ABSTRACT: Live weight gains of light and heavy calves grazing Plains Old World bluestem at three stocking rates were evaluated during the summers of 1997 and 1998. Initial weights of mixed-breed lightweight steers (LHT) were 141 SD = 17 kg (n = 214) in 1997 and 160 SD = 23 kg (n = 193) in 1998. Initial weights of mixed-breed heavy steers (HWT) were 265 SD = 17 kg (n = 115) in 1997 and 248 SD = 13 kg (n = 126) in 1998. Initial stocking rates for both sizes of steers were as follows: light, 392 kg of live weight/ha; moderate, 504 kg of live weight/ha (increased to 616 kg live weight/ha in 1998); and heavy, 840 kg of live weight/ha. Averaged gain and gain/hectare are reported as stocking rate by steer type within year. Heavy steers had greater ADG than LHT steers during both years. Forage intake, expressed as a percentage of BW, was greater (P = 0.05) for LHT (3.1%) than for HWT (2.8%) calves. Grazing time (min/d; 1998 only) was greater (P < 0.05) for steers in the moderate and heavy stocking rates. Forage in vivo DOM decreased (P < 0.05) as stocking rate increased. Both LHT and HWT steers had lower (P < 0.05) ADG at all three stocking rates during 1998 compared with 1997. Despite lower ADG, LHT steers had greater gain/hectare than HWT steers during both 1997 and 1998.

Key Words: Cattle, Grasses, Grazing, Growth, Stocking Rate


Introduction

Old World bluestem (Bothriochloa ischaemum) is one of the main warm-season grasses planted on marginal farmland in Oklahoma (Berg and Sims, 1995). The nutritive value of Old World bluestem declines rapidly as it matures (Dabo et al., 1987, 1988). Old World bluestem should be kept in a vegetative and actively growing stage as long as possible in order to achieve maximum performance of growing livestock (Dewald et al., 1985; Forbes and Coleman, 1993). One method of maintaining this actively growing condition may be manipulation of stocking rate. If initial stocking rates are based on units of live weight/hectare, rather than animals/hectare, lightweight calves offer the opportunity to stock more animals/hectare. However, young, lightweight calves may be particularly sensitive to changes in grazing management and(or) forage availability (Leaver, 1970). Investigation of the effects of stocking rate on gains of steers of different body weights may help identify what size or weight of calf can provide the greatest net return from grazed forages. Identification of optimal stocking rates for optimizing weight gain of growing cattle expressed as ADG and gain/hectare should aid in making decisions regarding management of Old World bluestem pastures. Furthermore, monitoring the effects of stocking rate on forage intake and nutritive value may aid in making forage management decisions. The objective of our study was to determine the effects of increasing stocking rate on live weight gain and gain/hectare of light and heavy steers grazing Plains Old World bluestem.
Materials and Methods

Research Site

The study site was located at the Bluestem Research Range, 11 km southwest of Stillwater, OK. The primary soil types at this site are Coyle loam, Coyle-Lucien complex, Grainola-Lucien complex, Renfrow loam, Stephenville-Darnell complex, Stephenville fine sandy loam, and Zaneis loam. Plains Old World bluestem (Bothriochloa ischaemum L. Keng) was established at this site in 1989. Nitrogen fertilizer was applied at a rate of 112 kg/ha and a herbicide (Grazon P-D; 2,4-D + Picloram, Dow AgroSciences, Indianapolis, IN) was applied to the Old World bluestem pastures during May of each year. A total of 105 ha of Old World bluestem was separated into 12 pastures averaging 8.7 ha in size. Dormant residual forage was removed by winter grazing prior to the growing season each year.

Stocking Rates

Our intent was to use a range of initial stocking rates that would reflect commercial grazing enterprises in terms of optimizing individual animal ADG and gain/hec tare. Previous reports under similar environmental conditions (Volesky et al., 1994; Teague et al., 1996; Coleman and Forbes, 1998) used much higher stocking densities and were conducted over a much shorter time period, and sometimes animals were totally removed from the experimental pastures to allow regrowth. Additionally, cattle gains in some of the studies were considerably lower and would lead to inadequate returns on a per-animal basis. Most of these studies used variable stocking rates, which in commercial grazing operations is very limited (Teague et al., 1996). We used season-long stocking with set stocking rates to more closely mimic commercial grazing practices.

Year 1. Two hundred fourteen mixed-breed light-weight steers (LHT; average initial wt = 141 kg, SD = 17 kg) and 115 mixed-breed heavier steers (HWT; average initial weight = 265 kg, SD = 17 kg) were used during yr 1. Initial stocking rates were light (LS, 392 kg live weight/ha), moderate (MS, 504 kg live weight/ha), and heavy (HS, 840 kg live weight/ha). For perspective, this resulted in stocking rates (steers/ha) for LS, MS, and HS of 2.78, 3.57, and 5.96, respectively, for LWT steers and 1.48, 1.90, and 3.17 for HWT steers. Gunter et al. (1995) reported that the recommended stocking rate for Pains Old World bluestem is approximately 2.22 steers/ha. The 69-d trial was initiated May 28, 1997, and final weights were recorded on August 8, 1997. Steers were removed on this date because of contractual agreements regarding delivery to the owner on August 12.

Year 2. One hundred ninety-three mixed-breed light-weight steers (LHT: average initial wt = 160 kg, SD = 23 kg) and 126 mixed-breed heavier steers (HWT: average initial weight = 248 kg, SD = 13 kg) were used during yr 2. Initial stocking rates were 392 kg live weight/ha (LS), 616 kg live weight/ha (MS), and 840 kg live weight/ha (HS). The moderate stocking rate was increased by approximately 112 kg live weight/ha to more evenly space the three stocking rates. The 109-d trial was initiated May 15, 1998, with final weights recorded on August 31, 1998. The length of the trial was extended 40 d during yr 2 to graze Old World bluestem throughout the duration of the growing season.

All stocking rate × cattle type combinations were replicated twice, resulting in a total of 12 groups. Steers of both cattle types were randomly assigned to treatments on the initial weigh date, and treatment groups were randomly assigned to pastures both years. At initial processing, steers received a Synovex-C (10 mg estradiol benzoate + 100 mg progesterone, Fort Dodge Animal Health, Fort Dodge, IA) implant during yr 1 and a Ralgro (36 mg Zeranol, Schering-Plough, Madison, NJ) implant during yr 2. Steers had ad libitum access to water and plain salt throughout the trial.

Sampling Procedures

In an attempt to equalize fill across treatments, all steers were placed in the same tallgrass prairie pasture 4 d prior to both initial and final weigh dates. All weights were taken following a 14-h shrink in which access to feed and water was withheld.

Forage nutritive value and OM intake measurements were conducted in the same manner during 1997 and 1998. Diet samples were collected in June, July, and August during 1997 and May, June, July, and August during 1998 using ruminally cannulated steers. Ruminal fistulation surgeries were conducted by clinicians at the Oklahoma State University Veterinary Hospital and all surgical and experimental procedures were approved by the Institutional Animal Care and Use Committee.

Eight ruminally cannulated steers (mean BW 242 ± 11 kg, 28 mo of age) were placed in Old World bluestem pastures approximately 7 d prior to each collection period. On d 1 of each collection period, two cannulated animals were assigned to each of four pastures. After each collection, the cannulated steers were moved to four different pastures and those pastures were sampled the following morning. All 12 pastures were sampled over a 3-d period in this manner. Samples were collected by removing the reticularuminal contents, allowing animals to graze for 1.0 to 1.5 h, then removing the masticate from the rumen and replacing the reticularuminal contents (Lesperance et al., 1960). The two masticate samples collected from each pasture were composited within pasture for analysis of forage nutritive value.

Forage OM intake was estimated once in August each year using intraruminal controlled release chromium boluses (Captec Chrome for cattle; CAPTEC (NZ) Ltd., Auckland, New Zealand). Four steers in each cattle type × stocking rate combination were given a Captec bolus.
Following a 6-d equilibration period, fecal samples were collected once daily for 4 d. Samples were composited across days for each steer and fecal output was calculated by the chromium dilution technique. Forage OM intake was calculated by dividing fecal output by forage OM indigestibility (i.e., 1 – in vivo digestible OM). Grazing time was estimated during 1998 using Vibracorders (Model K, Service Recorder, Waldo, OH).

Vibracorders were placed on two of the steers that were given chromium boluses (LHT and HWT) in each stocking rate × cattle type combination and grazing time was recorded over 7 d. The 1st d of recording was not included in the mean grazing time, allowing 1 df for adaptation to the collars.

**Laboratory Analyses**

Oven-dried (55°C) masticate and fecal composite samples were ground in a Wiley mill to pass a 2-mm screen and were analyzed for DM and ash. During yr 1, N content of masticate samples was analyzed as Kjeldahl N (AOAC, 1996). In yr 2, a combustion technique (Leco NS-2000, St. Joseph, MI; AOAC, 1996) was used for N analysis. Masticate samples were analyzed for NDF and ADF using the methods of Goering and Van Soest (1970).

A 48-h in vitro procedure similar to the method of Goering and Van Soest (1970) was used to estimate masticate organic matter disappearance (OMD). Masticate samples (0.5 g) were incubated in buffered ruminal fluid for 48 h. Alfalfa, bermudagrass, and wheat straw standards of known in vivo digestibility values were also included in each assay. Samples were frozen immediately following the 48-h incubation to stop microbial activity. Samples were thawed and an NDF extraction was performed on the residue. The post-NDF residue was then ashed. Post-NDF residual OM was calculated by subtracting NDF residue ash weight from the NDF residue weight. In vitro OMD was calculated by subtracting the post-NDF residual OM (g) from the initial OM (g), dividing by the initial OM (g), and multiplying by 100 to express it as percentage OM. These in vitro values were then converted to in vivo OM digestibility by applying the equation derived by regressing in vitro disappearance values of the standards on known in vivo digestibility values. In vivo DOM was calculated by multiplying in vivo OM digestibility by sample OM and was expressed as a percentage of DM.

Fecal samples were analyzed for chromium concentration as described by Williams et al. (1962). Fecal samples were ashed then digested in a solution of phosphoric acid, manganese sulfate, and potassium bromate. Chromium concentration of fecal composite samples was determined using a Perkin-Elmer Model 400 atomic Absorption Spectrophotometer (Perkin-Elmer, Norwalk, CT).

**Results and Discussion**

**Cattle Type: Light vs Heavy Steers**

*Performance.* Average daily gains were greater (Figures 1 and 2) for HWT than for LHT steers during both years. Daily gain (kg) of HWT ranged from 1.01 to 1.31 (1997) and from 0.73 to 0.83 (1998), whereas ADG of LHT steers ranged from 0.96 to 1.09 (1997) and from 0.60 to 0.77 kg. Teague et al. (1996) and Coleman and Forbes (1998) reported rates of gains for steers grazing Plains or WW-Spar Old World bluestem that ranged from .064 to 0.75 and 0.49 to 0.71, respectively, depending on forage mass or height. Gain/hectare was greater for LHT than for HWT steers during both years (Figures 3 and 4), indicating that setting stocking rates as kilograms of BW per hectare will allow for greater gain/hectare for LHT steers despite lower rates of gain per animal.

**Forage Intake, Grazing Time, and Forage Nutritive Value.** Forage intake (percentage of BW) of LHT steers was greater (P = 0.01; Table 1) than that of HWT steers.
Similar to our study, Zoby and Holmes (1983) observed greater forage intake (g/kg BW) for light steer calves (164 kg BW) than for cows and steers (631 kg BW). Greater forage intake expressed as grams per kilogram of BW by lightweight steers may be expected as a result of the relationship of rumen volume to body weight. Owens and Goetsch (1988) reported that rumen volume can be estimated from BW kg as follows: rumen volume = BW$^{0.57}$. Thus, lighter ruminants have a larger rumen in relation to BW and consume larger amounts of feed when expressed as a percentage of BW, as we observed for LHT vs HWT steers.

Forage intake, expressed as kilograms per steer, was greater ($P = 0.01$; Table 1) for HWT steers. This increased consumption may have contributed to greater ADG attained by HWT vs LHT steers. Similarly, Zoby and Holmes (1983) observed greater forage intakes (kg/animal) for large cattle.

Grazing time was measured during 1998 only. Light steers spent more time grazing ($P = 0.05$; Table 1) than HWT steers, which may imply increased selectivity of light steers. However, we cannot conclude this, because nutritive value samples were not collected with LHT steers. An increase in grazing time for LHT compared with HWT steers may be due to greater intake as a percentage of BW; however, light steers consumed less forage in absolute amounts (kg/steer), which may imply lower harvest efficiency for LHT steers. Harvest efficiency expressed as grams of forage OM intake-kilogram of BW$^{-1}$-minute of grazing$^{-1}$ (Table 1) was not different between LHT and HWT steers. However, harvest efficiency expressed as grams of forage OM intake per minute of grazing (Table 1) was greater ($P = 0.02$) for HWT than for LHT steers, which is a reflection of greater absolute intake of forage and less grazing time for HWT steers. The combination of increased grazing time and lower absolute intakes of forage of slightly

<table>
<thead>
<tr>
<th>Item</th>
<th>Steer type$^a$</th>
<th>Light</th>
<th>Heavy</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage OM intake, % of BW</td>
<td></td>
<td>3.1$^f$</td>
<td>2.8$^f$</td>
<td>0.12</td>
</tr>
<tr>
<td>Forage OM intake, kg/steer</td>
<td></td>
<td>7.3$^g$</td>
<td>9.5$^g$</td>
<td>0.41</td>
</tr>
<tr>
<td>Grazing time, min/ha</td>
<td></td>
<td>665$^f$</td>
<td>624$^f$</td>
<td>11.9</td>
</tr>
<tr>
<td>Harvest efficiency$^d$</td>
<td></td>
<td>0.04$^f$</td>
<td>0.05$^g$</td>
<td>0.004</td>
</tr>
<tr>
<td>Harvest efficiency$^e$</td>
<td></td>
<td>9.9$^f$</td>
<td>15.6$^g$</td>
<td>1.28</td>
</tr>
</tbody>
</table>

$^a$Initial weights pooled across years: 151 kg for light and 256 kg for heavy steers.

$^b$Standard error of the mean, $n = 32$ for intake and $n = 12$ for grazing time and harvest efficiency data.

$^c$Expressed as grams of forage OM intake-kg of BW$^{-1}$-min of grazing$^{-1}$.

$^d$Expressed as grams of forage OM intake/min of grazing.

$^e$Means within a row without common superscripts differ ($P < 0.05$).
lower nutritive value may have contributed to lower gains of LHT vs HWT calves.

Forage nutritive value components were combined across months and years for analysis of differences in forage nutritive value between steer types and stocking rates. Crude protein (12.4 vs 13.2% of OM for LHT and HWT steers, respectively) and DOM (65.5 and 66.4% of DM for LHT and HWT steers, respectively) content of masticate samples collected from pastures grazed by HWT steers tended to be greater (\(P < 0.07\)). Crude protein content of the forage was adequate to support gains of HWT steers that were observed both years (NRC, 1984). However, LHT steers would have required minimum CP levels of 14.1% (NRC, 1984) to sustain gains in the light, moderate, and heavy stocking rates.

**Stocking Rate**

**Performance.** As stocking rate (kg/ha) increased during 1997, ADG of HWT steers decreased linearly (\(P = 0.06\); \(Y = 1.48 - 0.0005x\), \(S_{yx} = 0.09\), \(r^2 = 0.62\); Figure 1); however, stocking rate did not affect (\(P = .40\)) daily gains of LHT steers. A linear decrease in ADG was observed as stocking rate increased for LHT calves during 1998 (\(P = 0.03\); \(Y = 0.85 - 0.0003x\), \(S_{yx} = 0.03\), \(r^2 = 0.73\); Figure 2), but stocking rate did not affect (\(P = 0.35\)) daily gains of HWT steers. Declining ADG as a result of increasing stocking rate is well established in the literature (Jones and Sandland, 1974; Hart et al., 1976). More specifically, Coleman and Forbes (1998) reported significant declines in season-long gains of steers grazing Plains Old World bluestem as stocking rate increased. Stocking rates in the current study were lighter than those used by Coleman and Forbes (1998), and differences in the relationship between ADG and stocking rate between the two studies may be a reflection of this fact. However, Teague et al. (1996) reported minimal differences in ADG of steers grazing in WW-Spar Old World bluestem stocked to maintain three different forage heights.

A decline in ADG as stocking rate increased would be expected for both LHT and HWT steers independent of year-to-year variation. However, the interaction regarding the relationship between steer type and stocking rate among years makes it difficult to draw conclusions regarding the response of LHT or HWT steers to increasing stocking rate. Similar to our study, Volesky et al. (1994) observed a difference in the slope of regression lines describing the relationship between ADG and grazing pressure between years. One may conclude that the influence of year-to-year variations in forage mass and quality may often cause differences in the relationship between ADG and grazing pressure.

**Forage Intake, Grazing Time, and Forage Nutritive Value.** Mean forage intakes were pooled across steer type and year because no significant two-way interactions were detected among these variables. Forage intake did not differ (Table 2) among stocking rates.

Therefore, a decline in ADG was not due to differences in forage intake among stocking rates.

Steers in the LS rate spent less time grazing than steers in the MS or HS rates (\(P < 0.02\); Table 2), whereas grazing time was similar between the MS and HS rates. The energy expended during consumption of feedstuffs, both forage and concentrate, is highly correlated to the amount of time spent eating and is more related to eating time than amount of feed ingested (Susenbeth et al., 1998). There was no difference in either expression of harvesting efficiency among stocking rates (Table 2).

Declining ADG as stocking rate increased was not due to decreasing forage nutritive value. The only forage nutritive value component that differed among stocking rates was DOM, which declined (\(P < 0.05\)) as stocking rate increased (67.1, 65.9, and 65.1% of DM for LS, MS, and HS, respectively). The differences were slight and effects on steer performance due to declining DOM of this magnitude should have been minimal.

**Gain per Hectare.** Gain/hectare increased (\(P < 0.05\)) as stocking rate increased for both LHT and HWT steers during 1997 and 1998 (Figures 3 and 4). As stocking rate increases, gain per animal often decreases and gain/hectare increases (Harlan, 1958; Phillips and Coleman, 1995).

Plains Old World bluestem, when managed properly, has the potential to produce large amounts of forage, with reported season-long gains at or near 220 kg/ha (Sims, 1988) and 350 kg/ha (Volesky et al., 1994). Gain/hectare for both LHT and HWT steers in the HS rate was greater than 220 kg/ha during both years and was greater (\(P < 0.05\)) for LHT than for HWT steers at all stocking rates. Gain/hectare increased at a greater rate as stocking rate increased (\(P < 0.05\)) for LHT than for HWT steers, so the difference in gain/hectare between LHT and HWT steers increased as stocking rate in-

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**Table 2.** Forage OM intake, grazing time, and harvest efficiency of steers grazing Old World bluestem in the light, moderate, and heavy stocking rates

<table>
<thead>
<tr>
<th>Stocking ratea</th>
<th>Item</th>
<th>Light</th>
<th>Moderate</th>
<th>Heavy</th>
<th>SEb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forage OM intake, %/BW</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forage OM intake, kg/steer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grazing time, min/dc</td>
<td>598c</td>
<td>672c</td>
<td>665c</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td>Harvest efficiencycd</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>Harvest efficiencyd</td>
<td>13.5</td>
<td>12.5</td>
<td>12.2</td>
<td>1.56</td>
</tr>
</tbody>
</table>

\(a\)Stocking rates: 392 and 840 kg initial live weight/ha for light and heavy stocking rates, respectively; moderate stocking rate = 504 and 616 kg initial live weight/ha for 1997 and 1998, respectively.

\(b\)Standard error of the mean, \(n = 32\) for intake and \(n = 12\) for grazing time and harvest efficiency data.

\(c\)Expressed as grams of forage OM intake/kg of BW\(^{-1}\)-min of grazing.

\(d\)Expressed as grams of forage OM intake/min of grazing.

\(e\)Means within a row without common superscripts differ (\(P < 0.05\)).
creased even though ADG of LHT was less than ADG of HWT steers. This relationship implies greater potential for gain/hectare and subsequent profitability of LHT calves at every stocking rate, and this potential increases as stocking rate increases.

Decreased gain of individual animals is often compensated by increased gain/hectare. However, some have reported decreased gain/hectare at very high stocking rates (Mott, 1960; Riewe, 1961). In the current study, gain/hectare did not decline for either steer type at any stocking rate during either year, and gains continued to increased linearly. Therefore, stocking rate did not exceed the potential for increased gain at any point.

Year: 1997 vs 1998

Performance. Average daily gain for both LHT and HWT steers was greater during 1997 than during 1998. Average daily gain exceeded that reported by Coleman and Forbes (1998) for steers grazing Plains OWB during both years. The decline in gain for 1998 may have been influenced by differences in precipitation between the two years. During 1997, precipitation was above average in the months of June, July, and August, but precipitation was below average during these three months in 1998 (Figure 5). Effects of precipitation on animal performance may be due to the impact of precipitation on forage nutritive value.

Forage Intake and Nutritive Value. Forage nutritive value directly affects gains of animals. In the current study, all forage nutritive value components were different ($P < 0.05$) between the two years (Table 3) and may have been due to lower precipitation during 1998. Neutral detergent fiber and ADF content of masticate samples was greater ($P < 0.05$) and DOM content was lower ($P = 0.02$) in 1998 than in 1997. Hodgson and Wilkinson (1968) reported that forage OM digestibility had greater impacts on forage intake and performance of Jersey heifers than forage allowance. A decline in DOM would have a negative impact on gain, unless the steers were able to consume more forage during 1998. Intake of forage is often closely related to reticuloruminal fill, which is associated with digestibility, and fiber content of the ingested forage (Allison, 1985). Increasing fiber components and decreasing DOM of forage would suggest that steers would be unable to increase intake between the two years, and intake was not different between the two years.

Implications

Lightweight steers offer producers the opportunity to stock more animals per hectare if initial stocking rates are based on units of live weight per hectare, rather than animals per hectare. Despite lower individual animal ADG, lightweight steers provide more gain per hectare if they are stocked in this manner. Because of the large forage production potential of fertilized Old World bluestem, stocking rates can be considerably higher than traditional stocking rates on summer tallgrass prairie. Additionally, grazing Old World bluestem while it is vegetative allows producers to take advantage of its high nutritive value and production prior to its relative large decline in the fall. This management system could increase profitability of grazing programs on Old World bluestem for producers who have the expertise to receive and manage lightweight growing cattle.

Table 3. Chemical composition of Old World bluestem during 1997 and 1998a

<table>
<thead>
<tr>
<th>Item</th>
<th>1997</th>
<th>1998</th>
<th>SEb</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>12.2c</td>
<td>13.4d</td>
<td>0.25</td>
</tr>
<tr>
<td>NDF</td>
<td>81.4d</td>
<td>82.9d</td>
<td>0.36</td>
</tr>
<tr>
<td>ADF</td>
<td>42.0d</td>
<td>52.3d</td>
<td>0.27</td>
</tr>
<tr>
<td>DOM</td>
<td>69.5d</td>
<td>62.5c</td>
<td>0.34</td>
</tr>
<tr>
<td>Ash</td>
<td>10.6d</td>
<td>9.6c</td>
<td>0.35</td>
</tr>
</tbody>
</table>

aData pooled across all pastures within year and expressed as a percentage of OM, except DOM, which is expressed as a percentage of DM.

bStandard error of the mean, $n = 72$.

c,dMeans within a row without common superscripts differ ($P < 0.06$).

Figure 5. Precipitation for the months of April, May, June, July, and August during 1997 and 1998 at the Mar- ena site of the Oklahoma Mesonet system near the bluestem research range and the historical average for Payne County in Oklahoma.

Literature Cited

grasses as affected by cultivar and maturity. J. Range Manage. 41:40–48.


