J. Range Manage.
47:215-219, May 1994

Tiller defoliation patterns under frontal, continuous, and rotation grazing

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Abstract

An investigation was conducted to characterize the intensity and frequency of tiller defoliation in 'Plains' Old World bluestem (*Bothriochloa ischaemum* (L.) Keng) under frontal, continuous, and 2-paddock rotation grazing systems. Frontal grazing allows cattle a continuous opportunity to graze fresh forage via a livestock-pushed sliding fence that allocates and controls grazing within a pasture. Nearly 100% of frontal grazing tillers were defoliated at least once during a 3-hour period as the frontal fence was advanced over the transect area. The initial defoliation intensity of tillers under frontal grazing was also significantly higher and remaining tiller height less than that of tillers under rotation or continuous grazing ($P < 0.05$). Tillers under frontal grazing were defoliated at a faster rate compared to rotation or continuous grazing, but cattle had access to them for only 6 to 8 days of the entire grazing season. Season-long defoliation frequency was estimated to be 2.4, 4.6, and 4.7 times for frontal, continuous, and rotation grazing, respectively. Tillers that originated from the perimeter of a tussock were initially taller than those arising from the center ($P < 0.05$); however, frequency and intensity of defoliation was similar for both tiller locations. Significant relationships were also described between defoliation frequency and stocking rate and between defoliation frequency and herbage allowance. Defoliation frequency increased linearly as stocking rate increased; and conversely, defoliation frequency decreased quadratically as herbage allowance increased. Data from this study suggest that the pattern of tiller defoliation under frontal grazing enhanced forage production which allowed the maintenance of higher stocking rates.

Key Words: *Bothriochloa ischaemum*, defoliation frequency, defoliation intensity, grazing systems, herbage allowance, 'Plains' Old World bluestem, stocking rate

Grazing systems have the ability to alter the nature and complexity of plant-animal interactions. To assist in the understanding of plant-animal interactions, it is important to identify the basic patterns and characteristics of tiller defoliation within grazing systems. Furthermore, defoliation regime or pattern is a major variable influencing plant response to grazing (Gillen et al. 1990). In recent years, several researchers have addressed the impacts of short duration or rotational grazing management on tiller defoliations (Gammon and Roberts 1978, 1980; Pierson and Scarnecchia 1987; and Gillen et al. 1990). Important fundamental relationships have been described for several tiller defoliation and animal management variables.

Frontal grazing[1] is a method of intensive grazing management that allows livestock a continuous opportunity to graze fresh forage during active growth (Volesky 1990). This system features a livestock-pushed, sliding fence that allocates and controls grazing within a pasture. Cattle advance the moveable fence by pushing on a cable with their foreheads to gain access to ungrazed forage. Frontal grazing has similarities with rotational grazing systems in which short grazing periods in a paddock are coupled with high stocking densities. Volesky et al. (1994) reported that steer production per hectare was similar between frontal and continuous grazing, but that frontal grazing provided about 100 more steer-days ha^{-1} grazing even though end-of-season standing crop was equal in both treatments.

Little is known about the frequency and intensity of defoliation under frontal grazing. The objectives of this study were to characterize and compare the frequency and intensity of defoliation of individual tillers of 'Plains' Old World bluestem (*Bothriochloa ischaemum* (L.) Keng) under frontal, rotation, and continuous grazing.

Materials and Methods

These studies were conducted during 1991 at the USDA-ARS Grazing Research Laboratory near El Reno, Okla. The 26-year mean annual precipitation at this location is 807 mm. April through August precipitation during 1991 was 97% of the long-term mean. Study pastures were 'Plains' Old World bluestem growing predominantly on a Norge silt loam (fine-silty, mixed, thermic Udic Paleustoll) soil. All pastures were burned in March and received 84 kg ha^{-1} N in May.

Grazing Treatments

Treatments were replicated twice and included frontal, 2-paddock rotation, and continuous grazing systems. Grazing was initiated 24 May using yearling steers with a mean live weight of 282 kg. Fifty steers were used in each frontal grazing pasture (7.5 ha) and 12 in each continuous and rotation grazing pasture (1.8 ha), resulting in a rate of 6.7 head ha^{-1}. Put-and—take steers were used to ensure that all 3 treatments had a similar amount of residue (1,500 kg ha^{-1}) left at the end of the 76-day grazing period.

The main feature of the frontal grazing system was a 50 m wide, livestock-pushed, sliding-fence that allocates and controls grazing within a pasture. Cattle advance the moveable fence by pushing a cable with their foreheads to gain access to ungrazed forage. Main components of the moveable front fence include: (1) an electric wire and an insulated push-cable; (2) a centrally located pace-governor; and (3) sleds which support the electric wire and push-cable. The frontal fence is attached at each end to a single high-tensile lateral wire through a bracketed set of pulleys. A back-fence is used and periodically moved to maintain it about 100 m from the frontal fence. The back-fence prevents cattle from accessing previously grazed areas. Operation and components of the frontal grazing system are further described by Volesky (1990) and Volesky et al. (1990).

A frontal grazing pasture consisted of 2 adjacent rectangular strips 50 m wide and 750 m long. The 50 m wide frontal fence was

[1]The main components and equipment for frontal grazing are patented and manufactured by Fernando R. Pereda, Tucuman 10, Piso I. (1049) Buenos Aires, Argentina.

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Manuscript accepted 13 Nov. 1993.

initially placed about 50 m from the end of a strip. Grazing proceeded down the long axis of one strip to the end. Equipment was then moved to the adjacent strip and grazing continued back in the opposite direction to complete a cycle. Two cycles were completed under frontal grazing. The entire 7.5-ha area was covered during the first cycle in 60 days with a mean frontal fence movement of 25 m day^{-1}. The second cycle lasted 16 days (70 m day^{-1}) and covered 75% of the pasture. Twenty-five percent of the pasture, covering the area that would be grazed last during cycle 1, was cut for hay in June because forage would have been excessively mature by the time it was frontally grazed.

Rotation grazing pastures were subdivided into 2 paddocks each 0.9 ha in size. Steers were rotated between paddocks every 2 to 3 weeks. Initial stocking density was 6.7 and 13.4 head ha^{-1} in continuous and rotation grazing treatments, respectively. Stocking density under frontal grazing was dynamic, depending on frontal fence movement and back-fence position, but was typically within the range of 80 to 170 head ha^{-1}.

Defoliation Measurements

Two permanent 20-m long transects were established in each pasture. Ten tussocks of 'Plains' Old World bluestem were randomly selected along the length of each transect. Within each tussock, 1 center tiller and 1 perimeter tiller were selected and identified with a small piece of plastic-coated wire placed around the tiller's base. Tiller location (center or perimeter) was considered a subplot. Tiller defoliation characteristics under continuous and rotation grazing were determined during 3 trial periods lasting 14, 10, and 10 days, respectively. These trials corresponded to the beginning, middle, and end of the summer grazing season. Trial 1 was from 24 May through 7 June; trial 2 was from 1 July through 11 July; and trial 3 was from 28 July through 8 August.

Tillers were examined daily during each trial and occurrences of defoliation recorded. Regrazing was determined by marking grazed leaves or stems with white latex paint. Height was measured from the ground to the highest point of the extended tiller. Intensity of tiller defoliation was visually estimated and a rank of 0 to 3 assigned. Zero indicated no defoliation, 1 had $<$ 25% leaf area removed (light), 2 had 25 to 75% leaf area removed (moderate), and 3 had $>$ 75% leaf area removed (heavy). Height of all marked tillers was measured on day 0 and every 5 days thereafter. Nonsenesced leaves over 5 mm long were counted on day 0 and on the last day of each trial period. Under continuous and rotation grazing, the same transects and tillers were monitored for all trials. Numbers of marked tillers that were missing or dead were recorded for each trial period. Missing tillers were those that were either completely pulled up while being grazed or buried by dung pats. Tillers classified as dead included those that were trampled or severely defoliated and subsequently died or completely senesced. New tillers were selected before trials 2 or 3 to assure 40 tillers per pasture.

Tiller defoliation measurements under frontal grazing were made using the same techniques as for continuous and rotation grazing. Transects were established parallel to the frontal fence. Observations were made immediately before the frontal fence and then 3 hours later after the frontal fence had passed over the transect area. Tillers were then examined daily. Trial periods under frontal grazing were 2 to 4 days depending on when back-fence advancement excluded marked tillers from grazing. Trial 1 for frontal grazing began 10 days later than trial 1 for continuous and rotation grazing to allow the steers to become accustomed to the system. New transects and tillers were selected for trial 2 at the point where about 65% of the pasture had been frontally grazed. Trial 3 used the same transects and tillers of trial 1 and occurred during the second cycle of the frontal grazing system. These tillers had a 44-day rest period.

Forage standing crop was measured at the start and end of each trial period using an electronic capacitance meter (Vickery et al. 1980). One hundred readings were taken at random throughout each continuous and rotation grazing pasture. Probe readings in frontal grazing were taken along transects before grazing and then after steers had advanced the frontal fence over the transects. The capacitance meter was calibrated with clipped samples taken over the summer grazing period. The prediction equation was:

$$\text{kg ha}^{-1} = -167.95 + 13.647 * \text{meter reading} \; (P<0.01, R^2 = 0.84, N = 230).$$

Analysis of variance procedures (SAS Institute, Inc. 1988) were used to evaluate treatment (whole-plot) and tiller location (subplot) effects on tiller height, number of leaves, lost tillers, and defoliation level within trials or on specific sampling days. Treatment effects were tested using treatment by replication as the error term. When significant treatment or location differences ($P \leq 0.05$) were indicated by F-tests, means were compared using least significant differences (LSD). The model analyzing standing crop did not contain location. Because grazing treatments dictated stocking density and stocking rate during the trial periods, regression analyses were used to evaluate relationships between tiller defoliation frequency (times day^{-1}) and stocking rate (steer-days ha^{-1}) and between defoliation frequency and herbage allowance (kg steer-day^{-1}). Herbage allowance was calculated using standing crop data from day 0 of each trial. Area used in frontal grazing stocking rate calculations was determined from the area that was grazed as the frontal fence advanced during the trial period.

Results and Discussion

Defoliation Frequency Classes

The distribution of trial 1 defoliation frequency classes by day under frontal grazing was markedly different compared to rotation or continuous grazing (Fig. 1). Under frontal grazing, 98% of the tillers were defoliated at least once within the 3-hour period that they became accessible through advancement of the frontal fence. After 1 day of frontal grazing, 18% of the tillers were defoliated twice, 80% once, and 2% remained ungrazed. Seven percent of continuous grazing tillers were defoliated once and 93% remained ungrazed after 1 day. Thirty-four percent of rotation grazing tillers were defoliated once and 66% remained ungrazed after 1 day.

Stocking density under rotation grazing was twice that of continuous grazing for this initial 14-day trial. This resulted in more tillers being defoliated one or more times sooner compared to continuous grazing (Fig. 1). By day 14, 36% of tillers under rotation grazing were defoliated 3 or more times compared to only 10% under continuous grazing. The maximum number of times frontal grazing tillers were defoliated was 3 and this occurred on 3% of the tillers.

The pattern of a high percentage of frontal grazing tillers being grazed during advancement of the frontal fence and then a relatively small percentage being regrazed during the following 3 to 4 days corresponds with forage utilization data reported by Volesky et al. (1994). Forty-eight to 66% forage utilization occurred as cattle grazed and simultaneously advanced the frontal fence. An additional 15 to 20% increase in utilization occurred before the area was excluded from grazing by the back-fence.

The general distribution pattern of defoliation frequency classes for trials 2 and 3 was similar to that of trial 1, especially under frontal grazing. However, during trial 3, the percentage of continuous grazing tillers in all defoliation classes was lower because stocking density was lower at that time.

A limiting factor to accurate defoliation frequency data in any grazing strategy is the interval between tiller sampling or observation. Frontal grazing tillers sampled before the frontal fence and then 3 hours later after it had advanced over the transect area showed 98% of the tillers being defoliated at least once. Jensen et

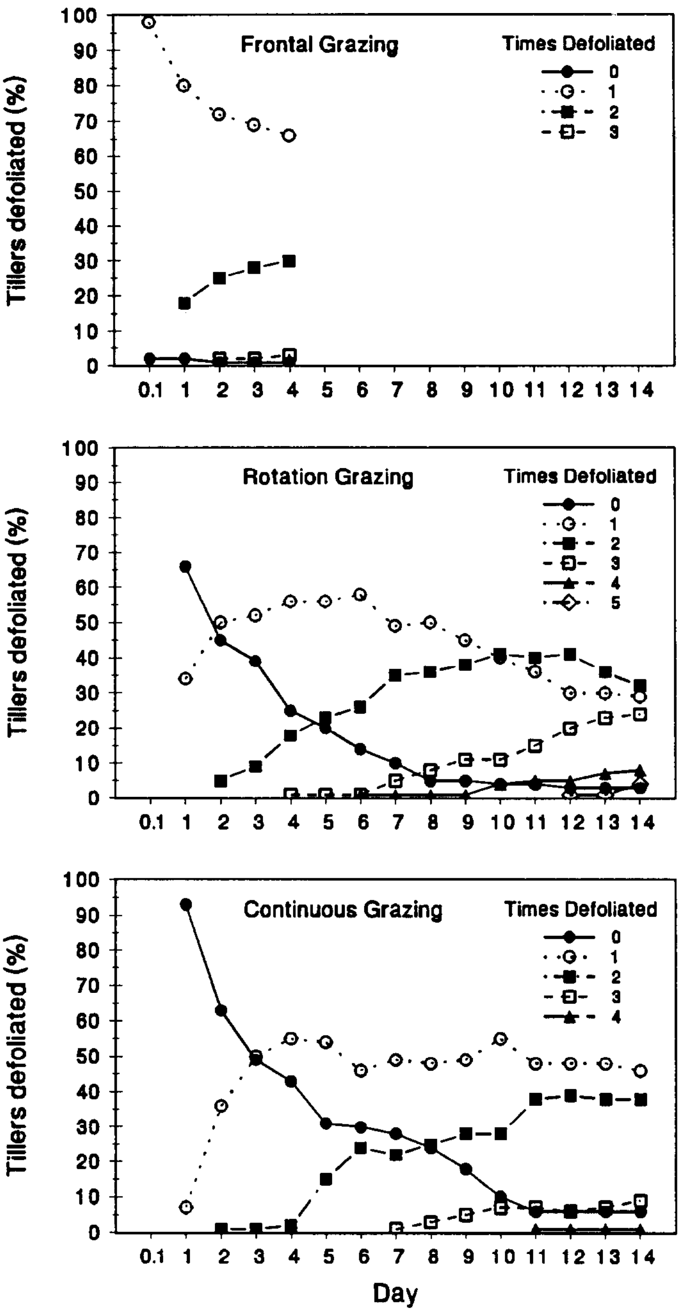

Fig. 1. Distribution of defoliation frequency classes by day under frontal, rotation, and continuous grazing systems (trial 1).
Day 0.1 under frontal grazing corresponds to sampling that occurred 3 hours after initial sampling and frontal fence had advanced over the transect area.

al. (1990) suggested that the concept of a single defoliation within a grazing period has merit because that single defoliation would result in a moderate amount of leaf area removal for the defoliated tiller and favor rapid recovery from defoliation. An average of 63% of a frontal grazing tiller's height was removed during the trial periods, which would probably be considered a moderate level for Old World bluestem. Season-long stocking rate (steer-days ha^{-1}) under frontal grazing was 34% higher compared to rotation and continuous grazing. However, end-of-season standing crop was similar in all 3 treatments (Volesky et al. 1994). In addition, 25% of a frontal grazing pasture's area was cut for hay. This suggests that the pattern of tiller defoliation under frontal grazing enhanced forage production. Burton et al. (1963) found that forage production of 'Coastal' bermudagrass (*Cynodon dactylon* (L.) Pers.) increased as time between clippings increased from 3 to 6 weeks. Several mechanisms for this response have been suggested: increased tillering; maintenance of optimum leaf area index; a greater proportion of younger leaves and hence more efficient photosynthesis; and removal of older tissues that may lose more dry matter by respiration than they fix by photosynthesis (Hart and Balla 1982).

Defoliation Frequency

There was a significant relationship between tiller defoliation frequency (times day^{-1}) and stocking rate (P<0.05, Fig. 2). This regression showed a linear increase in the frequency of defoliation as stocking rate increased. This fundamental relationship has been

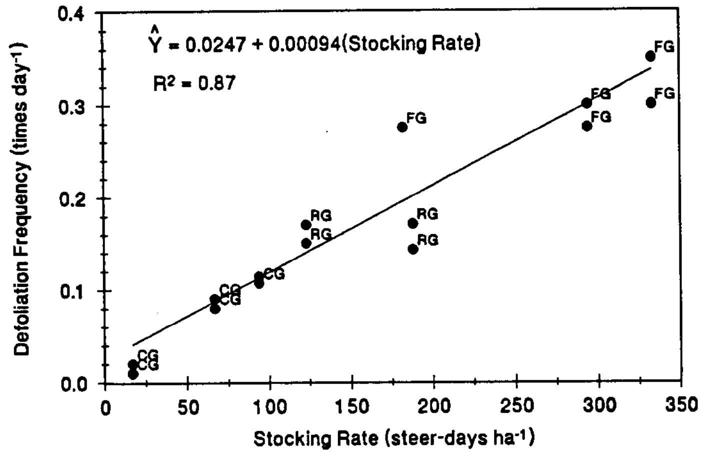

Fig. 2. Relationship between tiller defoliation frequency and stocking rate for frontal (FG), rotation (RG), and continuous (CG) grazing systems. One frontal grazing data point data point is hidden.

reported by others with various forage species (Hodgson and Ollerenshaw 1969, Hart and Balla 1982).

There was a correlation between stocking rate and herbage allowance; therefore, the regression of tiller defoliation frequency on herbage allowance was also significant (P<0.05, Fig. 3). However, this relationship had a quadratic fit and describes the decline in defoliation frequency as herbage allowance increases. Other researchers (Jensen et al. 1990, Gillen et al. 1990, Curll and Wilkins 1982) have also described this defoliation frequency and

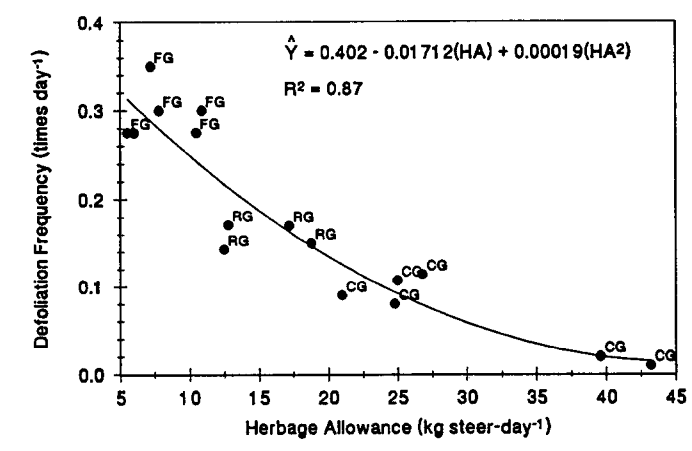

Fig. 3. Relationship between tiller defoliation frequency and herbage allowance (HA) for frontal (FG), rotation (RG), and continuous (CG) grazing systems.

Table 1. Intensity of defoliation and height (mm) of remaining tiller after first grazing and percentage of tillers missing/dead during each trial.

Treatment	Trial 1			Trial 2			Trial 3		
	Intensity category[1]	Height	Missing/ dead[2]	Intensity category	Height	Missing/ dead	Intensity category	Height	Missing/ dead
		(mm)	(%)		(mm)	(%)		(mm)	(%)
Frontal grazing	2.7^A	72^A	9	2.0^A	294^A	11	2.0^A	77^A	4^A
Rotation grazing	1.8^B	93^B	5	2.0^A	62^B	10	—[3]	—	
Continuous grazing	1.9^B	93^B	3	2.5^B	40^B	10	2.7^B	35^B	21^B

[1]Three defoliation intensity categories: (1) <25% leaf area removed; (2) > 25 < 75% leaf area removed, and (3) > 75% leaf area removed.
[2]Missing tillers were those that were either pulled up while being grazed or buried by dung pats. Dead tillers were those that were trampled or severely defoliated and subsequently died or completely senesced.
[3]The rotation grazing treatment was not sampled during trial 3.
[AB]Within trial, means within categories having unlike letters differ ($P<0.05$.

herbage allowance relationship.

Although marked tillers were defoliated at a faster rate under frontal compared to rotation or continuous grazing (Fig. 1), cattle had access to them for only 6 to 8 days of the entire grazing season. Tillers under frontal grazing were defoliated on average of 1.3 times during cycle 1 and 1.1 times during cycle 2 equaling a total of 2.4 times for the 76-day grazing season. This was substantially less than that of tillers under rotation or continuous grazing. During the 34 days (trials 1, 2, and 3) of actual tiller observation in continuous grazing, tillers were defoliated an average of 2.4 times. Season-long estimates, based on the defoliation frequency rate and stocking rates, show that tillers were defoliated 4.6 times under continuous and 4.7 times under rotation grazing. In a unique system like frontal grazing, where nearly all the cattle in the pasture are grazing at, and simultaneously advancing the frontal fence, it is quite possible that any given tiller could be defoliated several times in a 3-hour period. Thus, the observed defoliation frequency of 2.4 times per season under frontal grazing may be low.

Regardless of the exact defoliation frequency, the frontal grazing system is efficient in that nearly 100% of the tillers were uniformly defoliated at least once in a short time span. Under both rotation and continuous grazing, the percentages of tillers that were never defoliated during the entire season were very low. However, the percentage of tillers that were defoliated only once or twice was considerable and in addition, numerous tillers were defoliated 6 or more times. This nonuniform frequency of tiller defoliated is evidence of 'patch' or 'spot' grazing resulting in an inefficient harvest of available tillers. Gammon and Roberts (1980) reported that for certain plant species, even under short-duration grazing, there was selection for tillers that had been previously grazed.

Defoliation Intensity and Tiller Characteristics

Defoliation intensity of a tiller's first grazing was higher ($P<0.05$) under frontal compared to rotation or continuous grazing during trial 1 (Table 1). Correspondingly, height of remaining tillers after defoliation was 21 mm less under frontal compared to rotation and continuous grazing ($P<0.05$). Defoliation intensity during trial 2 was higher under continuous compared to frontal or rotation grazing. This higher estimation of defoliation intensity was proably a consequence of those tillers having had the opportunity to be grazed during trial 1 and the interim period between trials. Tillers under rotation grazing had just completed a 2-week rest period. New frontal grazing tillers were selected for trial 2 at the point where the 65% of the pasture had been frontally grazed. The Old World bluestem at this time was relatively mature with culms elongated and nearly complete inflorescence emergence. Mean tiller height under frontal grazing was 592 mm on day 0 of trial 2. The height of these tillers after their first defoliation (294 mm) was higher compared to rotation or continuous grazing ($P<0.05$).Tiller height after grazing was substantial under frontal grazing because primarily leaves were grazed and the extended inflorescence remained intact. These data suggest that there is an interaction between forage maturity and intensity or pattern of tiller defoliation.

Trial 3 initial tiller defoliation intensity was higher and height of remaining tiller less under continuous compared to frontal grazing ($P<0.05$, Table 1). This again was probably a consequence of the continuous grazing tillers having had the opportunity to be grazed season long. Trial 3 frontal grazing tillers were the same ones used during trial 1 when the system was in its first cycle. These tillers had a 44-day rest period and an initial height of 165 mm on day 0 of trial 3.

The percentage of marked tillers missing or dead was similar among treatments during trials 1 and 2 ($P>0.05$, Table 1). Even with the very high stocking densities under frontal grazing, tillers were not lost primarily to trampling or severe defoliation and death, but nearly half were buried by dung pats. More trial 3 tillers were classified as missing or dead under continuous compared to frontal grazing ($P<0.05$). This was attributed to the number of tillers that had undergone repeated defoliation and either died or completely senesced. Mean height of continuous grazing tillers on the final day was only 46 mm. In addition, the warm and dry weather of early August probably enhanced the senescence of tillers that had been moderately or severely defoliated.

Mean height of tillers on day 0 of each trial was greater under frontal compared to rotation or continuous grazing ($P<0.05$, Table 2). This was because day 0 for frontal grazing during trial 1 began 10 days after grazing started to allow steers to become adapted to the system and be able to advance the frontal fence on their own. New tillers were used for frontal grazing trial 2 and trial

Table 2. Mean tiller height (mm), number of leaves, and standing crop (kg ha^{-1}) on day 0 and final day of each trial period.

Treatment	Height		Leaves		Standing crop	
	Day 0	Final day	Day 0	Final day	Day 0	Final day
	--- (mm) ---		--- (no) ---		--- (kg ha^{-1}) ---	
Trial 1						
Frontal grazing	242^A	57^A	4.8	1.6^A	3010^A	890^A
Rotation grazing	175^B	63^A	5.0	2.5^B	2360^B	1480^B
Continuous grazing	177^B	97^B	5.0	3.3^C	2420^B	1830^B
Trial 2						
Frontal grazing	592^A	249^A	5.6^A	2.7	4280^A	2040^A
Rotation grazing	142^B	74^B	6.7^B	3.1	2390^B	510^B
Continuous grazing	62^B	49^B	3.7^C	3.3	1530^C	720^B
Trial 3						
Frontal grazing	165^A	76	6.4	2.4	1530^A	490
Continuous grazing	49^B	46	3.9	3.2	690^B	580

[ABC]Within trials, treatment means followed by unlike letters differ ($P<0.05$).

3 tillers had the rest period between cycles.

The differences in tiller height, number of leaves, and total standing crop between day 0 and the final day of each trial indicate a much greater intensity of defoliation during the trial period under frontal compared to rotation or continuous grazing (Table 2). Among trials, tiller height removed between day 0 and the final day of each trial period was 63, 55, and 24% under frontal, rotation, and continuous grazing, respectively. Leaf removal followed a similar pattern. These data are, however, inclusive only for frontal grazing because those tillers were sampled only when cattle had access to them. No data are available for rotation and continuous grazing during the periods between trials.

Tiller location affected ($P<0.05$) height on day 0 of trial 1. Perimeter tillers were 40 mm taller than those originating from the center of a tussock. It was hypothesized that perimeter tillers would be defoliated less severely and less often and remain taller throughout the grazing season because in their natural state, many were positioned nearly horizontal to the soil surface. There was a treatment by location interaction ($P<0.05$) for tiller height on the final day of trial 1. Perimeter tillers were taller than center tillers only under rotation grazing. There were no other significant location or interaction effects on height during subsequent trials and sampling days, thus rejecting the hypothesis.

Conclusions

Several tiller defoliation measurements were different under the 3 grazing treatments. The differences, however, were at least partly associated with stocking rate and herbage allowance. Frontal grazing has similarities to short-duration grazing strategies where low herbage allowances and combined with high stocking densities. The cattle themselves primarily regulate the size of the grazing area by advancement of the frontal fence. The result was a uniform defoliation of nearly 100% of the tillers in a relatively short time period. This type of defoliation pattern suggests enhancement of regrowth and forage production under frontal grazing.

Literature Cited

Burton, G.W., J.E. Jackson, and R.H. Hart. 1963. Effects of cutting frequency and nitrogen on yield, in vitro digestibility, and protein, fiber, and carotene content of Coastal bermudagrass. Agron. J. 55:500–502.

Cull, M.L. and R.L. Wilkins. 1982. Frequency and severity of defoliation of grass and clover by sheep at different stocking rates. Grass and Forage Sci. 37:291–297.

Gammon, D.M., and B.R. Roberts. 1978. Patterns of defoliation during continuous and rotational grazing of the Matopos Sandveld of Rhodesia. I. Selectivity of grazing. Rhod. J. Agr. Res. 16:177–131.

Gammon, D.M., and B.R. Roberts. 1980. Aspects of defoliation during short duration grazing of the Matopos Sandveld of Zimbabwe. Zimbabwe J. Agr. Res. 18:29–38.

Gillen, R.L., F.T. McCollum, and J.E. Brummer. 1990. Tiller defoliation patterns under short duration grazing in tallgrass prairie. J. Range Manage. 43:95–99.

Hart, R.H., and E.F. Balla. 1982. Forage production and removal from western and crested wheatgrass under grazing. J. Range Manage. 35:362–366.

Hodgson, J., and J.H. Ollerenshaw. 1969. The frequency and severity of defoliation of individual tillers in a set-stocked sward. J. Br. Grassld. Soc. 24:226–234.

Jensen, H.P., R.L. Gillen, and F.T. McCollum. 1990. Effects of herbage allowance on defoliation patterns of tallgrass prairie. J. Range Manage. 43:401–406.

Pierson, F.B., and D.L. Scarnecchia. 1987. Defoliation of intermediate wheatgrass under seasonal and short-duration grazing. J. Range Manage. 40:288–232.

SAS Institute, Inc. 1988. SAS/STAT user's guide, release 6.03 edition, SAS Institute Inc., Cary, N.C.

Vickery, P.J., I.L. Bennett, and G.R. Nicol. 1980. An improved electronic capacitance meter for estimating herbage mass. Grass and Forage Sci. 35:247–252.

Volesky, J.D., F. de Achaval O'Farrell, W.C. Ellis, M.M. Kothmann, F.P. Horn, W.A. Phillips, and S.W. Coleman. 1994. A comparison of frontal, continuous, and rotation grazing systems. J. Range Manage. 47:210-214

Volesky, J.D. 1990. Frontal grazing: forage harvesting of the future? Rangelands. 12:177–181.

Volesky, J.D., D.P Mowrey, and F. Achaval. 1990. Frontal grazing: a new method of forage harvesting. p. 142–146. *In:* Proc. Amer. Forage and Grassld. Counc., Blacksburg, Va.