Combined Effects of Stocking Rate and Supplemental Feeding Level on Adult Beef Cows Grazing Native Rangeland in Texas[1]

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ABSTRACT: A grazing study was conducted over 4 yr to determine the effects of stocking rate and supplemental feeding levels on intake, and BW and body condition changes by adult beef cows. Stocking rates were 12.3, 16.5, and 24.7 animal units/(100 ha·yr). Supplemental feed treatments included a negative control (NC) and 300 g/(cow·d) of CP with either 2 (L), 4 (M), or 8 (H) Mcal/(cow·d) of DE from early December to late March. Groups fed supplements (L, M, and H) lost less BW from fall to spring ($P < .01$) and reciprocally gained less BW from spring to weaning ($P < .01$) than NC cows. The L cows tended ($P = .14$) to lose less BW between fall and spring than M and H cows. Treatment effects on condition score were similar to those for BW change. Forage intake, estimated by measurements of fecal output, was greater by supplemented cows ($P = .02$); L was greater than M and H ($P = .004$). Increased stocking rate correlated with increased fall-to-spring BW losses ($P < .002$), spring-to-weaning BW gains ($P < .0001$), and decreased winter forage intake ($P < .005$). These data provide quantitative bases for the effects of stocking rate and supplemental feeding on BW and condition dynamics. Low-level feeding of a high-protein supplement can increase intake of dormant range forage, thereby increasing nutrient intake. High-level feeding of low-protein supplements seems to increase nutrient status primarily by providing supplemental nutrients. Increasing stocking rate to the reported extremes decreased forage intake and resulted in unfavorable BW and condition changes.

Key Words: Cattle, Stocking Rate, Grazing, Supplementary Feeding

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Introduction

Rangelands in the Edwards Plateau region of West Texas are grazed commonly by single or mixed livestock species for 8 to 12 mo annually. Plants found on these ranges vary in form, period of growth, and nutritional value (Huston et al., 1981). Animal diets vary in nutritional value among seasons, to the extent that the grazing animal usually consumes required amounts of protein and energy during the growing season but inadequate amounts during late fall and winter (Huston et al., 1986). Generally, beef cows are mated to give birth just before the onset of the growing season. Heavy lactation and breeding will thereby coincide with spring growth of vegetation that has maximum nutritional value for grazing animals. Thus, the months of late pregnancy and weeks of early lactation that precede spring green-up are a critical nutritional period. Weight and condition changes are normal and expected in cows that are well adapted to the existing environment (Sowell et al., 1992), but excessive weight and condition losses can affect productivity. A long-held concept is that cows can lose up to 15% of BW between fall and spring (including conceptus) and maintain satisfactory conception rates (Pope, 1967). Management practices that influence BW changes of cows on rangeland include stocking rate (Heitschmidt et al., 1982) and supplementation (Lusby et al., 1976). Our study was conducted to determine the effects of rate of stocking and level of supplemental feeding on voluntary forage intake and resulting BW changes by grazing beef cows.

Materials and Methods

Study Site. The study was conducted on a 532-ha area of Edwards Plateau rangeland in McCulloch County, TX. The area was described previously as consisting of four range sites (adobe, low stony hill, deep upland, and shallow) supporting a diverse assemblage of warm- and cool-season grasses, forbs, trees, and shrubs (Rector, 1983). For 8 yr preceding

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the start of this study, the area was grazed at a common rate of 6.1 ha/animal unit (**AU**) with cattle and(or) sheep and goats. Average annual rainfall is 63 cm in a bimodal pattern; May and September are the peak rainfall months. Annual rainfall during the 4-yr study period averaged 60.1 cm, with normal distribution. The annual frost-free period averages 226 d from late March to mid-November (Rector, 1983). Elevation of the area is approximately 600 m, and slope rarely exceeds 5%.

Experimental Design and Application of Treatments. The study was conducted and analyzed according to a randomized complete block design (SAS, 1991) with four feed treatments (**TRT**) and three stocking rates (**SR**) imposed during three consecutive years (blocks). Pastures consisting of 165, 305, and 62 ha were grazed continuously at stocking rates of 12.3 (**SL**), 16.5 (**SM**), and 24.7 (**SH**) AU/(100 ha·yr), respectively. At all stocking rates, half the AU were cows, one-fourth were Rambouillet sheep, and one-fourth were Angora goats; this assumes that one cow-calf unit, five ewe-lamb units, and seven doe-kid units are equivalent animal units. Feed treatments were imposed on all cows at each stocking rate during the last 3 yr of the 4-yr study by use of Calan feeding gates (American Calan, Northwood, NH) located in each pasture. Where interactions ($P < .05$) occurred between feed treatments and stocking rates, treatment differences were examined at each stocking rate. Main effects of stocking rates were assessed using regression analysis. To determine whether stocking density influenced intake and productivity, the individual cows were considered replicates within each stocking rate. Treatments included a negative control (**NC**; no supplemental feed) and three feed treatments that provided equal amounts of CP and phosphorus, but low (**L**), medium (**M**), and high (**H**) levels of energy (Table 1). Levels shown in Table 1 were computed to provide approximately 42% of required CP and 10, 20, and 40% of required DE (L, M, and H, respectively) for 454-kg pregnant cows in average body condition (condition score 5) when fed at rates shown in Table 1. Actual feeding levels were unique for each cow and were based on BW and body condition (scale = 1 to 9) considering that a change of one body condition score (BCS) corresponded to a change of 34 kg of BW. Feeding levels were assigned for the duration of each feeding period on the basis of initial fall BW and BCS. Because the cows were rerandomized among feed treatments and stocking rates each year, the data for years were considered independent (blocks) rather than repeated observations. Therefore, the statistical model consisted of two factors in a randomized complete block design. The unbalanced data were analyzed for main effects of feed treatment and stocking rate and the feed treatment × stocking rate interaction. Contrasts of feed treatment effects were 1) NC vs L, M, and H, 2) L vs M and H, and 3) M vs H. The data are presented as least squares means.

Experimental Animals, Livestock Management, and Conduct of Trials. Adult, Hereford × Brangus cows

Table 1. Feeding treatments and composition of feeds used to determine effects of stocking rate and supplemental feeding on forage intake and productivity by beef cows on rangeland

Item	Energy feeding level[a]		
	L	M	H
Composition of supplements			
Ingredients, % air-dry basis			
Cottonseed meal	93	44	7
Sorghum grain	—	52	89.5
Urea	1	—	—
Molasses	3	3	3
Calcium phosphate[b]	3	1	.5
Nutrients, formulated			
CP, %	42	23.8	12.8
DE, Mcal/kg	2.75	3.17	3.44
P, %	1.53	.8	.4
Feeding rates			
Supplement, g/d[c]	714	1,260	2,340
Nutrients			
CP, g/d	300	300	300
DE, Mcal/d	2	4	8
P, g/d	11	10	9

[a]L = 2, M = 4, and H = 8 Mcal of DE for a 454-kg cow.
[b]Mono-dicalcium phosphate, 21% P.
[c]Feeding rates for cows weighing 454 kg at condition score (BCS) 5 on a 1 to 9 scale. Actual feeding rate varied with cow BW and BCS. Ranges in feeding rates were 682 to 790; 1,191 to 1,369; and 2,263 to 2,815 g/d for cows in groups L, M, and H, respectively, and ranging in BW from 420 to 633 kg.

were used as experimental units in a 4-yr study beginning in Fall, 1987. Stocking rates were imposed as indicated above beginning with the existing herd and flocks (sheep and goats). The sheep and goat portions of the animal population were maintained for the 4-yr period by replacing annually those animals that died or were culled. Sheep and goats were treated the same within and among pastures except for stocking rate, and the data were reported separately (Huston et al., 1992). At the beginning of each year of the study, the cows were tested for pregnancy by rectal palpation, and nonpregnant cows were removed and replaced with similar pregnant cows from an ancillary herd on the ranch. All cows were then rerandomized across stocking rates and treatments to equalize carryover effects. Cows were bred each year to Beefmaster bulls during a 75-d breeding season that started April 1. Calves were weaned in October at approximately 8 mo of age. Health management practices were applied to the herds according to accepted procedures (Consortium, 1988). Both male and female calves were vaccinated for clostridial diseases (seven-way) at an average age of 2 mo, and male calves were neutered by castration. In late May, cows and calves were treated for grubs (*Hypoderma* spp.) and the cows were given an insecticide-impregnated eartag for control of horn flies (*Haematobia irritans*). The cow herd was maintained Certified Brucellosis Free for the duration of the study. Plain salt and water were provided free choice throughout the study. A high-phosphorus mineral mixture (45% sodium chloride, 50% mono-dicalcium phosphate, and 5% cottonseed meal; 10.5% P) was made available during all of yr 1 and during non-treatment periods of yr 2 to 4. Year 1 (1987 to 1988) was dedicated to establishing stocking rate on the experimental pastures. All herds were fed and managed alike, and no data were recorded. During yr 2, 3, and 4 (1988 to 1989, 1989 to 1990, and 1990 to 1991, respectively) feed treatments were imposed for approximately 100 d beginning in early December. The cows were fed the weekly allowance of feed in three equal portions, usually in the morning on Monday, Wednesday, and Friday. Production data included cow BW and BCS in December, March, and October; calf weaning weights (October) adjusted to 210-d unisex BW; and cow conception. Body weights were taken unshrunk within 1 h of gathering, and body CS were recorded as the average of independent estimates of a panel of three trained technicians. Additional data included forage intake in yr 3 and standing crop of forage in yr 4.

Voluntary Intake of Forage. Intake of forage was estimated during the 1989 to 1990 trial from calculations of fecal output by the continuous-release, chromic oxide bolus technique (Ellis et al., 1981). The cattle were dosed on January 19 and were gathered and sampled (fecal grab) on January 30, February 1, and February 5 (d 11, 13, and 17, respectively). Fecal samples were stored frozen. Forage was sampled from each pasture by systematic plucking from sites and tufts that were observed to be grazed by the cattle. Feces were dried in a forced-draft oven at 60°C for 24 h, ground to pass a 1-mm screen, and ashed at 450°C for 6 h. The ash was oxidized in a distilled water-sulfuric acid-perchloric acid (150:150:200 mL) solution, and brought to standard volume with distilled water (Fenton and Fenton, 1979). Chromium concentration was determined in the diluted digest by atomic absorption at 357.9 nm in a nitrous oxide-plus-acetylene flame. Daily fecal output (**FO**) was estimated by dividing the concentration of Cr in the feces into the amount of Cr released daily by the bolus. Digestibilities of the supplemental feeds and forage samples were estimated by in vitro digestion of cell wall (Van Soest et al., 1966). We assumed that no associative effects occurred. Inoculum used in all procedures was obtained from one ruminally fistulated steer fed in drylot to allow ad libitum intake of medium-quality sorghum hay. Output of feces from forage origin was calculated by subtracting the feces attributed to the supplement (in vitro estimate) from total feces. Forage intake was calculated by dividing fecal output (forage) by forage indigestibility (1 − IVDMD). Intake data are reported only for cows that were lactating and consumed supplements completely during the intake determination period. In addition, two cows were eliminated because they had no detectable Cr in their feces, presumably because the boluses were regurgitated soon after dosing. No other problems with the method were evident.

Determinations of Standing Crop and Canopy. Standing crop was determined in early December, 1990 in the three pastures by a double-sampling technique that was a modification of the method of Edlefsen et al. (1960). Woody-plant canopy cover was estimated by the line interception method (Canfield, 1941).

Results and Discussion

Production data for cows that received the different feed treatments and grazed at the different stocking rates are shown in Tables 2, 3, and 4. A consistent pattern of complementarity developed for BW and body condition changes for the fall-to-spring and spring-to-fall periods. In treatment comparisons (Table 2), the NC group lost more BW than the fed groups ($P < .01$) during the dormant season but gained more BW ($P < .01$) during the growing season. A similar pattern was observed for changes in body condition score ($P < .01$ and .01, respectively). The 10-mo difference occurred for BW change ($P = .02$) but not for change in body condition ($P = .40$). Cows fed the L supplement tended ($P = .14$) to lose less BW

Table 2. Performance of beef cows given different supplemental feed treatments on rangeland

Item	Feeding levels[a]					Contrasts[b]		
	NC	L	M	H	SE	A	B	C
No. of cows[c]	24	24	25	22	—	—	—	—
Cow BW, kg								
Initial fall BW	518	510	506	513	10.5	—	—	—
Spring BW	412	458	448	445	10.1	—	—	—
BW at weaning	470	479	483	485	9.7	—	—	—
BW changes, kg								
Fall-to-spring	−106	−52	−58	−68	5.1	.01	.14	.25
Spring-to-weaning	58	21	35	40	5.3	.01	.03	.61
10-mo total	−48	−31	−23	−28	6.2	.02	.50	.61
Body condition scores (BCS)								
Initial fall BCS	5.5	4.9	4.7	4.8	.17	—	—	—
Spring BCS	3.8	3.8	3.9	4.0	.14	—	—	—
BCS at weaning	5.2	4.6	4.7	4.7	.16	—	—	—
BCS changes								
Fall-to-spring	−1.7	−1.1	−.8	−.8	.13	.01	.37	.92
Spring-to-weaning	1.4	.8	.8	.7	.14	.01	.95	.71
10-mo total	−.3	−.3	−.0	−.1	.17	.40	.52	.81
Adjusted calf BW, kg	220	237	229	240	4.7	.03	.68	.20
Conception, %	98	91	93	96	—	—	—	—

[a]Target feeding levels were 0 (NC) and 2 (L), 4 (M), and 8 (H) Mcal of DE/d for a 454-kg cow. Actual feeding levels were adjusted for BW and body condition score (Table 1).
[b]Probabilities of error ≤ values shown. Orthogonal contrasts were as follows: A = NC vs L, M, and H; B = L vs M and H; and C = M vs H.
[c]Body condition scores are reported for 1989 to 1990 and 1990 to 1991, only, for 15, 17, 18, and 15 cows fed at NC, L, M, and H feeding levels, respectively.

Table 3. Performance of beef cows grazing at three stocking rates in the Edwards Plateau region of Texas

Item	Stocking rate[a]						
	SL	SM	SH	SE	Reg[b]	R^2	*P*
No. of cows[c]	17	59	19	—	—	—	—
Cow BW, kg							
Initial fall BW	506	512	517	9.1	—	—	—
Spring BW	458	433	431	8.7	—	—	—
BW at weaning	471	468	499	8.4	—	—	—
BW changes, kg							
Fall-to-spring	−48	−79	−86	4.4	Q	.13	.002
Spring-to-weaning	13	35	68	4.6	L	.16	.0001
10-mo total	−35	−44	−18	5.4	Q	.08	.025
Body condition scores (BCS)							
Initial fall BCS	5.1	4.9	5.0	.15	—	—	—
Spring BCS	4.2	3.8	3.6	.12	—	—	—
BCS at weaning	4.9	4.5	5.1	.14	—	—	—
BCS changes							
Fall-to-spring	−.9	−1.1	−1.4	.11	L	.03	.17
Spring-to-weaning	.7	.7	1.5	.12	L	.16	.001
10-mo total	−.2	−.4	.1	.15	Q	.12	.023
Adjusted calf BW, kg	234	228	233	4.1	—	—	—
Conception, %	95	88	100	—	—	—	—

[a]Stocking rates were 12.3 (SL), 16.5 (SM), and 24.7 (SH) AU/(100 ha·yr).
[b]Linear (L) and quadratic (Q) regression equations: BW changes: fall-to-spring, $Y = 152 - 23.0X + .54X^2$; spring-to-weaning, $Y = -37 + 4.4X$; 10-mo total, $Y = 131 - 20.3X + .59X^2$. BCS changes: fall-to-spring, $Y = -.56 - .03X$; spring-to-weaning, $Y = -.72 + .09X$; 10-mo total, $Y = 2.29 - .34X + .01X^2$.
[c]Body condition scores are reported for 1989 to 1990 and 1990 to 1991, only, for 12, 40, and 13 cows at SL, SM, and SH stocking rates, respectively.

Table 4. Period weight changes by beef cows given different supplemental feed treatments on rangeland at three stocking rates

BW changes, kg	Feeding levels[a]					Contrasts[b]		
	NC	L	M	H	SE	A	B	C
Fall-to-spring								
Low stocking rate	−116	−19	−20	−39	14.6	.01	.61	.49
Medium stocking rate	−100	−70	−73	−72	5.8	.01	.70	.93
High stocking rate	−103	−70	−77	−99	10.4	.16	.17	.14
All cows	−106	−52	−58	−68	5.1	.01	.14	.25
Spring-to-weaning								
Low stocking rate	58	−25	12	−16	14.8	.01	.29	.34
Medium stocking rate	52	37	27	23	5.2	.01	.07	.56
High stocking rate	67	56	57	92	9.5	.93	.14	.02
All cows	58	21	35	40	5.3	.01	.03	.61

[a]Target feeding levels were 0 (NC) and 2 (L), 4 (M), and 8 (H) Mcal of DE/d for 454-kg cow. Actual feeding levels were adjusted for BW and body condition score (Table 1).
[b]Probabilities of error ≤ values shown. Orthogonal contrasts were as follows: A = NC vs L, M, and H; B = L vs M, and H; C = M vs H.

during the dormant season and gained less during the subsequent growing season (P = .03) than those fed the M and H supplements. Weight changes for the 10-mo period were almost identical for the fed groups. No consistent pattern emerged for changes in body condition among the fed groups.

As stocking rate increased, the cows lost more BW and body condition from fall to spring (Table 3; P = .002 and .17, respectively) and gained more BW and body condition from spring to fall (P = .0001 and .001, respectively). This tendency for cows that lose more BW during the winter to also gain more BW during the subsequent growing season has been reported by other researchers (Kropp et al., 1973; Heitschmidt et al., 1982).

Feeding level × stocking rate interactions occurred for fall-to-spring (P = .003) and spring-to-weaning (P = .001) BW changes, and data for each level and rate are included in Table 4. Feeding seemed to have less effect on fall-to-spring BW changes as stocking rate increased. At the high stocking rate, supplemental feeding only tended (P = .16) to decrease BW loss. Furthermore, greater BW losses tended to occur at high stocking with increased energy feeding (M and H vs L; P = .17) and with high compared with medium energy (H vs M; P = .14). Body weight gains during the spring-to-weaning period were greater for NC than for supplemented groups for SL (P < .01) and SM (P < .01), but not for the SH (P = .93) stocking rate. At high stocking, BW gain was different only for H compared with M (P < .01). Although not perfectly reciprocal, spring-to-weaning BW changes were generally the reverse of fall-to-spring BW changes and seemed compensatory.

Cow productivity was a secondary consideration in this study, and the capacity to identify differences was greatly compromised by the choice to rerandomize the cows among treatments and stocking rates each year. That is, the carryover effects were added to the random variation in terms of conception dates and age

Table 5. Intake by lactating beef cows grazing dormant winter forages and given various supplemental feed treatments[a]

Item	Feeding levels[b]					Contrasts[c]		
	NC	L	M	H	SE	A	B	C
No. of cows	10	5	6	7	—	—	—	—
DMI, g/kg of BW								
Forage	18.0	25.8	20.9	18.6	1.11	.02	.004	.25
Supplement	—	1.5	2.7	4.8	—	—	—	—
Total	18.0	27.3	23.6	23.4	1.12	.0002	.05	.90
Digestible DMI, g/kg of BW								
Forage	7.8	11.2	9.1	8.2	.51	.02	.007	.30
Supplement	—	1.0	2.0	3.7	—	—	—	—
Total	7.8	12.2	11.1	11.9	.51	.0001	.47	.37

[a]Data taken during yr 3, 1989 to 1990.
[b]Target feeding levels were 0 (NC), 2 (L), 4 (M), and 8 (H) Mcal of DE/d for a 454-kg cow. Actual feeding levels were adjusted for BW and body condition score (Table 1).
[c]Probabilities of error ≤ value shown. Orthogonal contrasts were as follows: A = NC vs L, M, and H; B = L vs M and H; C = M vs H.

Table 6. Intake by lactating beef cows grazing dormant winter forages at three stocking densities[a]

Item	Stocking rate[b] SL	SM	SH	SE	Reg[c]	r^2	P
No. of cows	8	16	4	—	—	—	—
DMI, g/kg of BW							
Forage	24.8	21.4	16.3	.97	L	.27	.005
Concentrate	2.3	2.3	2.2	—	—	—	—
Total	27.1	23.7	18.5	.97	L	.19	.02
Digestible DMI, g/kg of BW							
Forage	11.1	9.7	6.4	.44	L	.38	.0005
Concentrate	1.7	1.7	1.6	—	—	—	—
Total	12.8	11.4	8.0	.44	L	.21	.014

[a]Data taken during yr 3, 1989 to 1990.
[b]Stocking rates were 12.3 (SL), 16.5 (SM), and 24.7 (SH) AU/(100 ha·yr).
[c]Linear (L) regression equations:
DM intake – Forage, Y = 30.7 – .59X.
Total, Y = 32.3 – .56X
DDM intake – Forage, Y = 14.9 – .34X
Total, Y = 16.2 – .32X.

of calf at weaning. The one difference (P = .03) detected was the lower adjusted calf weaning weight for the NC vs the fed groups (Table 2), a borderline economic response. Calf weaning weight did not differ among the fed groups (Table 2) or among stocking rates (Table 3). Likewise, neither feeding treatment nor stocking rate had a detectable effect on conception. However, delayed conception can result from under nutrition and excessive BW loss before parturition (Wiltbank et al., 1962) and can increase the likelihood of decreased conception in subsequent years. A delayed effect on conception of low nutrition was reported for heifers by Meaker (1976).

Forage intake, measured during the 1989 to 1990 trial, was increased by supplementation (Table 5; P = .02). Higher levels of supplementation of lower CP supplements (M and H) corresponded to lower forage intake than observed when the higher CP supplement (L) was fed at a low level (P = .004). When relative digestibilities of forage and the supplements were considered, total digestible DMI was increased by supplementation (P = .0001), but no differences were detected among the three supplement treatments. However, more digestible DM from forage origin was consumed (P = .007), and thus a greater proportion of the total, when the higher CP supplement was fed at a low level. The lower intakes of forage by cows fed the M and H, especially H, may be underestimated because of negative associative effects on forage digestibility. Hence, the actual intakes of forage by cows fed M and H supplements were likely less than the values shown because of the negative effect of grain on forage digestibility (Chase and Hibberd, 1987).

Table 7. Canopy cover and herbaceous standing crop in pastures under low, medium, and high rates of stocking

Types of plants	Stocking rate[a] SL	SM	SH	SE
Trees and shrubs, % of canopy				
Desirables[b]	5.6	5.2	3.1	—
Undesirables[c]	4.3	8.7	12.9	—
Total browse cover	9.9	13.9	16.0	—
Herbaceous standing crop, kg/ha of total area				
Warm-season grasses	427.8	346.8	248.5	73.5
Texas Wintergrass	75.0	83.0	57.4	50.8
Herbaceous non-grasses	67.7	27.1	51.9	4.2
Total herbaceous plants	570.5	456.9	357.8	—

[a]Stocking rates were 12.3 (SL), 16.5 (SM), and 24.7 (SH) AU/(100 ha·yr).
[b]Included *Smilax bona-nox, Forestiera pubescens, Celtis reticulata, Quercus virginiana, Zanthoxylum hirsutum*, and *Quercus durandii* var; *breviloba*.
[c]Included *Mahonia trifoliolata, Acacia greggii, Prosopis glandulosa, Diospyros texana, Opuntia* spp, *Yucca* spp, and *Juniperus* spp.

Table 8. Multiple regression equations for effects of stocking rate (animal units [AU]/100 ha) and daily supplement dry matter (g/kg of body weight) or supplemental digestible energy (kcal/kg of body weight) on forage intake (g/kg of body weight)

X variables	n	Equation	SE	R	*P*
Stocking rate (X_1; AU/100 ha) and supplemental DM (X_2; g/kg of BW)					
+ NC[a]	28	$Y = 29.2 - .64X_1 + 13.2X_2 - 6.2X_2^2 + .76X_2^3$	.56	.69	.0001
− NC	18	$Y = 46.7 - .67X_1 - 6.5X_2 + .71X_2^2 + .04X_2^3$	.88	.49	.05
Stocking rate (X_1; AU/100 ha) and supplemental DE (X_2; kcal/kg of BW)					
+ NC	28	$Y = 29.0 - .62X_1 + 4.0X_2 - .57X_2^2 + .02X_2^3$	.57	.69	.0001
− NC	18	$Y = 44.4 - .67X_1 - 1.6X_2 + .05X_2^2 + .001X_2^3$	.88	.49	.005

[a]NC = negative control treatment group.

The effects of supplemental feeding on forage intake can be positive, negative, or null depending on forage quality and the composition of the supplement. Kartchner (1980) reported a null effect (additive) when forage quality was high (DMD = 55%) and a positive protein, but not energy, effect when forage quality was low (DMD = 41%). Lusby et al. (1976) found a strong negative effect (substitution) when a supplement was fed at a high compared with a moderate level (approximately 37 vs 18% of energy requirements, respectively). In our study, supplemental protein seemed to stimulate forage intake, whereas energy-dense supplements were additive with or may have decreased forage intake if forage DMD was decreased. Results similar to ours were reported by Beck et al. (1992) involving cattle fed ammoniated wheat straw. Intake responses to supplementation are likely mediated through gastrointestinal dynamics (Caton et al., 1988) but may include other sensory and motor processes.

Increases in stocking rate had negative linear effects on forage intake (Table 6; $P = .005$), total DMI ($P = .02$), forage digestible DMI ($P = .0005$), and total digestible DMI ($P = .014$). The lack of improvement in fit of a quadratic expression suggests that stocking rates, even at the lowest level, were higher than optimal for maximal forage intake. The range in standing crop for the three pastures (Table 7) is along the linear, lower region of the quadratic relationship (Huston and Pinchak, 1991) for the effect of standing crop on forage intake. The standing crop below which intake is limited varies with conditions, but usually exceeds the highest level we measured (570.5 kg/ha for SL). However, our standing crop estimates were within the range of those reported by Ralphs et al. (1990) at an alternate site in the Edwards Plateau region.

The combined effects of stocking rate and supplemental feeding on forage intake are shown in Table 8. Equations were developed using stocking rate (X_1; AU/100 ha) and the linear, quadratic, and cubic coefficients for supplemental feeding rate (X_2; grams/kilogram of BW) or supplemental energy (X_2; kilocalories/kilogram of BW) as independent variables. Separate equations were developed that excluded the NC cows and considered only intake data from cows that received protein and variable amounts of supplemental energy. The signs of the coefficients of X_2 and X_2^2 variables for supplemented groups were the reverse of equations that considered NC values. That is, when the NC cows were included, low level supplementation stimulated intake of forage. As stocking rate increased, forage intake decreased linearly. As supplemental feeding rate increased, forage intake increased to a maximal energy level, then decreased as supplemental energy was substituted for forage energy (Table 6). When NC cows were not included, the intercept was projected to an unrealistically high level of intake (46.7 g/kg of BW) because the only detectable effect of supplemental feeding was decreased forage intake.

Implications

Under conditions similar to those in our study, increasing stocking rate will decrease forage availability and subsequent forage intake, resulting in increased body weight fluctuations. If continued over years, a loss in productivity (conception) would likely result. Providing a low level of a high-protein supplement to cows grazing dormant range vegetation should increase forage intake and decrease body weight loss. Feeding a greater quantity of a low-protein, high-energy supplement also should decrease body weight loss; however, forage intake likely would not be increased by the high-energy supplement. Rather, nutrients provided by the high-energy supplement would either add to or substitute for forage nutrients.

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