Effect of mature body weight and stocking rate on cow and calf performance, cow herd efficiency, and economics in the southeastern United States

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ABSTRACT: Eight 4-ha mixed warm-season grass pastures in southwestern Arkansas (33°40′4″ N, 93°35′24″ W, and elevation 107 m) were stocked with either large mature size (571 kg [SD 55.2] BW) or small mature size (463 kg [SD 58.2] BW) spring-calving cows at 4 stocking rates (SR; 1, 1.5, 2, or 2.5 cow–calf pairs/ha) over 4 yr to test the effects of SR and mature body size on cow and calf performance and system economics. Each pasture received 112 kg/ha N as ammonium nitrate in May and was broadcast seeded to annual ryegrass (Lolium multiflorum Lam.) in mid October each fall along with 112 kg/ha N as ammonium nitrate. Data were analyzed by regression to determine the effects of cow size and SR on calf performance, cow BW change, calf gain, weaning weight per hectare, hay feeding requirements, and net returns. As SR increased, cow BW and BCS at weaning decreased ($P < 0.01$) by 26 kg and 0.36 condition scores, respectively, for each additional cow stocked per hectare ($R^2 = 0.44$). Calf BW at weaning in October increased ($P < 0.01$) 19 kg for each 100-kg increase in cow BW but was not affected ($P = 0.66$) by SR. As cow BW increased, calf BW at weaning per 100 kg cow BW decreased ($P < 0.01$) 6.7 kg for each 100-kg increase in cow BW but was not affected ($P = 0.44$) by SR. Neither cow BW nor SR affected ($P \geq 0.53$) pregnancy percentage, which averaged 88% over the 4-yr experiment. Calf BW weaned per hectare was not affected ($P = 0.75$) by cow BW but linearly increased ($P < 0.01$) by 217 kg for each additional cow per hectare SR. Hay feeding days and cost of hay per cow increased ($P \leq 0.05$) and kilograms of hay offered per cow tended ($P = 0.09$) to linearly increase with increasing SR, yet cow BW had no effects ($P > 0.22$). Although there were no effects ($P \geq 0.38$) of cow BW on carrying cost or net returns, increasing SR decreased ($P < 0.01$) total expenses by US$102/cow and increased net returns by $70/cow and $438/ha for each cow per hectare increase in SR. These data indicate that increasing cow size can increase weaning BW of calves but does not affect total production per hectare or profitability, even though weaning weight efficiency ratios were reduced. Increasing SR reduced cow BW and BCS at weaning and increased feeding of conserved forages but did not affect pregnancy rates and led to increases in total calf BW weaned per hectare and net returns.

Key words: beef cattle, cow mature body weight, economics, performance, stocking rate


INTRODUCTION

The costs of maintaining a beef cow and the unit cost of production of weaned calves have increased over the past 5 yr. Additionally, cow carrying costs (which include costs such as pasture management, stored forage and supplementation, interest, and other assorted costs) have increased along with a 30% increase in cow mature size over the last 30 yr (McMurry, 2008). McMurry (2008) calculated that
average cow slaughter weights have increased from 475 kg in 1975 to 621 kg in 2005. A 30% larger cow requires 22% more daily maintenance energy (NRC, 1996) and will consume 22 to 28% more forage DM daily, decreasing cow carrying capacity of the farm or increasing input costs associated with pasture management, supplementation, and stored forages. Stocking rate is a fundamental variable for managing pastures with distinct impacts on individual animal performance, BW production per unit of land area, and economic returns to the producer (Aiken, 2016), and there is a distinct relationship between stocking rate and animal performance for each environment and forage type (Bransby et al., 1988). There has been little research determining the holistic impacts of cow mature size on pasture carrying capacity, preweaning and postweaning growth of offspring, cow production efficiency, and pasture production economics. Determination of the economic optimum stocking rates is essential for each environment. Riechers et al. (1989) simulated stocking rate adjustments using variations in livestock prices and annual forage production. This simulation indicated that maximizing the stocking rate enhances the possibility of greater net returns compared with lower stocking rate alternatives tested but the net returns were more variable and the annual costs per cow were considerably higher. Therefore, the objective of this experiment was to test the effects of stocking rate and mature body size on cow and calf performance, cow herd efficiency, and system economics.

**MATERIALS AND METHODS**

All procedures in the following experiments were approved by the University of Arkansas Institutional Animal Care and Use Committee (protocol number 12043).

**Research Site and Treatments**

This research was conducted at the University of Arkansas Southwest Research and Extension Center in southwestern Arkansas (33°40′4″ N, 93°35′24″ W, and elevation 107 m). Cows (n = 56; age = 7.6 ± 2.6 yr) used at the onset of this experiment were selected from a group of 100 mature spring-calving beef cows (ranging in age from 5 to 12 yr) and segregated into groups with large mature size (HVY; n = 28; 564 kg [SD 27.3] BW; BCS = 5.5 ± 0.2; hip height = 135 ± 2.5 cm) or small mature size (LGH; n = 28; 459 kg [SD 28.8] BW; BCS = 5.3 ± 0.2; hip height = 126 ± 2.5 cm). Cows in each mature size group were placed on 4-ha pastures (n = 8) at 4 stocking rates (SR; 1, 1.5, 2, or 2.5 cow–calf pairs/ha) over 4 yr with the objective to test the effects of SR and mature body size on cow and calf performance, cow herd efficiency, and system economics. Cows were on pasture throughout the experiment (except during the winter of 2009/2010, when cows were removed from pastures due to extremely wet conditions and flooding) unless culled for reproductive failure or failure to wean a calf. Cull cows, cows that lost their calf, or cows that died were replaced with mature cows (>5 yr of age) of similar breeding and mature BW to maintain similar SR among pastures. Over the 4-yr experiment, the BW of the cows in the fall at the onset of the annual experiment was adjusted to a common BCS of 5.0, using equations described by Fox et al. (1988), and averaged 463 kg (SD 58.2) for LGHT and 571 kg (SD 55.2) for HVY.

Cows were of predominantly English breeding (≥75% Angus) with some Hereford, Bos indicus, or Continental breed (Simmental) influence. Cows were assigned to treatments based on BW, parity, and breed composition. Cows within each group were exposed to an Angus bull that had passed a breeding soundness examination during May and June. Cows calved during a 60-d period in February and March and calves were weaned during the initial week of October each year. Pregnancy status was determined for cows via rectal palpation by an experienced veterinarian (Powell and Perry Veterinary Clinic, Hope, AR) at the time of weaning.

Cow BW and BCS (1 to 9 scale; Richards et al., 1986) were collected (unshrunk) in January (before calving), May (following the calving season and before bull turnout), and October (at separation of calves from dams for weaning). Cows were gathered from pastures at 0700 h, separated from calves and weighed, reunited with their calf, and returned to pastures within 5 h. Within 24 h of birth, calves were weighed to determine birth BW, navels were treated with iodine, and male calves were castrated. Calf BW was also measured (unshrunk) in May and October (weaning). Cows were vaccinated for prevention of *Clostridium chauvoei*, *Clostridium septicum*, *Clostridium novyi* Type B, *Clostridium haemolyticum* (known also as *C. novyi* Type D), *Clostridium tetani*, and *Clostridium perfringens* types C and D (Covexin 8; Merck Animal Health, Madison, NJ) infections; bovine rhinotracheitis, bovine virus diarrhea (types 1 and 2), parainfluenza 3, and bovine respiratory syncytial viruses (Triangle 5; Bohringer Ingelheim Vetmedica, St. Joseph, MO) infections; and *Campylobacter fetus* var. *venerealis*, *Leptospira pomona*, *Leptospira hardjo*, *Leptospira grippotyphosa*, *Leptospira canicola*, and *Leptospira icterohaemorrhagiae* (TriVib 5L;
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Boehringer Ingelheim Vetmedica) infections. Cows were treated for internal parasites with a subcutaneous injection of 1% wt/vol doramectin (10 mg/mL at a dose of 1 mL/50 kg BW; Dectomax; Zoetics, Kalamazoo, MI) in October, at weaning, and for internal and external parasites with a topical application of 0.5 mg/kg of BW of moxidectin (Cydectin; Boehringer Ingelheim Vetmedica) in May, before breeding, each year.

While on pasture, cows and calves were allowed free access to drinking water sourced from a well in automatic-fill concrete water tanks and were given free-choice access to nonmedicated mineral. Mineral was offered in covered feeders designed for mineral supplementation (Ground Mineral Feeder; Sioux Steel Co., Sioux City, IA). The mineral mixture (Sunbelt Custom Minerals, Inc., Sulfur Springs, TX) had a targeted daily intake of 114 g/cow and contained 14% Ca and 7% P from CaCO₃ and Ca₃(PO₄)₂, 5% Mg from MgO, and 14% NaCl as well as vitamins (661,500 IU/kg vitamin A, 221 IU/kg vitamin E, and 66,150 IU/kg vitamin D) and trace minerals (1,000 mg/kg Mn from MnSO₄, 2,355 mg/kg Fe from FeSO₄, 1,250 mg/kg Cu from CuSO₄, 3,000 mg/kg Zn from ZnSO₄, 20 mg/kg Co from CoCO₃, and 25 mg/kg I from ethylenediamine dihydroiodide).

**Pasture Management**

Pastures used in this experiment were Una silt clay loam, which is characterized as deep, poorly drained, level soils (0 to 1% slopes) on a floodplain with a seasonally high water table in the winter and spring, and were predicted to produce 18.5 animal-unit months of forage per hectare (Hoelscher and Laurent, 1979). Warm-season forage species in pastures were dominated by dallisgrass (Paspalum dilatatum Poir.) and bermudagrass [Cynodon dactylon (L.) Pers.].

Each pasture received 112 kg/ha N as ammonium nitrate in May to promote growth of warm-season grasses and was broadcast seeded with 28 kg/ha annual ryegrass (cv. Marshall; Lolium multiflorum Lam.) each fall along with 112 kg/ha N as ammonium nitrate. Pastures were split into two 2-ha paddocks and cows grazed each paddock 2 wk of each month. Pastures were sprayed in late May each year with 1.5 L/ha of 10.2% active ingredient 4-amino-3,5,6-trichloropicolinic acid, triisopropanolamine salt (plicoram), and 39.6% active ingredient 2,4-dichlorophenoxyacetic acid triisopropanolamine salt (Trooper P + D Herbicide; Nufarm Americas Inc., Burr Ridge, IL).

After annual ryegrass was seeded, cows were restricted to 0.4 ha near a water source and were fed warm-season grass hay (9% CP and 53% TDN, DM basis) ad libitum in ring-type feeders until the annual ryegrass reached a height of 20 cm by early March each spring. Thereafter, cows were allowed access to both annual ryegrass and ad libitum hay until warm-season grass pastures were had sufficient forage available for grazing. Hay was replaced by a new bale when 10 to 15% of the previous bale remained. Weight of bales was estimated by weighing 20 random bales and averaging their weight monthly during the hay feeding periods.

Precipitation during the experimental period is presented in Table 1 by year for each growing season (winter = November, December and January; spring = February, March, and April; summer = May, June, and July; and autumn = August, September, and October). In the summer and autumn of 2009, precipitation was 209% of normal, and the winter of 2009/2010 had normal precipitation levels, which resulted in flooded pastures during the autumn and winter feeding period. The spring, summer, and autumn of 2010 and the winter, summer, and autumn of 2010 to 2011 had below-normal precipitation levels. The precipitation of the 2011 to 2012 production year returned to 91% of normal.

**Forage Sampling and Analysis**

Pastures were sampled at mid month throughout the grazing season for each forage type. Warm-season grass pastures were sampled monthly beginning in May through October each year. Annual ryegrass was sampled beginning in February through April of each year. Forage mass in each pasture was estimated using a calibrated rising-plate meter with 20 sampling points per pasture (Michell and Large, 1983). Calibration samples were collected by clipping all forage within a single 0.1-m² frame in each pasture, after noting rising plate height, on each date. Forage was clipped to a 2.5-cm stubble height with hand shears. Clipped calibration samples were dried to a constant weight under forced air at 60°C. Dry weights of these clippings were used to relate forage mass (kg DM/ha) to plate height within each treatment using linear regression for forage mass prediction. Forage mass prediction equations for the rising plate data were generated using the regression procedure of SAS (SAS Inst. Inc.,

<table>
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<th>Year</th>
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*Table 1. Precipitation (cm) at the University of Arkansas Southwest Research & Extension Center (Hope, AR) from May 2009 to October 2012*
Cary, NC) using the clipping data for each collection period. The regression of rising plate reading on clipped DM yield resulted in equations that explained 76% of the variation ($P < 0.01$) in forage mass (kg/ha) for annual ryegrass and 74% of the variation ($P < 0.01$) in forage mass for warm-season grasses.

To estimate the quality of forage consumed by cattle, forage samples were collected to be representative of diets consumed by grazing cows from all pastures by clipping forage to mimic forage selected by grazing cows. Forage samples collected for nutrient analysis were dried to a constant weight at 60°C in a forced-air oven and ground to pass a 2-mm screen (Thomas A. Wiley Laboratory Mill, model 4; Thomas Scientific, Swedesboro, NJ) for analysis using near-infrared reflectance spectroscopy (Feed & Forage Analyzer model 6500; FOSS North America, Eden Prairie, MN). The CP calibration equation had a SE of calibration (SEC) of $0.92$, a SE of cross-validation (SECV) of $0.93$, and $R^2 = 0.96$. The NDF calibration equation had a SEC of $2.63$, a SECV of $2.73$, and $R^2 = 0.95$. The ADF calibration equation had a SEC of $1.66$, a SECV of $1.70$, and $R^2 = 0.93$.

**Economic Analysis**

Enterprise budgeting techniques were used with data collected during the 4-yr experiment to estimate expected values for production costs, revenue, and net return for each production system on each pasture represented by each SR (AAEA, 2000). Annual land cost was set at US$45/ha, based on rental rates published by the USDA National Agricultural Statistics Service (2015). Cow replacement rates were set at 15% based on the actual pregnancy percentage of 88% (12% replacement rate due to reproductive failure) plus a 3% replacement rate based on cow age or failure to wean a calf. Cost of replacement females were estimated using the 5-yr average Arkansas auction market prices from 2009 to 2014 (USDA Agricultural Marketing Service, 2016) of pregnant Medium and Large frame replacement females and the BW of the cows placed on pasture. The price of fertilizer, seed, and pesticide; application cost of fertilizer and pesticide; and cost of mineral are based on regional price and cost of machinery operations as described by Stiles and Griffin (2007). Annual costs of pasture management and agronomical inputs were fertilizer and fertilizer application, estimated at $158/ha; annual ryegrass seed and planting, estimated at $32/ha; pesticide for weed control and pesticide application, estimated at $90/ha; and interest, which was 8%. Cost of inputs for cow management was estimated to be $29/cow for mineral, and health care costs of $25/cow for HVY cows and $22/cow for Lght cows were included. Bull costs were calculated based on a 25 cow-to-bull ratio, $4,500 bull purchase price, and $2,000 salvage value with annual costs of $46.25/cow exposed calculated using the Bull Expense Calculator (Whittle, 2007). Sales price and profitability scenarios were constructed using 5-yr average October Arkansas auction market prices (2009 to 2014) of Medium frame, number 1 steers and heifers and Boning Utility (80 to 85% Lean) cows (USDA Agricultural Marketing Service, 2016).

**Forage Mass and Nutritive Quality**

The relationship of cow BW and SR on forage mass and forage nutritive quality for the spring grazing season (March and April), summer grazing season (May, June, and July), and autumn grazing season (August and September) are presented in Fig. 1, 2, and 3, respectively. In the spring (Fig. 1), cow BW and SR had no effect on CP ($P = 0.94$, $R^2 = 0.005$), NDF ($P = 0.42$, $R^2 = 0.07$), TDN ($P = 0.41$, $R^2 = 0.05$) concentration of the annual ryegrass forage, or forage mass ($P = 0.21$, $R^2 = 0.12$), but in all cases, CP and TDN concentrations were in excess of requirements for lactating beef cows in peak milk (NRC, 1996).

During the summer (Fig. 2), cow BW and SR had no effects ($P ≥ 0.16$) on forage NDF concentration
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within the model that explained very little of the variation in NDF concentration ($P = 0.25, R^2 = 0.04$). Forage CP during the summer was reduced ($P = 0.01$) by 0.8% for each 100-kg increase in cow BW, but forage CP was increased ($P = 0.04$) by 1.6% for each additional cow per hectare increase in SR. Also during the summer grazing season, for each 100-kg increase in cow BW, forage TDN tended ($P = 0.08$) to decrease by 1.2% percentage units, but forage TDN increased ($P = 0.04$) by 3.03% percentage units for each additional cow per hectare increase in SR. Increasing SR decreased ($P < 0.01$) forage mass by 1,228 kg for each cow per hectare increase in SR and increasing cow BW by 100 kg decreased ($P = 0.05$) forage mass by 550 kg/ha.

During the autumn grazing period (Fig. 3), even though cow BW did not affect ($P \geq 0.26$) forage CP, NDF, or TDN concentration, for each additional cow per hectare increase in SR, NDF decreased ($P < 0.01$) by 2.91% percentage units whereas CP and TDN increased ($P < 0.01$) 2.98 and 6.30% percentage units, respectively. Forage mass, likewise, was not affected ($P = 0.50$) by cow BW, but as SR increased, forage mass declined ($P < 0.01$) by 1,323 kg/ha for each additional cow per hectare (Fig. 3).

**Cow Performance and Calf Performance**

As per experimental design, cow BW in May (data not shown) was increased ($P < 0.01$) by 0.94 kg for each kilogram increase in cow BW the previous fall, but SR did not affect ($P = 0.44$) cow BW in May (May cow BW = $101.56 + 0.94 \times $ cow BW $- 11.85 \times $ SR; $P < 0.01, R^2 = 0.58$). There was no effect of cow BW or SR on cow BCS ($P = 0.24, R^2 = 0.09$) in May. The lack of impact of SR or cow BW on cow BCS in May can be explained by the lack of difference in forage nutritive quality observed during the spring (Fig. 1) and the presence of ad libitum hay fed during the winter feeding period. Even though hay feeding days were increased with SR, the quality of the hay was sufficient to have minimal effects on BCS.
The effect of cow BW and SR on cow performance at weaning is presented in Fig. 4. At weaning in October (Fig. 4), cow BW was affected ($P < 0.01$) by both cow BW the previous fall (increasing by 73 kg for every 100-kg increase in BW the previous fall) and SR, which decreased BW by 26 kg per additional cow stocked per hectare ($R^2 = 0.44$). Body condition score of cows at weaning in October (Fig. 4) did not differ ($P = 0.90$) due to cow BW but decreased ($P = 0.03$) 0.36 condition scores for each additional cow stocked per hectare. Loss in BW during the summer (Fig. 4) was greater ($P < 0.01$) for HVY cows and tended to increase ($P = 0.09$) with increasing SR. Loss in cow BW was increased ($P < 0.01$) by 21 kg for each 100-kg increase in BW, and for each cow per hectare increase in SR, loss in cow BW during the summer tended ($P = 0.09$) to increase by 15 kg. Pregnancy percentage was not affected ($P \geq 0.67$) by either cow BW or SR and averaged 88 ± 10.6% across both cow BW and SR, which explained only 3% of the variation in pregnancy (pregnancy percentage = $81.8 - 0.007 \times$ cow BW + $3.93 \times$ SR; $P = 0.67$, $R^2 = 0.03$).

The effect of cow BW and SR on the performance of calves is presented in Fig. 5. Calf BW in May before the start of grazing warm-season grass was not affected ($P \geq 0.13$) by either cow BW or SR, but calf BW at weaning in October increased ($P < 0.01$) 19 kg for each 100-kg increase in cow BW but was not affected ($P = 0.66$) by SR. Even though calf BW at weaning increased with increasing cow BW, weaning efficiency (kg calf weaned per 100 kg cow BW) decreased ($P < 0.01$) 6.7 kg for each 100-kg increase in cow BW but was not affected ($P = 0.44$) by SR. The calf BW weaned per hectare was not affected ($P = 0.75$) by cow BW but linearly increased ($P < 0.01$) by 217 kg for each additional cow per hectare SR.

Hay Feeding

Due to flooding of pastures, during the winter of 2009/2010, cows were commingled within BW group.
and hay was fed from 14 October 2009 to 6 March 2010, at which time the cows were sorted into their original BW and SR groups and replaced on original pastures. During the fall and winter of 2010/2011, cows in the 2.5 cows/ha SR groups were fed hay from 15 October 2010 to 14 February 2011, cows in the 2.0 cows/ha SR groups were fed hay from 25 October 2010 to 14 February 2011, cows in the 1.5 cows/ha SR groups were fed hay from 20 December 2010 to 14 February 2011, and cows in the 1.0 cow/ha SR groups were fed hay from 26 December 2010 to 14 February 2011 for HVY cows and from 3 January 2011 to 14 February 2011 for LGHT cows. In the drought year from 2011 to 2012, cows in the 2.5 cows/ha SR groups were fed hay from 22 July 2011 to 21 February 2012 whereas cows in the 2.0 cows/ha SR groups were fed hay from 2 September 2011 to 21 February 2012, cows in the 1.5 cows/ha SR groups were fed hay from 3 October 2011 to 21 February 2012, and cows in the 1.0 cow/ha SR groups were fed hay from 10 November 2011 to 21 February 2012.

The effect of cow BW and SR on hay feeding and hay costs is presented in Fig. 6. Hay feeding days was not affected by cow BW ($P = 0.22$) but increased ($P = 0.02$) 37 d for each additional cow per hectare increase in SR. Likewise, the kilograms of hay offered per cow was not affected ($P = 0.51$) by cow BW but tended ($P = 0.09$) to increase by 439 kg with each additional cow increase in SR. Hay offered per feeding day as a percentage of cow metabolic BW was not affected ($P = 0.11$) by SR but tended ($P = 0.08$) to decrease as cow BW increased. Total hay cost per cow was not affected ($P = 0.56$) by cow BW but increased ($P = 0.05$) $47/ cow for each additional cow per hectare increase in SR.

Economics

The effect of cow BW and SR on total costs and net returns on both a per-cow and a per-hectare basis is presented in Fig. 7. Although there was no effects ($P = 0.38$) of cow BW on carrying costs per cow or on a per-hectare basis, increasing SR decreased ($P < 0.01$) total expenses on a per-cow basis (Fig. 7A) in a quadratic ($P = 0.02$) fashion (cost, $S$/cow = 1,004.5 + 0.22 × cow BW – 486.4 × SR + 109.9 × SR$^2$; $P < 0.01$, $R^2 = 0.53$). Cost per
Cow decreased as SR increased from 1 to 2 cows/ha but remained constant from 2 to 2.5 cows/ha. Total expenses per cow were spread over more units of production with increasing SR, even though there was more hay feeding and hay feeding expenses (Fig. 6) as SR increased. Cow carrying costs per hectare (Fig. 7B) increased \((P < 0.01)\) cost by $486/ha for each additional cow per hectare increase in SR. As observed with total costs, net returns per cow or per hectare were not affected \((P \geq 0.94)\) by cow BW. As SR increased, net returns per cow increased $70 for each additional cow per hectare increase in SR, and per-hectare net returns increased by $438/ha for each cow per hectare increase in SR.

**DISCUSSION**

**Cow BW**

As discussed previously, McMurry (2008) concluded that cow BW in the United States has increased over the last 30 yr based on average cow slaughter weights. Using estimations from the NRC (1996), a 30% larger cow requires 22% more energy per day for maintenance and consumes 22 to 28% more forage DM per day, which can decrease the cow carrying capacity of the farm or increase input costs associated with pasture management, supplementation, and stored forages. Zoby and Holmes (1983) estimated that at low SR, Friesian cows weighing 631 kg consumed 21 and 16% more forage in spring and summer pastures, respectively, than Friesian cows weighing 439 kg. Research by Lusby et al. (1976a,b) and Kropp et al. (1973) reported that Holsteins with average BW of 549 kg consumed 25% more roughage in a drylot and 50% more forage on pasture than Hereford–Holstein crossbred cows with an average BW of 470 kg, further supporting the estimates of the NRC (1996).

Research from the University of Arkansas Southeast Research and Extension Center (Whitworth et al., 2006) also indicated that cow production efficiency ratios (205-
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In calf weaning weight/cow BW at weaning) were less for larger cows, larger cows cost more to maintain, and larger cows were less profitable than smaller cows. Several studies have considered the impact of mature cow size on energetic and/or production efficiency. Troxel et al. (2004) identified that cow production efficiency and metabolic efficiency of cows in 18 Arkansas cow herds were negatively correlated with the dam’s BW (–0.58 and –0.41, respectively). Kress et al. (1969) determined that energetic efficiency was negatively correlated with cow weight unless the salvage weight of the cow is considered, but with increasing number of lactations, the importance of salvage weight is reduced, indicating that over the productive life of a cow, a smaller cow’s efficiency is greater. Hawkins et al. (1965) reported that cows weighing less at weaning weaned more calves and more total BW over their life than heavier cows. Therefore, the trend in the industry for larger cows can have large impacts on whole farm efficiency and economies of production, but this may be dependent on the production environment.

The decreased carrying capacity and increased input costs that is commonly thought to occur with larger cows were not observed in the current research, which is likely due to the environment the research was conducted. Although confounded with milk production potential, Kropp et al. (1973) and Wyatt et al. (1977) found that BW change during the summer of heavier Holstein cows did not differ from lighter BW Hereford–Holstein crossbred cows, but BCS at the end of lactation was 2 condition scores less for the larger cows, regardless whether cows were maintained in a drylot or on native range. Larger Holstein cows (albeit having a greater milk production potential) in the Wyatt et al. (1977) experiment also weaned heavier calves than the smaller Hereford–Holstein crossbred cows whether maintained in a drylot or on native range pastures. Kropp et al. (1973) reported that the larger Holstein cross cows weaned heavier calves than the smaller Hereford–Holstein crossbred cows when supplementation rates were greater, but not at lower supplementation rates. In support of the

**Figure 5.** Effect of cow BW (large mature size [HVY], denoted by + and ——, and small mature size [LGHT], denoted by ▲ and —) and stocking rate (SR; 1.0, 1.5, 2.0, and 2.5 cows/ha) on calf BW in May (A) and at weaning in October (B), weaning efficiency (kg calf BW weaned per 100 kg cow BW (C), and BW weaned per hectare (D). Although cow BW was analyzed based on average cow BW in each pasture, regression lines for HVY and LGHT BW groups were calculated from the regression equation shown using the average BW of each BW group to simplify presentation.
current research, an analysis by Long et al. (1975) indicated that cows with greater production potential are better suited for less restricted environments.

Modeling conducted in the late 1970s (Notter et al., 1979a,b) indicated that increasing cow mature size and subsequent increases in energy requirements had little effect on reproductive efficiency when cows were fed high-quality diets and energy costs were low. If the increases in cow size led to a reduction in breeding rates, cow herd efficiency was reduced and cost of production was increased. These changes are highly environmentally dependent as discussed by Jenkins and Ferrell (1994), who found that as feed availability increased, performance of breeds with larger mature size increased to a greater extent than breeds with a lesser mature size. Notter et al. (1979b) and Long et al. (1975) agreed that smaller cows are relatively more economically efficient when maintained on pasture or marginal environments, whereas larger cows were found to be more efficient when maintained in less restrictive environments or a drylot. In the current study, conducted in a sub-tropical environment with average annual precipitation of 138 cm (Table 1) and year round forage production potential, HVY cow’s calf weaning weights were increased compared to LGHT cow’s calf weaning weights. But other measures of productivity (pregnancy rates and net returns) were comparable with LGHT cow productivity, even though measures of weaning efficiency (kg of calf BW weaned per 100 kg cow BW) were reduced in HVY cows. Scasta et al. (2015) reported that large cows are not able to meet genetic production potential in a semiarid high-elevation rangeland production environment in Wyoming and, similar to the current research, smaller cows had greater weaning efficiency ratios than larger cows.

**Stocking Rate**

Increasing SR has long been shown to decrease animal performance for cow–calf (Kothmann et al., 1971; Hart et al., 1988; Aiken and Bransby, 1992;
Gillen and Sims, 2002) and growing cattle systems (Willms et al., 1986; Aiken and Bransby, 1992; Gunter et al., 2005; Morgan et al., 2012) when defoliation at higher SR exceeds vegetation regrowth rate. This reduction has been linked to reductions in herbage allowance (kg forage/kg animal BW) limiting diet selectivity, diet quality, DMI, and herbage regrowth rate (Roth et al., 1990). In the current study, forage nutritive quality actually increased with increasing SR during the summer (Fig. 1) and autumn (Fig. 2), which is indicative of sampling of herbage at an earlier phenological growth stage as SR increased. The decline in forage mass with increasing SR probably reduced forage DMI and grazing selectivity, resulting in increased BW loss by cows and loss in BCS as SR increased, even with observed increases in forage nutritive quality. Forage availability of the 2.5 cows/ha SR approached the level (1,150 kg forage DM/ha) that the NRC (1996) suggested will result in decreased DMI. Zoby and Holmes (1983) found that Friesian cows grazing at a low SR were able to consume 32 and 11% more forage DM than cows stocked at a high SR during the spring and summer, respectively, and large cattle were least likely to compensate for this reduction in forage availability by alterations in grazing behavior, such as increasing bite rate and grazing time.

There was no effect of SR or cow BW on pregnancy percentage in the current research (Fig. 4D). A retrospective power analysis indicates that, as the experiment was designed, the minimum difference in pregnancy percentage between treatments that would be detectable was 20.9% and given the current level of variation and treatment differences, 250 experimental units would be required to separate treatments. Body condition scores, although decreasing with increasing SR at weaning, did not differ at calving or before the breeding season. The observed BCS of the cows in this study were greater than the BCS commonly thought to impact reproductive performance (Selk et al., 1988). Richards et al. (1986) indicated that post-
parturition. Pregnancy percentage of cows that calved with BCS > 5.

Total animal product per unit of land area has been shown to increase up to a point even though individual animal is decreased, until animal performance is reduced to such an extent that animal product per unit of land area begins to decrease (Mott, 1960; Jones and Sandland, 1974; Bransby et al., 1988). Aiken and Bransby (1992) reported that as SR increased, BW gain of steers decreased to a greater extent with increased SR than BW gain of cows and calves, and their findings are supportive of the lack of response of calf weaning weight to increasing SR in the current experiment, and they also found that calf gain per hectare continued to increase at all SR. In contrast to results of the current experiment, Gaertner et al. (1992) reported that increasing SR of spring-calving cows grazing mixed cool-season annual and warm-season perennial grasses in northeast Texas reduced forage availability from >2,400 to <800 kg/ha, which decreased weaning weight 40 kg. Bagley et al. (1987) found that increasing the SR of cows grazing bermudagrass in Louisiana from 2.9 to 3.8 cows per hectare decreased weaning weight 12 kg/cow for spring-calving cows but increased calf BW weaned per hectare 22%. In Louisiana, Wyatt et al. (2012a,b, 2013a,b) reported that increasing SR of cows from 1.25 to 2.75 cows/ha under continuous grazing (Wyatt et al., 2012a) or rotational grazing (Wyatt et al., 2012b) management increased forage nutritive value, similar to the current research, yet they also found that increasing SR decreased calf BW production per cow but increased BW weaned per hectare (Wyatt et al., 2012a, 2013b). Kothmann et al. (1971) found that increasing the SR of cows grazing native range in the Rolling Plains region of Texas from 0.09 to 0.2 cows/ha decreased weaning weight per cow by 11 kg yet calf production per hectare was increased by 8 kg/ha. Gillen and Sims (2002) reported that cows grazing native range in northwestern Oklahoma had 13% lower weaning weights when cows were stocked at 0.22 cows/ha compared with 0.11 cows/ha, but even with this reduction in weaning weight per cow, weaning weight per hectare was nearly doubled at the higher SR.

**Economics**

The costs of maintaining a beef cow and the unit cost of production of weaned calves have increased over the past 5 yr. Variable costs, such as fuel, fertilizer, and herbicides, have been blamed as the primary culprits; however, fixed costs such as equipment, hired labor, and land have increased as well. Additionally, cow carrying costs have increased because of a 30% increase in cow size over the last 30 yr (McMurry, 2008).

The SR used in the current study (from 1.0 to 2.5 cows/ha) resulted in linear increases in net return up to the maximum SR used, yet as SR increased from 2.9 to 3.8 cows per hectare in Louisiana, Bagley et al. (1987) reported reductions in both net return per cow and net return per hectare, even though calf BW weaned per hectare increased. In the current experiment, neither the maximum production per hectare nor the maximum net return per hectare were identified, but in evaluating the production and net returns presented by Bagley et al. (1987), the highest SR used in this research is likely very near the SR with the maximum net return. In an economic analysis of the cow–calf performance data presented by Wyatt et al. (2013b), Wyatt et al. (2013a) found results similar to the current research, in that as SR increased, total specified costs increased but increases in sales revenue increased net return over total expenses. Gillen and Sims (2002) also found that although calf weaned BW per hectare generally increased across years, maximum net returns were maximized at 0.17 cows/ha. Determination of the economic optimum SR is essential for each environment, because in the short run, it is often seen that maximum production is the most profitable, especially in highly favorable market conditions, but it is unlikely that this production level is sustainable for the long term. Gillen and Sims (2002) calculated that the economically optimum SR was 78% of the SR with maximum animal production per hectare. Riechers et al. (1989) simulated SR adjustments using variations in livestock prices and annual forage production. This simulation indicates that maximizing SR enhances the possibility of enhancing net returns compared with lower SR alternatives tested, but the variation in net returns was greater and the annual costs per cow were considerably higher. Parsch et al. (1997) reported that models indicate that the economically optimum SR of growing cattle was at 83% of the SR that maximized gain per hectare, and increasing SR was accompanied with increases in production risk related to weather and increased variance in weight gain and net return. An economic analysis of a SR study of Israeli range cows (Seligman et al., 1989) determined that cost of supplemental feed inputs is just as important in determination of the most profitable SR. Seligman et al. (1989) concluded that when supplemental hay and concentrates are expensive, net value of production per hectare decreases with higher SR even though production per hectare increases, but if fixed costs of land and management are high, the net profitability of production is increased with higher SR.

These data indicate that in the environment that this research was conducted, increasing cow size increases weaning BW of calves but does not affect total calf BW production per hectare or profitability. Even
though weaning weight efficiency ratios were reduced as cow BW increased, this does not appear to negatively affect productivity or net returns of the cow–calf enterprise. Increasing SR reduces cow BW and BCS at weaning and increases feeding of conserved forages and variable costs but did not affect pregnancy rates and led to increases in total calf BW weaned per hectare and net returns per hectare.

LITERATURE CITED


