CASE STUDY: Effect of Limiting Access to Winter Wheat Pasture on Performance of Angus, Brahman, Romosinuano, and Reciprocal Cross Calves

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ABSTRACT

The CP content of winter wheat pasture exceeds the daily CP requirement of beef stocker calves by more than 100%. Excess N is excreted as urinary N and may subsequently be lost through volatilization. The objective of this experiment was to determine stocker calf performance when wheat forage DMI was limited by physically removing calves from the pasture. In each of 3 yr (4 pastures/yr), stocker calves (BW = 251 ± 3.8 kg) were assigned to graze wheat pasture continuously (control) or to graze wheat pasture for 3.5 d/wk (limit-grazed) plus be confined in a dry lot for 3.5 d/wk. Calves in the limit-grazed group were fed supplemental feed and had ad libitum access to hay when not on pasture. Limiting access to wheat pasture decreased (P < 0.01) ADG during the 120-d winter wheat grazing period (0.72 vs. 0.66 kg). During the 50-d spring grazing season, steers from the limit-grazed group compensated for the lower ADG during the winter grazing period and had greater (P < 0.01) ADG (1.19 vs. 1.10 kg) than steers from the control group. As a result, overall ADG (0.84 ± 0.04 kg) for the 170-d stocker phase was not different (P = 0.39) between the 2 management treatments. Winter stocker performance was affected by breed type more than spring stocker performance. Limiting access to winter wheat pasture increased carrying capacity of the pasture and the amount of BW gain produced per hectare, but the additional cost of hay and supplement fed to limit-grazed steers reduced overall profitability of the stocker enterprise.

Key words: beef cattle, limit grazing, nitrogen excretion, wheat pasture

INTRODUCTION

Wheat pasture is the primary forage resource for beef stocker calf enterprises in the southern Great Plains region (Phillips et al., 1996; Peel, 2003; Horn, 2006). Crude protein concentration of winter wheat pasture during the winter grazing period ranges from 23 to 28% of DM (Mader et al., 1983; Vogel, 1988; Gallavan et al., 1989), which is more than twice the dietary requirement of a 227-kg calf grazing winter wheat with an anticipated ADG of 0.8 kg (NRC, 1996). Stocker calves grazing winter wheat pasture retain less than 15% of the N consumed and excrete approximately 60% of the N consumed in the urine as urea (Phillips et al., 1995). Urinary N is susceptible to volatilization, which adds to atmospheric N emissions (van Groenigen et al., 2005; Archibeque et al., 2007).

Vogel et al. (1987, 1989) reported a decrease in the amount of wheat forage consumed by stocker calves when wheat or sorghum silage was fed daily. In these studies, silage DMI increased as forage allowance decreased, producing a gradient in the quantity of wheat forage consumed, dietary...
were approved by the Animal Care and Use Committee. After weaning, steer calves (n = 479) were transported from Brooksville, Florida, to the USDA-ARS Grazinglands Research Laboratory (35°32' N latitude, 98°02' W longitude) near El Reno, Oklahoma. The study was conducted for 3 consecutive years (2002 through 2005), using 3 calf crops and a total of 12 pastures (4 pastures/yr x 3 yr). On arrival (average date October 18), steers were placed in pens or in small paddocks of dormant warm-season grasses and fed a mixed diet for 31 d (range 29 to 35 d) to recover from the stress of transit and to adapt to the new environment. At the end of the posttransit period, steers (mean BW 251 ± 8.6 kg) were blocked by breed and randomly assigned to 1 of 4 wheat (Triticum aestivum, var. Pioneer 2174) pastures. Pastures (mean size = 26 ha) were chemically fallowed each summer, planted (100 kg of seed/ha) with a no-till drill (row spacing 23 cm; average planting date September 15) and a total of 90 kg of N/ha was applied in 2 applications, 1 in the fall at planting and 1 in the spring on approximately February 15.

During the winter phase (mean grazing period 120 d; range 115 to 127 d; November to March), 2 pastures were grazed continuously (control; stocking rate of 0.83 ± 0.08 ha/steer; pasture size of 35 ± 13.9 ha), and 2 pastures were grazed one-half of the time (limit-grazed; stocking rate of 0.43 ± 0.04 ha/steer; pasture size of 17 ± 4.2 ha). The stocking rate of control pastures was based on the amount of wheat biomass present at the initiation of grazing and was set to provide enough forage biomass for a 120-d grazing season. The stocking rate of limit-grazed pastures was twice the stocking rate used in control pastures. During the winter grazing period, calves in the limit-grazed groups were placed in pens 3 times each week for 28 h to limit access to wheat pasture to 84 h or 3.5 d/wk. Limiting access to wheat pasture was used to limit wheat forage intake. When not grazing wheat pasture, steers had ad libitum access to grass hay (9.6% CP, 1.22 Mcal NE$_{\text{a}}$/kg, and 0.66 Mcal NE$_{\text{a}}$/kg; Soil, Water and Forage Analytical Laboratory, Stillwater, OK) and were limit-fed (3 meals/wk) a pelleted supplement at the rate of 1.4% of BW/meal (DM basis). The pelleted supplement was commercially available and had a guaranteed nutrient content of 9% CP, 2.25% fat, and 19% crude fiber.

The spring grazing season began in mid-March and used 2 winter wheat pastures established the previous fall. Each pasture had calves from 1 control and 1 limit-grazed group. Stocking rate during the spring grazing season was 0.23 ± 0.029 ha/steer and the grazing period was 50 d (range 48 to 54 d) in length. Steers were weighed on arrival and at the beginning and end of the winter and spring grazing periods. All BW were unshrunk.

Rather than use the 9 breed types described by Riley et al. (2007), we classified the calves into the following 5 breed classes: purebred Angus calves (Angus), purebred Brahman calves (Brahman), purebred Romosinuano calves (Romo), calves with 50% Angus breeding (Angus crossbred), and calves that were crosses of 2 tropical breeds (Tropical crossbred). The number of calves within each breed class and year is shown in Table 1. Observations of BW, BW gain, and ADG during the winter grazing periods were analyzed as a split-plot design using the GLM procedure (SAS Institute Inc., Cary, NC) and the test

### MATERIALS AND METHODS

The steers used in this experiment were part of a long-term beef cattle genetic evaluation study conducted at the USDA-ARS Subtropical Agricultural Research Station (25°55' N latitude, 82°39' W longitude) near Brooksville, Florida. A detailed description of the 3 breeds of beef cattle (Angus, Brahman, and Romosinuano), breeding design, and management of the cow herd and calves before weaning are given by Riley et al. (2007). Steers were purebred Angus, Brahman, and Romosinuano, or reciprocal crosses.

All procedures used in the experiment conducted at the USDA-ARS Grazinglands Research Laboratory were approved by the Animal Care and Use Committee. After weaning, steer calves (n = 479) were transported from Brooksville, Florida, to the USDA-ARS Grazinglands Research Laboratory (35°32' N latitude, 98°02' W longitude) near El Reno, Oklahoma. The study was conducted for 3 consecutive years (2002 through 2005), using 3 calf crops and a total of 12 pastures (4 pastures/yr x 3 yr). On arrival (average date October 18), steers were placed in pens or in small paddocks of dormant warm-season grasses and fed a mixed diet for 31 d (range 29 to 35 d) to recover from the stress of transit and to adapt to the new environment. At the end of the posttransit period, steers (mean BW 251 ± 8.6 kg) were blocked by breed and randomly assigned to 1 of 4 wheat (Triticum aestivum, var. Pioneer 2174) pastures. Pastures (mean size = 26 ha) were chemically fallowed each summer, planted (100 kg of seed/ha) with a no-till drill (row spacing 23 cm; average planting date September 15) and a total of 90 kg of N/ha was applied in 2 applications, 1 in the fall at planting and 1 in the spring on approximately February 15.

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### Table 1. Number of calves in each breed class within year

<table>
<thead>
<tr>
<th>Breed class</th>
<th>ANG</th>
<th>BRA</th>
<th>ROM</th>
<th>ANGX</th>
<th>TROPX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>12</td>
<td>16</td>
<td>25</td>
<td>60</td>
<td>29</td>
</tr>
<tr>
<td>Year 2</td>
<td>14</td>
<td>19</td>
<td>21</td>
<td>63</td>
<td>36</td>
</tr>
<tr>
<td>Year 3</td>
<td>13</td>
<td>14</td>
<td>28</td>
<td>81</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>49</td>
<td>74</td>
<td>204</td>
<td>113</td>
</tr>
</tbody>
</table>

1. Breed classes: ANG = AA; BRA = BB; ROM = RR; ANGX = AB, BA, AR, and RA; and TROPX = BR and RB, where the first letter is the sire and the second letter is the dam breed (A = Angus; B = Brahman; R = Romosinuano).
2. Year: 1 = 2002 to 2003 grazing season; 2 = 2003 to 2004 grazing season; 3 = 2004 to 2005 grazing season. Steers within a breed class were randomly assigned to 1 of 4 pastures each year.
option to create 2 error terms. Year
(df = 2), treatment (df = 1), and the
year × treatment interaction (df = 2)
were tested with error a (df = 6;
pasture within year and treatment).
Breed class, breed class × year, breed
class × treatment, and breed class ×
year × treatment were tested by error
b (df = 24; breed class within treat­
ment and year). Means are reported as
least squares means, and means
were separated using the TUKEY op­
tion within the GLM procedure.

A different GLM model was used to
analyze animal performance during
the spring grazing period and overall
(winter + spring) animal perfor­
ance. Two wheat pastures were
grazed each spring by 1 control and 1
limit-grazed group and were used as
replications within year. Replication
and year were tested by error a (df = 2). Treatment, breed class, and 2-fac­
tor interactions were tested by error
b (df = 27). Means are reported as
least squares means, and means
were separated using the TUKEY option
within the GLM procedure.

Forage mass was determined at the
beginning of the winter grazing period
(average date November 19) by clip­
ing a 0.5-m² area (3/pasture) to a
residual height of 2.5 cm. Clipped for­
age was placed in a preweighed paper
bag. The preweighed bag and fresh
biomass were weighed and dried in a
forced-air oven for 72 h at 60°C before
being reweighed to determine DM
concentration and grams of forage
DM per 0.5 m². The amount of forage
mass (kg of DM/ha) and stocking rate
were statistically analyzed as a
completely randomized block design.
Pasture was used as the experimental
unit. Year, treatment, and the year
× treatment interaction were tested by
the residual term (6 df). Means
are reported as least squares means,
and means were separated using the
TUKEY option within the GLM pro­
cedure.

Estimates of daily DMI during the
winter grazing season were calculated
using a combination of the average
BW for the winter season and ADG
for each pasture, NE requirements
for maintenance and growth (NRC,
1984), and NE density of wheat for­
age, hay, and supplement. Average
BW [(initial BW + final BW) ÷ 2]
for the winter grazing season was
used to calculate the amount of NE
(Mcal NE/d) needed for maintenance
(NEm, 0.77 Mcal/kg BW0.75, NRC,
1984). Average daily gain was used
to calculate the NE (Mcal/d) require­
ment for BW gain (NEg, 0.557 ×
BW0.75 × BW gain1.07, NRC, 1984).
The energy density of wheat forage
was assumed to be 1.70 Mcal
NEm/kg and 1.07 Mcal NEg/kg and was
based on digestibility values observed
in experiments at this laboratory
(Ford, 1984; Vogel, 1988). Net energy
to the hay fed to the limit-grazed group
were calculated to be 1.22 Mcal
NEg and 0.66 Mcal
NEg from samples submitted to the
Soil, Water, and Forage Analytical
Laboratory. Net energy values (Mcal/
kg) for supplement fed were 1.89 Mcal
of NEm and 1.25 Mcal NEg based on
reported values (http://cnrit.tamu.
edu/ganlab/GANlab_webpage.htm).
In the limit-grazed group, equal por­
tions of the NEm and NEg needed
were assumed to come from the wheat
forage consumed and the combination
of supplement plus hay.

Nitrogen concentration in the
wheat forage was set at 4.06% of the
DM and was based on observations
from experiments at this laboratory
reported by Mader et al. (1983), Ford
(1984), Vogel (1988), and Gallavan
et al. (1989). Hay and supplement N
concentrations were 1.54 and 1.60% of
DM. Apparent wheat forage N digest­
bility values were assumed to be 85%
for wheat forage and 80% for supple­
ment plus hay (Vogel, 1988). Esti­
mates of DMI and N metabolism were
statistically analyzed using the GLM
procedure as a completely random­
ized block design (SAS Institute Inc.).
Pasture was used as the experimental
unit. Year, treatment, and the year
× treatment interaction were tested by
the residual (6 df). Means are reported
as least squares means, and means
were separated using the TUKEY op­
tion within the GLM procedure.

Calculations of the economic impact
of limit-grazing winter wheat pasture
on the profitability of the stocker
component in a combined livestock­
grain production system use 2 types
of lease agreements (stocker lease
agreements; http://osufacts.okstate.
edu). Under these lease agreements, 2
pricing methods were selected to cal­
culate gross receipts ($/ha) for each
pasture for the winter grazing period.
A range of prices were used to bracket
the average price received by Oklaho­
ma wheat pasture stocker operations
(Hossain et al., 2004). Method I used
rates ranging from $4.40/100 kg BW
monthly ($2.00/100 lb BW monthly)
through $7.16/100 kg BW monthly
($3.25/100 lb BW monthly). Method
II used rates ranging from $0.44/kg
BW gained ($0.20/lb BW gained)
through $0.99/kg BW gained ($0.45/
lb BW gained). No deductions were
made for any other expenses, with
the exception of supplemental feeds
(hay and pelleted supplement) fed
to the limit-grazed groups (adjusted
gross receipts). The costs for pellet­
ized supplement and hay were $0.155/
kg DM ($0.07/lb DM) and $0.082/kg
DM ($0.037/lb DM). Observed ADG,
number of grazing days, stocking rate
(steers/ha), and BW for each pasture
were used to calculate gross receipts
and adjusted gross receipts as dollars
per hectare. Linear regression (SAS
Institute Inc.) was used to determine
the relationship between gross receipts
and rental rate within leasing method
and grazing management treatment.

RESULTS AND DISCUSSION

The amount of forage mass (kg of
DM/ha) was greater (P < 0.05) dur­ing
yr 1 and 3 of the experiment as
compared with yr 2 (Table 2). Stock­
ing rate was adjusted annually so that
forage allowance (kg of DM/steer) at
the beginning of the winter grazing
period was not different (P > 0.10)
among years. Forage mass was similar
(P > 0.10) between treatment groups,
and stocking rate was adjusted so
that the control group had a forage
allowance of 1,889 kg/steer and the
limit-grazed group had a forage allow­
ance of 1,141 kg/steer. Although the
limit-grazed group had a lesser (P <
Table 2. Forage biomass (kg DM/ha) and forage allowance by year and grazing management treatment

<table>
<thead>
<tr>
<th>Item</th>
<th>Year</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Forage biomass</td>
<td>2,950a</td>
<td>1,880b</td>
</tr>
<tr>
<td>Forage allowance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kg DM/steer</td>
<td>1,729</td>
<td>1,368</td>
</tr>
<tr>
<td>kg DM/100 kg BW</td>
<td>694</td>
<td>519</td>
</tr>
</tbody>
</table>

a,bMeans in the same row and year or treatment with different superscripts differ, P < 0.05.

Year: 1 = 2002 to 2003 grazing season; 2 = 2003 to 2004 grazing season; 3 = 2004 to 2005 grazing season.

Management treatment: CON = control, ad libitum access to wheat pasture; LGW = limit-grazed, steers limited to a total of 3.5 d/wk on wheat pasture.

0.05) forage allowance, no more than 50% of the total DMI was anticipated to come from wheat forage.

The forage biomass reported in this experiment was similar to reports by Pinchak et al. (1996) and Horn et al. (1995) for winter wheat pastures in the southern Great Plains. Forage biomass can vary from year to year depending on planting date, available moisture, and daily temperatures (Zhang et al., 2008a,b). By using forage allowance (kg of forage DM/steer), which integrates forage biomass and stocking rate, stocker operators can ensure that forage availability is relative constant across years (Scaglia et al., 2009a,b). During the winter grazing period, forage allowance decreases with time because the removal rate (grazing pressure) exceeds the rate of regrowth (Horn et al., 1995; Phillips and Albers, 1999). Horn et al. (1995) increased the stocking density from 1.24 to 1.79 steers/ha to decrease the forage allowance at the beginning of the winter wheat pasture grazing season from 1,190 to 740 kg/steer. As the forage allowance decreased, wheat forage DMI and ADG decreased. Based on observations reported by Horn et al. (1995), Vogel (1988), and Ford (1984), we concluded that a forage allowance of no less than 1,000 kg/steer is needed to initiate the winter grazing season and that once the forage allowance drops below 400 kg/stocker calf, total daily DMI and ADG will decrease (Zhang et al., 2008a,b). In the present experiment, forage allowance at the beginning of the winter wheat grazing period was 1,889 kg/steer in the control group and was above the 1,000-kg threshold. In the limit-grazed group, the forage allowance was 1,141 kg/steer at the beginning of the winter grazing period, but wheat forage had to provide only 50% of the daily DMI requirement. Forage allowance can be reduced if supplemental feed is provided, and animal performance will not be affected if total energy intake is not reduced (Altom and Schmedt, 1984; Wagner et al., 1984; Horn et al., 1995).

This experiment was conducted in an eco-region described as a temperate environment (Bailey, 2009). Monthly mean daily maximum and minimum temperatures and the amount of rainfall during each of the 3 experimental periods are shown in Table 3. The maximum and minimum

Table 3. Weather data for the 2002 to 2003, 2003 to 2004, and 2004 to 2005 grazing seasons, and historical data obtained at the Grazinglands Research Laboratory

<table>
<thead>
<tr>
<th>Item</th>
<th>Month</th>
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</thead>
<tbody>
<tr>
<td>Season 2002 to 2005</td>
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<tr>
<td>Temperature, °C</td>
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<tr>
<td>Maximum</td>
<td>14.9</td>
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<tr>
<td>Minimum</td>
<td>0.8</td>
</tr>
<tr>
<td>Rainfall, mm</td>
<td>86.4</td>
</tr>
<tr>
<td>Season 2002 to 2005</td>
<td></td>
</tr>
<tr>
<td>Temperature, °C</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>14.6</td>
</tr>
<tr>
<td>Minimum</td>
<td>2.5</td>
</tr>
<tr>
<td>Rainfall, mm</td>
<td>26.4</td>
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<tr>
<td>Season 2002 to 2005</td>
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</tr>
<tr>
<td>Temperature, °C</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>14.2</td>
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<tr>
<td>Minimum</td>
<td>4.2</td>
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<tr>
<td>Rainfall, mm</td>
<td>128.8</td>
</tr>
<tr>
<td>Historical data</td>
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<tr>
<td>Temperature, °C</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>16.0</td>
</tr>
<tr>
<td>Minimum</td>
<td>2.0</td>
</tr>
<tr>
<td>Rainfall, mm</td>
<td>44.0</td>
</tr>
</tbody>
</table>

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Forage biomass and forage allowance by year and grazing management treatment.
daily temperatures observed in this experiment were similar to the long-term averages. Cumulative precipitation during the winter grazing period was 14.8, 16.7, and 16.4 cm during yr 1, 2, and 3, respectively, and was similar to the long-term average of 17.4 cm (November through early March).

The spring grazing period had fewer days than the winter grazing period (50 vs. 120 d). Forage management goals differ between winter and spring grazing seasons. In the winter, plant growth rate is minimal and stocking rate is based on allocating accumulated biomass over a 100- to 120-d period. In the spring, plant growth rate is rapid and stocking rate is based on potential plant growth, which is driven by the amount of available moisture, amount of available N, and increased daily temperatures (Phillips et al., 1996; Phillips and Albers, 1999; Zhang et al., 2008a,b). Cumulative precipitation during the spring grazing period (March to May) was 6.0, 5.3, and 2.2 cm during yr 1, 2, and 3, respectively. These amounts were less than the long-term average of 14.9 cm.

The Brahman, 50% Angus, and Tropical crossbred steers had greater (P < 0.01; Table 4) BW at the beginning of the winter grazing period than did the Angus or Romosinuano steers. Within the purebred classes, Angus steers gained BW more rapidly (P < 0.01) than did the Brahman steers, whereas the Romosinuano steers were intermediate. Steers with 50% Angus breeding had less (P < 0.01) winter ADG than did Angus steers, but had greater (P < 0.01) winter ADG than did steers in the Brahman, Romosinuano, or Tropical crossbred breed classes. As anticipated, ADG was greater during the spring grazing period than during the winter grazing period (Table 4). Angus, 50% Angus, and Tropical crossbred steers had similar rates of BW gain, and they gained BW more rapidly (P < 0.05) than did Romosinuano and Brahman steers.

The steers used in yr 1 had greater (P < 0.01) rates of BW gain during both grazing periods than did the steers used in yr 2 and 3 (Table 5). Steers assigned to the control groups gained BW more rapidly than did steers in the limit-grazed groups during the winter grazing period (Table 5). During the spring grazing period, steers in the limit-grazed group compensated for the lesser winter BW gain. As a result, overall ADG was not different (P = 0.33) between steers assigned to the control and limit-grazed groups. Breed class interacted with treatment during the winter grazing season (P < 0.05). In comparison with the control groups, limit-grazing Brahman steers increased winter ADG (P < 0.05) by 12%. Winter ADG was not different (P > 0.10) between the control and limit-grazed groups within the other breed classes (P > 0.10).

An interaction between breed class and year was observed for winter (P = 0.04) and spring (P = 0.06) ADG. When ADG within a pasture for the Angus steers was set at 100, these interactions were no longer significant (P > 0.10). Indexed winter ADG for 50% Angus, Romosinuano, Brahman, and Tropical crossbred steers were, respectively, 90, 75, 64, and 74% of that observed for Angus steers. During the spring grazing season, 50% Angus, Romosinuano, Brahman, and Tropical crossbred steers had ADG that were, respectively, 104, 92, 81, and 99% of that observed for Angus.

The overall performance of stocker calves used in this experiment was within the range of previous reports based on experiments conducted at this laboratory (Mader et al., 1983; Vogel et al., 1987; Phillips et al., 2001). As anticipated, ADG during the spring was greater than during the winter (Phillips et al., 2001). Tropicaly adapted breeds of beef cattle gain BW at a slower rate on wheat pasture during the winter than do temperate breeds, but during the spring, when temperatures are warmer, steers from tropically adapted breeds can gain BW more rapidly (Phillips et al., 2005, 2006). An ADG

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### Table 4. Body weight and ADG of steers in each breed class during the winter and spring wheat pasture grazing periods (least squares means and SE)

<table>
<thead>
<tr>
<th>Item</th>
<th>Breed class</th>
<th>Winter phase</th>
<th>Spring phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ANG</td>
<td>BRA</td>
<td>ROM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>234</td>
<td>251</td>
<td>226</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>0.86</td>
<td>0.54</td>
<td>0.64</td>
</tr>
<tr>
<td>Final BW, kg</td>
<td>399</td>
<td>364</td>
<td>359</td>
</tr>
<tr>
<td>Total BW gain, kg</td>
<td>165</td>
<td>113</td>
<td>133</td>
</tr>
<tr>
<td>Overall ADG, kg</td>
<td>0.96</td>
<td>0.67</td>
<td>0.78</td>
</tr>
</tbody>
</table>

*Means in the same row with different superscripts differ, P < 0.01.

'Breed classes: ANG = AA; BRA = BB; ROM = RR; ANGX = AB, BA, AR, and RA; and TROPX = BR and RB, where the first letter is the sire and the second letter is the dam breed (A = Angus; B = Brahman; R = Romosinuano).
of 0.65 kg has been reported for Brahman × Angus steers in experiments in which purebred Angus steers gained 0.86 kg while grazing winter wheat pastures in Oklahoma (Phillips et al., 2005). Calves sired by bulls of other tropical breeds have also had less winter ADG on wheat pasture compared with calves from British breeds (Phillips et al., 2005). Direct comparison of purebred Angus and Romosinuano steers grazing winter and spring wheat forage showed that Angus steers gained BW faster than did Romosinuano steers (0.82 vs. 0.61 kg) during the winter but that ADG was similar (0.50 kg) during the spring (Phillips et al., 2006). However, locating the cow herd in a more temperate environment may mitigate the negative effect of using tropically adapted breeds to generate stocker calves for grazing winter wheat pastures in the southern Great Plains (Thrift et al., 1999). When using calves generated at the USDA-ARS Laboratory in Boonville, AR, we observed that Hereford-sired calves from purebred Brahman dams during the winter wheat grazing season (Phillips et al., 2001).

Calculated DMI was 5.90 ± 0.15 kg/d (2.03 ± 0.03% of BW) and was not different (P > 0.10) between treatment groups. After subtracting the amount of supplement and hay DM consumed by steers in the limit-grazed groups, the amount of wheat forage DM consumed was estimated to be 2.03 ± 0.15 kg/d, which was 35% of the estimated amount consumed by steers in the control group (5.84 ± 0.15 kg/d). Because steers in the limit-grazed group replaced wheat forage with hay, dietary energy density was less, and as a result, ADG was decreased.

Using the estimated DMI data, we can calculate daily N intake (g/d) for each treatment group. Steers in the control group consumed more wheat forage (5.84 vs. 2.03 kg/d) and therefore had a greater (237 vs. 144 g/d) calculated N intake. Steers in the control group also had a greater ADG (0.72 vs. 0.66 kg) and therefore retained more N (19 vs. 17 g/d) than steers in the limit-grazed group. However, the amounts of N excreted in the feces and urine by steers in the control group were 36 and 182 g/d, as compared with 29 and 98 g/d for the steers in the limit-grazed group. We concluded that reducing access to winter wheat pasture could decrease the amount of wheat forage consumed, reduce the N intake, and lessen the amount of N excreted in the urine.

Daily DMI of stocker calves grazing winter wheat pasture have been estimated to be 2.67% of BW when using labeled wheat forage (Vogel et al., 1989). In a similar experiment at this laboratory, Ford (1984) reported DMI of 1.87 and 3.09% of BW. Scaglia et al. (2009a,b) used the difference in biomass before and after grazing to estimate forage intake for steers grazing ryegrass pastures. They reported DMI of 2.1% BW and an ADG of 1.2 kg. When using the average BW and ADG reported by Mader et al. (1983), Horn et al. (1995), and Phillips et al. (2006) for stocker calves grazing winter wheat pasture and the same technique used in this paper, we calculated an average DMI of 2.4% BW for steers grazing winter wheat pasture. Estimates of DMI in the present experiment were lower than those in previous reports, but so was the ADG. The smaller DMI may be a partial explanation for the smaller winter ADG by tropically adapted beef breeds (Phillips et al., 2006).

Feeding supplements to stocker calves on winter wheat pasture has been shown to increase (positive associative effects), decrease (negative associative effects), or have no effect (substitution effect) on total DMI (Ford, 1984; Vogel et al., 1989; Horn et al., 2005). Scaglia et al. (2009a) concluded that feeding supplements in the morning affected grazing behavior, total DMI, and animal performance. Feeding supplements every day increases the labor cost and may increase the cost per kilogram of BW.
Nitrogen is a highly dynamic and mobile element, and significant losses of N within grazed pastures can occur because of nitrate leaching and gaseous emissions of NH₃ and N₂O (Zaman et al., 2009). The N concentration of a urine patch is equivalent to applying 700 to 1,000 kg N/ha (Zaman et al., 2009). Ammonia itself is not a greenhouse gas, but it is a secondary source of N for conversion to N₂O. The majority of N in urine excreted by beef cattle is found as urea, but urea is quickly hydrolyzed to NH₃ and emitted as a gas (Cole et al., 2005, 2006; Uchida et al., 2008). Yan et al. (2007) correlated N intake and the quantity of N excreted in the urine and feces of beef cattle. Fecal excretion of N ranged from 22 to 53% of the N consumed, and urinary N excretion ranged from 22 to 77% of the N consumed. The most effective strategy to reduce N excretion by beef cattle is to manipulate the dietary N concentration (Cole et al., 2005, 2006; Yan et al., 2007).

Estimated gross receipts ($)/ha calculated by 2 methods for pastures grazed by the control groups are shown in Table 6. In a survey of winter wheat pasture stocker enterprises, Hossain et al. (2004) reported a mean lease rate of $6.03/100 kg BW monthly ($2.74/100 lb BW monthly) and $0.70/kg BW gained ($0.32/lb BW gained). Applying these average rental rates to our observations, gross receipts for pastures grazed by the control groups were $72.71/ha (method I) and $75.85/ha (method II).

Estimated gross receipts for pastures that were limit-grazed were approximately twice those estimated for the control pastures, reflecting the impact of doubling the stocking rate (Table 7). Using the average rental rates reported by Hossain et al. (2004), we calculated gross receipts of $141.63/ha (method I) and $136.31/ha (method II) for limit-grazed pastures. Our management strategy of 28 h on wheat pasture and 28 h off was implemented to mitigate the negative effects of daily supplementation on grazing behavior and labor costs. However, calves consumed more hay than anticipated while in the dry lot, which reduced the wheat forage intake below the target of 50% DMI and resulted in reduced ADG.

Reducing the wheat forage intake did decrease the calculated N intake and urinary N excretion. Lowering the urinary N concentration can decreased N emissions from urine spots in pastures and from manure in feedlots (Cole et al., 2005, 2006; van Groenigen et al., 2005). However, soil characteristics that promote anaerobic activity, such as compaction, addition of dung, and wet conditions, could increase the percentage of urinary N emitted as N₂O (Uchida et al., 2008; Zaman et al., 2009).

### Table 6. Gross receipts ($/ha; mean ± SD) for the winter grazing period for pastures (n = 6) assigned to the control groups using 2 leasing methods and varying rental rates

<table>
<thead>
<tr>
<th>Rate ($/ha)</th>
<th>Method I</th>
<th>Method II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4.40</td>
<td>$53.07 ± 12.31</td>
<td>$53.07 ± 12.31</td>
</tr>
<tr>
<td>$4.95</td>
<td>$59.70 ± 13.85</td>
<td>$59.70 ± 13.85</td>
</tr>
<tr>
<td>$5.50</td>
<td>$66.34 ± 15.39</td>
<td>$66.34 ± 15.39</td>
</tr>
<tr>
<td>$6.05</td>
<td>$72.97 ± 16.92</td>
<td>$72.97 ± 16.92</td>
</tr>
<tr>
<td>$6.60</td>
<td>$79.61 ± 18.46</td>
<td>$79.61 ± 18.46</td>
</tr>
<tr>
<td>$7.15</td>
<td>$86.24 ± 20.00</td>
<td>$86.24 ± 20.00</td>
</tr>
</tbody>
</table>

1Method I rental rate = $/100 kg BW monthly; Y = $21 E⁻¹⁴ + $12.065 × rate; P < 0.001; R² = 0.36.

2Method II rental rate = $/kg BW gained; Y = $21 E⁻¹⁴ + $12.063 × rate; P < 0.001; R² = 0.36.

### Table 7. Gross receipts ($/ha; mean ± SD) and adjusted gross receipts ($/ha; mean ± SD, adjusted for the cost of supplemental feeds) for the winter grazing period for pastures (n = 6) assigned to the limit-grazed groups using 2 leasing methods and varying rental rates

<table>
<thead>
<tr>
<th>Rate ($/ha)</th>
<th>Gross receipts ($/ha)</th>
<th>Adjusted gross receipts ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4.40</td>
<td>$103.38 ± 5.63</td>
<td>$30.98 ± 10.45</td>
</tr>
<tr>
<td>$4.95</td>
<td>$116.30 ± 6.33</td>
<td>$18.06 ± 10.81</td>
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<tr>
<td>$5.50</td>
<td>$129.22 ± 7.04</td>
<td>$5.13 ± 11.19</td>
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<tr>
<td>$6.05</td>
<td>$142.14 ± 7.75</td>
<td>$7.79 ± 11.61</td>
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<tr>
<td>$6.60</td>
<td>$155.07 ± 8.45</td>
<td>$20.71 ± 12.05</td>
</tr>
<tr>
<td>$7.15</td>
<td>$167.99 ± 9.16</td>
<td>$33.63 ± 12.52</td>
</tr>
</tbody>
</table>

1Method I rental rate = $/100 kg BW monthly; Y = $24 E⁻¹² + $23.50 × rate; P < 0.001; R² = 0.91. Adjusted gross receipts = gross receipts - $134.36.

2Method II rental rate = $/kg BW gained; Y = $34 E⁻¹² + $193.62 × rate; P < 0.001; R² = 0.65. Adjusted gross receipts = gross receipts - $134.36.
pastures. However, when these gross receipts were adjusted for the cost of supplemental feeds, the adjusted gross receipts were $7.22/ha (method I) and $1.95/ha (method II). To double the stocking rate in pastures assigned to the limit-grazed treatment, 531 ± 77.8 kg of hay DM and 585 ± 60.2 kg of supplement DM were needed per hectare, at a cost of $134.36. If limit-grazed management is to be used to decrease the amount of urinary N excreted by grazing stocker calves, a less expensive source of supplemental feedstuffs must be developed.

**IMPLICATIONS**

A management strategy of cycling stocker calves on and off wheat pasture at 28-h intervals was effective in reducing wheat forage intake. However, ADG was reduced because calves consumed more hay in the dry lot than anticipated, which decreased wheat forage and dietary energy intakes. Limit-grazing of wheat pastures increases carrying capacity, allows the producers to purchase more animals in the fall, when calf prices are low, for use in the spring, reduces the concentration of N in the urine, and has the potential to reduce the amount of N that winter wheat pasture grazing systems emit to the atmosphere. However, the cost of BW gain was greater for the limit-grazed group than the control group, and gross receipts were reduced. A less expensive source of supplemental feedstuffs must be developed if limit-grazing management is to be used.

**LITERATURE CITED**


Phillips, W. A., E. E. Grings, and J. W. Holk­


Vogel, G. J. 1984. Kinetics of ruminal nitrogen digestion of wheat forage and high protein feedstuffs and the effects of supplemental


