initial tiller height was 10 and 20 cm greater for indiangrass than big bluestem and little bluestem, respectively (Fig. 1). Grazing pressures of 30 and 40 kg AUD^{-1} decreased little bluestem height linearly while tiller height for other species decreased curvilinearly over time. Tiller height decreased more rapidly as grazing pressure increased, among all species. The amount of height reduction was similar for big bluestem and indiangrass which were both greater than little bluestem. However, by the end of the trial, tiller height at the more intense grazing pressures (10-20 kg AUD^{-1}) tended to be equal among species. Indiangrass tiller height leveled off before the end of the trial. Cattle were removed from the 8 kg AUD^{-1} pasture on day 7 of Trial 2, for lack of available forage.

Trial 3 was most similar to Trial 2 in relation to how tiller height responded to species and grazing pressure. When grazing pressure was 20-40 kg AUD^{-1} little bluestem height decreased linearly (Fig. 1). Big bluestem and indiangrass were affected similarly by grazing pressure. Tiller height for these species decreased in a curvilinear manner over time and at similar levels of magnitude. Although total height removed was greatest for big bluestem and indiangrass; at intense pressure little bluestem was grazed to a lower final height. This result may be a function of growth form whereby little bluestem (a bunchgrass) has more vegetative tillers concentrated in one spot allowing animals to spend less time searching for these tillers. Also, tiller height of little bluestem was initially shorter. Cattle were removed from the 10 kg AUD^{-1} pasture on day 9 of Trial 3, for lack of available forage.

In summary, among all trials, tiller height reduction was less severe in spring vs. mid and late season. Tiller height decreased as grazing pressure increased, and at a faster rate in mid and late summer compared to spring. Tiller height was similar for big bluestem and indiangrass and decreased to a greater extent than little bluestem from spring to late summer. When grazing pressure was 10 kg AUD^{-1} in Trials 1 and 2, tiller height had a lower limit of 6-8 cm for all species. In

Trial 3, the lower limit for tiller height varied amomg species from 7-19 centimeters. The increase of lignified plant tissue in late summer may explain the difference in final tiller height.

The intensity of defoliation based on the proportion of leaf area removed was inversely related to tiller height (Fig. 2). Similarities and contrasts among species and grazing pressures, relative to the proportion of leaf area removed, were similar to those of tiller height results.

Managers could plan the length of the grazing period on a target level of leaf area removed or tiller height. Since individual species would not be expected to reach the same level of defoliation (for instance a grazing code of 3, moderate defoliation) at the same time; grazing period could be based on an average target level of defoliation among the most important species. The data from this study clearly shows the differences in defoliation intensity between species. For instance (with the species composition in this study), if a manager's objective was to achieve moderate defoliation on big bluestem at 20 kg AUD^{-1} in the spring, this would occur in about 8 days of grazing (Fig. 2). However, indiangrass would have severe defoliation (grazing code 4) and little bluestem light-moderate defoliation. Averaging for moderate defoliation over all species would reduce the length of the grazing period to 6 days. Using the same grazing pressure and target levels of defoliation intensity in late summer would result in no change in grazing period length because all species would reach moderate defoliation on day 5 or 6. If the manager reduced grazing pressure in late summer from 20 to 30 kg AUD^{-1} the grazing period for moderate defoliation averaged over all species would then increase to 7 or 8 days.

The hypothesis that opportunity for selection decreases with an increase in grazing pressure (Holmes 1980) was supported by this study. As grazing pressure increased, there was a tendency for tiller height and proportion of leaf area removed to become more uniform among species by the end of the grazing trial. This effect was generally limited to grazing pressures of 10 and 20 kg AUD^{-1} in this study.

Frequency of Defoliation

Chi-square analysis showed significant differences among frequency of defoliation classes between all grazing pressures within all trials ($P<0.01$). Generally, when grazing pressure increased more tillers were defoliated 2 and 3 times within a trial. Also, tillers were always spread across at least three defoliation classes at all grazing pressures and for all species.

The frequency of defoliation for a given species and grazing pressure varied most between Trial 1 and the other two trials. For all three species, Trial 1 had the most undefoliated tillers when grazing pressure was 40 kg AUD^{-1}. When grazing pressure was 10-30 kg AUD^{-1} tillers were spread among more defoliation frequency classes.

During Trial 2, when grazing pressure was 8 kg AUD^{-1}, defoliated tillers for all species were spread among 3 defoliation frequency classes. The majority of tillers received 2 defoliations. When grazing pressure was 16-32 kg AUD^{-1} the frequency distributions of defoliated tillers tended to be wider. Tillers in the 8 kg AUD^{-1} pasture had narrower defoliation frequency distributions because the trial only lasted 6 days instead of 10.

During Trial 3, all grazing pressures had tillers of all species distributed among 4 defoliation frequency classes.

The frequency of defoliation was subject to a species by grazing pressure interaction. During Trial 1, indiangrass and big bluestem had more tillers defoliated in the higher frequency classes than little bluestem. When grazing pressure was 20-40 kg AUD^{-1}, little bluestem had the most undefoliated tillers.

All species in Trial 2 had tillers in 3 or more defoliation frequency classes under all grazing pressures. The frequency of defoliation was similar for all species when grazing pressure was 8 kg AUD^{-1}. However, when grazing pressure decreased, the frequency of defoliation differed among species. Big bluestem and indiangrass had wider defoliation frequency distributions than little bluestem in most cases.

All species in Trial 3 had relatively more tillers defoliated once under most grazing pressures compared to Trial 2. Similar to Trial 2, big bluestem and indiangrass had wider defoliation frequency distributions than little bluestem.

The frequency of tiller defoliation was highly dependent on species, and grazing pressure. Kothmann (1984), and Pierson and Scarnecchia (1987) reached similar conclusions. Among most grazing pressures and trials, indiangrass had multiple defoliations on tillers in fewer days than big bluestem and indiangrass. Grazing pressures above 10 kg AUD^{-1} had 60-80% of all tillers defoliated twice or less times. Gammon (1984) concluded some tillers receive multiple defoliations even at light grazing pressure.

A common objective of short duration grazing is to attempt to defoliate all tillers in a pasture once during the grazing period. Under our study conditions, such an objective is virtually impossible to achieve given the large number of species on a site. By the time the least preferred species on a range site are defoliated once, the most preferred species will most likely have been defoliated 2 or more times. This species selectivity will occur even at the most intense grazing pressures.

The frequency of defoliation for any given species will depend on species composition as well as distribution of a species within a site or pasture. The specific patterns found in this study would be expected to change under different species compositions and range sites. Gammon and Roberts (1978a) reached a similar conclusion in Zimbabwe, Africa. Although specific changes may occur, the underlying relationship of defoliated tillers being spread across two or more defoliation classes on a mixed species site would be highly probable. Managing intensive grazing systems requires range managers to know their key species and relative composition to effectively manipulate defoliation patterns, and improve animal distribution. Experimenting with different amounts of grazing pressure and learning to visually estimate the intensity of defoliation are justified in planning livestock movements under intensive grazing systems.

Summarizing, in the spring, all three species had the largest proportion of undefoliated tillers occur at the lightest grazing pressure. The frequency of defoliation increased with grazing pressure in the spring in most cases. Generally, at 10 kg AUD^{-1}, each species had a steady increase in the proportion of tillers defoliated from one to three times in spring and late summer.

Frequency and Intensity of Defoliation

The intensity of defoliation, in terms of proportion of leaf area removed, increased with each defoliation (Table 4). Generally, intensity was moderate for the first defoliation; moderate to severe the second defoliation; and severe afterwards.

Conclusions

The defoliation patterns of tallgrass prairie species are affected by grazing pressure, number of grazing days in a period, and segment of the growing season.

Defoliation patterns had similar trends in each trial. Intensity and frequency of defoliation increased over the length of the grazing period. However, the hypothesis proposed by Reece (1986), that a given species would not be expected to be severely defoliated through the entire season is not supported in this study (e.g. indiangrass).

Some implications for management can be drawn from the results presented. During spring, light grazing pressure (more than 30 kg AUD^{-1}) may result in inefficient forage use if even utilization is important. Such a grazing pressure would leave an abundance of leaf area on tillers and allow forage quality to decline early, also there would be little control over tiller selectivity. Grazing pressures from 20-30 kg AUD^{-1} would prove more efficient, even though some tillers would be expected to be severely defoliated they would probably recover at this time of the season.

In the tallgrass prairie of Oklahoma, forage quality declines in mid July (Waller et al. 1972). Grazing pressure around 20 kg AUD^{-1} may have to be reduced because defoliation frequency and intensity increases at this time. Reducing the grazing pressure would allow for relatively greater selectivity of tillers and help maintain animal performance. Grazing pressure would be naturally reduced as the grazing season progressed because forage consumption would not be expected to keep pace with forage growth rate under most situations. There are several alternatives for reducing grazing pressure should further action be necessary. One way of reducing grazing pressure is to reduce stock density. Such an alternative should only be necessary under extreme grazing pressure. Another alternative for reducing grazing pressure would be to decrease the stocking rate for the rotation system. In August, if forage is needed for dormant season grazing further reductions in grazing pressure may be warranted. Managers should be cautious though, since extremely light grazing pressure causes excessive tiller selection and may result in the most preferred species being grazed out of a pasture in the long run. In Nebraska, after 6 years, the frequency of prairie sandreed [Calamovilfa longifolia (Hook.) Scribn.] declined under short duration grazing, but increased in ungrazed exclosures (Reece 1986).

The reasons for success or failure of short duration grazing systems are not completely understood. There is little doubt that managerial skill is a major source of success, but broadening our knowledge of how plants and grazing animals interact under these systems is necessary for developing more scientific explanations. Further study of individual plant defoliation and grazing animal behavior should be encouraged over a broad range of rangeland environments.

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APPENDIX A

Table 1. Range of pasture sizes, grazing pressure, average steer weight (pre-trial), during spring and summer 1987.

	Trial 1	Trial 2	Trial 3
Pasture size (ha)	.20-.80	.06-.24	.15-.24
Grazing pressure (kg AUD^{-1})	10,20,30,40	8,16,24,32	10,20,30,40
Steer weight (kg)	295	305	351

Table 2. Mean pre- trial and post-trial standing crop (kgDM ha^{-1}) for three grazing trials in 1987.

Trial	Initial Standing Crop	Final Standing Crop: Grazing Pressure (kg AUD^{-1}) 10	20	30	40
1	1083	498[b1]	1020[a]	1076[a]	1146[a]
2[2]	2929	586[c]	981[bc]	2038[a]	1693[ab]
3	4094	947[b]	2190[ab]	2547[a]	3077[a]

1 Values with the same superscript within a row are not significantly different from each other, P=0.05.
2 Grazing pressures for Trial 2 were 8, 16, 24, and 32 kg AUD^{-1}.

Table 3. Coefficients of polynomial regression equations for tiller height and grazing code, N=number, R^2=coefficient of determination, Sy,x=standard error of the estimate G=grazing pressure, D=day of grazing. $P<0.05$.

Species	Trial	N	R^2	Sy,x	b_0	b_1G	b_2G^2	b_3D	b_4D^2	b_5GxD	b_6GxD^2	b_7G^2xD	$b_8G^2xD^2$
<u>Tiller Height</u>													
Big bluestem	1	48	.87	1.87	16.46	0.469	-0.009	-1.958		0.450	-0.001		
	2	44	.90	3.59	38.87	0.073		-9.921		0.166	-0.015		
	3	46	.69	6.32	41.93	0.272		-5.054	0.260				
Indiangrass	1	48	.86	2.94	31.16	-0.070		-5.801	0.281	0.143	-0.008		
	2	44	.92	4.00	43.65	-0.131	0.009	-7.898	0.151		0.023		$-4x10^{-4}$
	3	46	.86	4.43	39.15	0.365		-6.268	0.350				
Little bluestem	1	48	.94	1.00	15.88	0.320	-0.007	-2.344		0.108		-0.001	
	2	44	.86	3.14	30.50	0.105		-4.419	0.065	0.690			
	3	46	.98	1.28	23.53	1.021	-0.019	-6.373	0.293	0.158	-0.008		$-3x10^{-5}$
<u>Grazing Code</u>[1]													
Big bluestem	1	48	.91	0.32	1.45	-0.017		0.396		-0.007	$-2x10^{-4}$		$-5x10^{-6}$
	2	44	.93	0.26	1.33	-0.010		0.691	-0.037	-0.002			
	3	46	.96	0.20	2.19	-0.105	0.002	0.774	-0.057	-0.062	0.002		$-9x10^{-6}$
Indiangrass	1	48	.87	0.44	0.94	0.002		0.908	-0.052	-0.021	0.002		
	2	44	.92	0.31	1.52	-0.018		0.695	-0.042				
	3	46	.93	0.28	2.96	-0.142	0.002	0.535	-0.031		$2x10^{-4}$		$-3x10^{-6}$
Little bluestem	1	48	.96	0.20	1.38	-0.252	$4x10^{-4}$	0.505		-0.022	$-1x10^{-4}$	$3x10^{-4}$	
	2	44	.86	0.33	1.30	-0.012		0.467	-0.010	-0.006			
	3	46	.92	0.26	1.06	-0.003		0.685	-0.034	-0.016	0.001		

[1] defoliation intensity based on relative amount of leaf area removed on a tiller.

Table 4. Mean grazing codes for 3 grazing frequency classes among species and grazing pressures; 1X=first time a tiller was grazed, 2X=second time a tiller was grazed, 3X=third time grazed.

	1X				
	Trial				
Treatment	1	2	3	2X	3X
<u>Species</u>					
Little bluestem	3.0[a12]	2.6[b]	2.6[b]	3.2[b]	3.7[b]
Big bluestem	3.1[a]	3.1[a]	2.9[a]	3.6[a]	3.8[ab]
Indiangrass	3.0[a]	3.1[a]	2.9[a]	3.7[a]	3.9[a]
<u>Grazing Pressure (kg AUD^{-1})</u>					
10	3.3[a]	3.3[b]	3.1[b]	3.7[a]	3.9[b]
20	2.9[bc]	2.8[a]	2.6[a]	3.6[a]	3.8[a]
30	3.1[ab]	2.7[a]	2.5[a]	3.3[b]	3.6[c]
40	2.7[c]	2.8[a]	2.9[c]	3.3[b]	3.8[a]

[1] values with the same superscript within columns are not significantly different from each other, P=0.05.
[2] grazing codes (defoliation intensity): 1=undefoliated, 2=light, 3=moderate, 4=severe.

List of Figures

Fig. 1. Relationship between tiller height and grazing pressure for 3 species during three 10 day grazing trials.

Fig. 2. Relationship between grazing code and 4 grazing pressures for 3 species during three 10 day grazing trials.

Fig. 3. Defoliation frequency distributions for species among 4 grazing presuures (kg AUD^{-1}) during three 10 day grazing trials. Numbers over bars indicate frequency of defoliation within a trial.

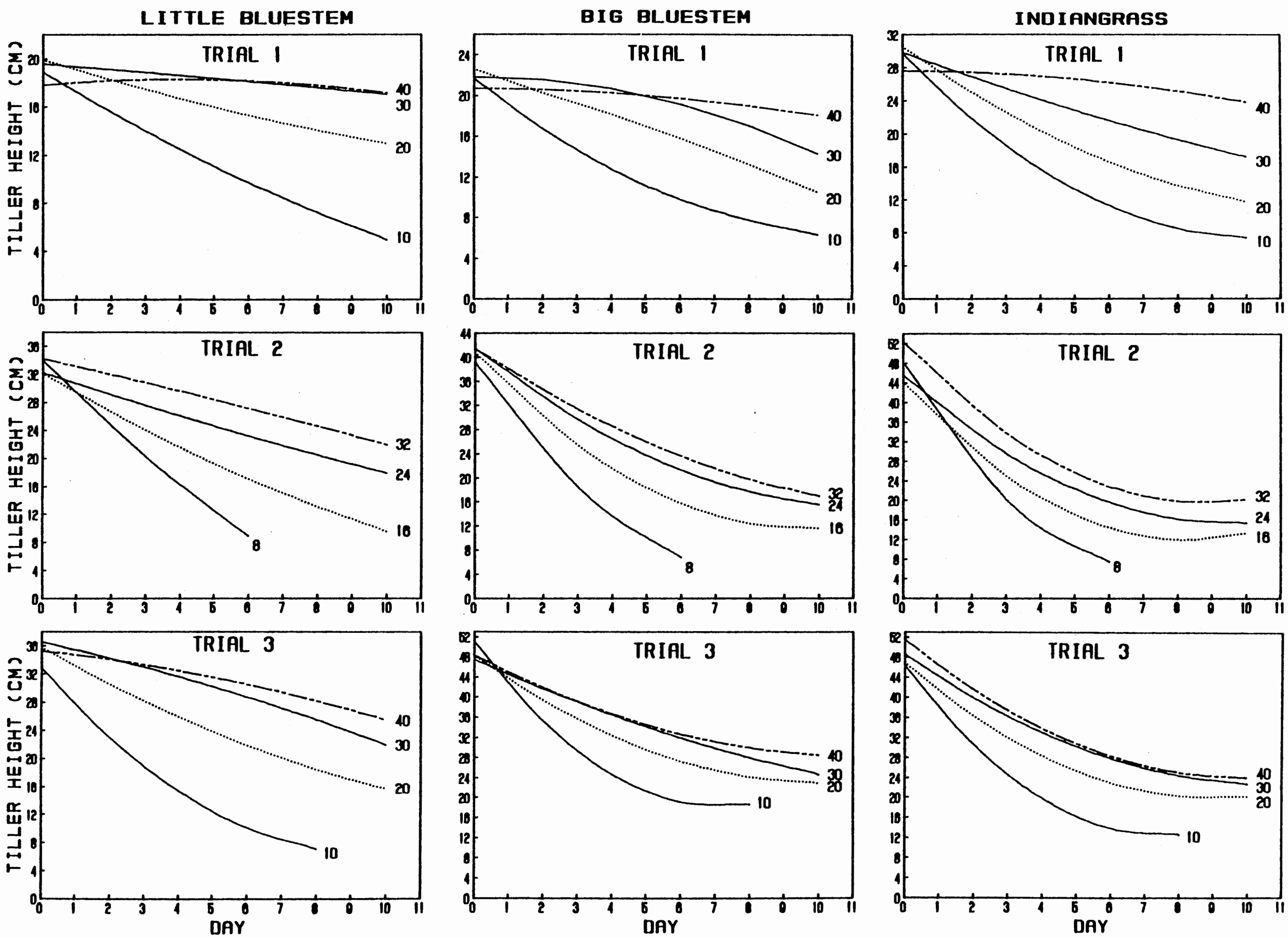
LITTLE BLUESTEM
BIG BLUESTEM
INDIANGRASS
TRIAL 1
TRIAL 2
TRIAL 3
TILLER HEIGHT (CM)
DAY
40
30
20
10
32
24
16
8

Fig. 1

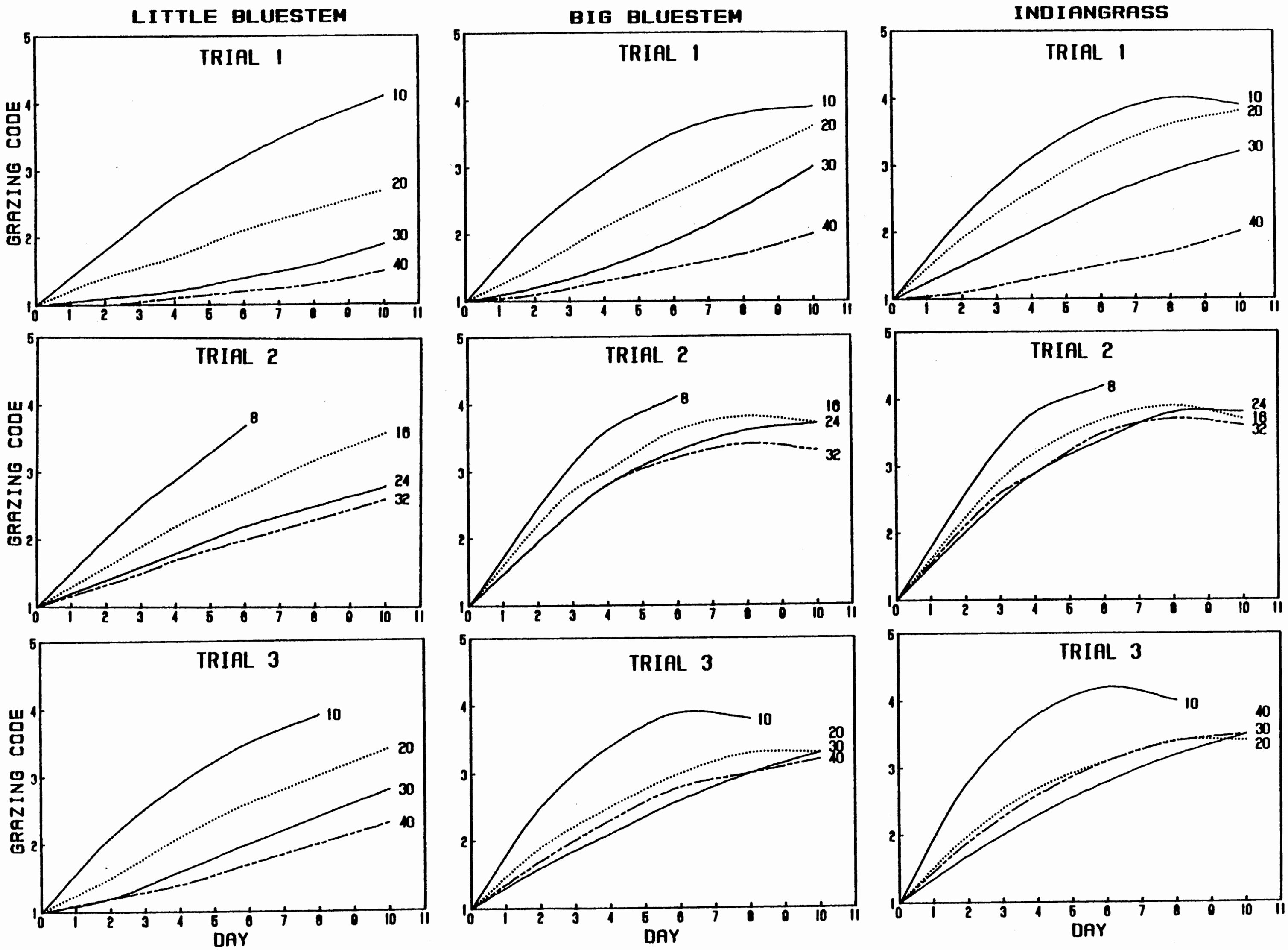
LITTLE BLUESTEM
BIG BLUESTEM
INDIANGRASS
TRIAL 1
TRIAL 2
TRIAL 3
GRAZING CODE
DAY
10
20
30
40
8
16
24
32

Fig. 2

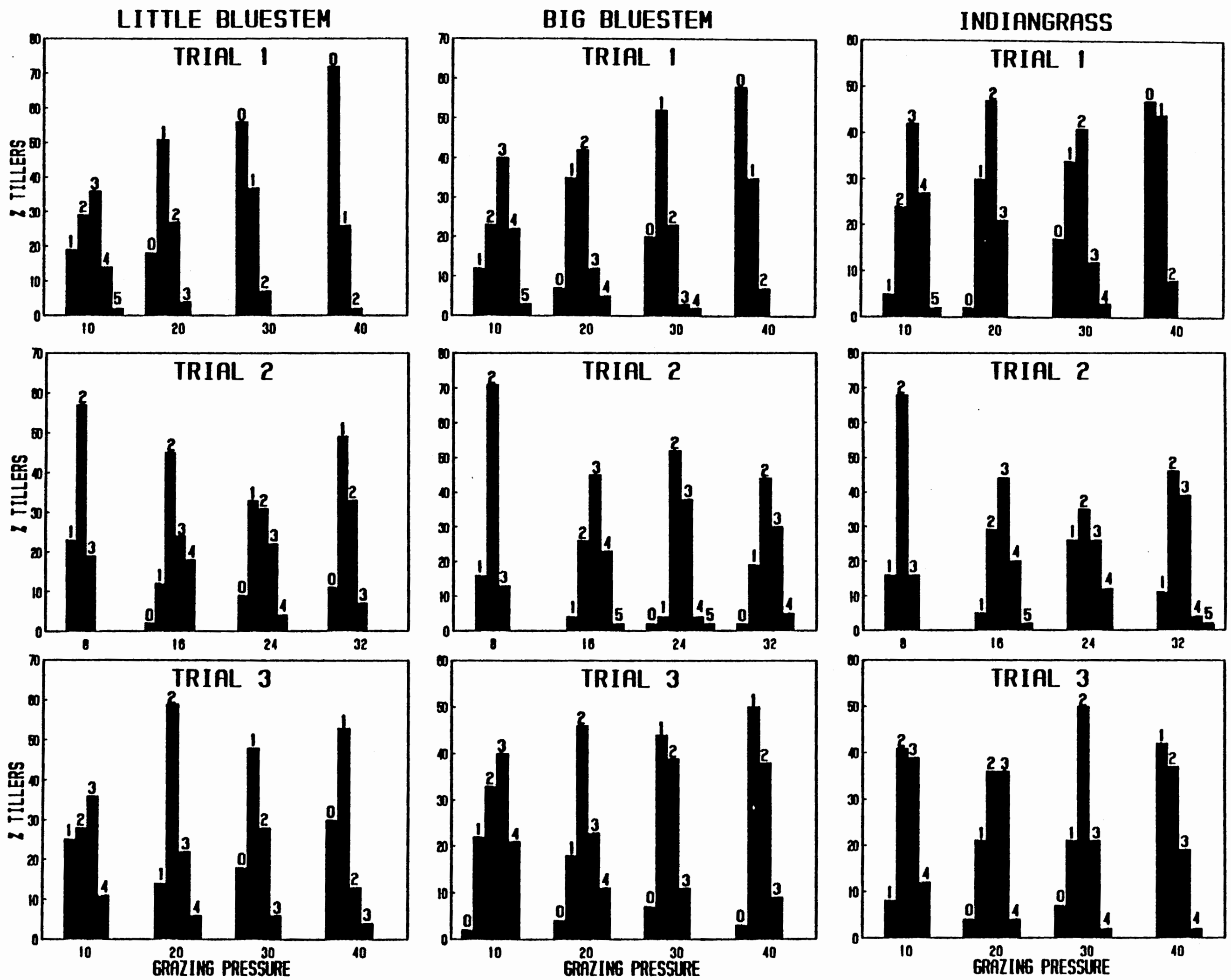
LITTLE BLUESTEM
BIG BLUESTEM
INDIANGRASS
TRIAL 1
TRIAL 2
TRIAL 3
% TILLERS
GRAZING PRESSURE

Fig. 3

VITA

Holger Peter Jensen

Candidate for the Degree of

Master of Science

Thesis: EFFECTS OF GRAZING PRESSURE ON DEFOLIATION PATTERNS OF TALLGRASS PRAIRIE

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