2007

Effects of stocking rate and corn gluten feed supplementation on performance of young beef cows grazing winter-stockpiled tall fescue-red clover pasture

R. Driskell
Iowa State University

J.R. Russell

Daryl R. Strohbehn
Iowa State University, stroh@iastate.edu

Daniel G. Morrical
Iowa State University, morrical@iastate.edu

Stephen K. Barnhart
Iowa State University, sbarnhar@iastate.edu

See next page for additional authors

Authors
R. Driskell, J.R. Russell, Daryl R. Strohbehn, Daniel G. Morrical, Stephen K. Barnhart, and John Lawrence

Published December 8, 2014

Effects of stocking rate and corn gluten feed supplementation on performance of young beef cows grazing winter-stockpiled tall fescue-red clover pasture[1]

R. Driskill,* J. R. Russell,*[2] D. R. Strohbehn,* D. G. Morrical,* S. K. Barnhart,† and J. D. Lawrence‡

*Department of Animal Science, †Department of Agronomy, and ‡Department of Economics, Iowa State University, Ames 50011

ABSTRACT: A winter grazing experiment was conducted to evaluate the effects of stocking rate and corn gluten feed supplementation on forage mass and composition and the BW and BCS of bred 2-yr-old cows grazing stockpiled forage during winter. Two 12.2-ha blocks containing Fawn, endophyte-free, tall fescue and red clover were each divided into 4 pastures of 2.53 or 3.54 ha. Hay was harvested from the pastures in June and August of 2003 and 2004, and N was applied at 50.5 kg/ha at the initiation of stockpiling in August. On October 22, 2003, and October 20, 2004, twenty-four 30-mo-old Angus-Simmental and Angus cows were allotted by BW and BCS to strip-graze for 147 d at 0.84 or 1.19 cow/ha. Eight similar cows were allotted to 2 dry lots and fed tall fescue-red clover hay ad libitum. Corn gluten feed was fed to cows in 2 pastures to maintain a mean BCS of 5 (9-point scale) at each stocking rate and in the dry lots (high supplementation level) or when weather prevented grazing (low supplementation level) in the remaining 2 pastures at each stocking rate. Mean concentrations of CP in yr 1 and 2 and IVDMD in yr 2 were greater ($P < 0.10$) in hay than stockpiled forage over the winter. At the end of grazing, cows fed hay in dry lots had greater ($P < 0.05$) BCS in yr 1 and greater ($P < 0.10$) BW in yr 2 than grazing cows. Grazing cows in the high supplementation treatment had greater ($P < 0.10$) BW than cows grazing at the low supplementation level in yr 1. Cows in the dry lots were fed 2,565 and 2,158 kg of hay DM/cow. Amounts of corn gluten feed supplemented to cows in yr 1 and 2 were 46 and 60 kg/cow and did not differ ($P = 0.33$, yr 1; $P = 0.50$, yr 2) between cows fed hay or grazing stockpiled forage in either year. Estimated production costs were greater for cows in the dry lots because of hay feeding.

Key words: beef cow, stockpiled forage, winter grazing, corn gluten feed

J. Anim. Sci. 2007. 85:1577–1586
doi:10.2527/jas.2006-466

INTRODUCTION

Feed costs represent approximately 60% of the total costs for a cow herd in the upper Midwest (Strohbehn, 2001). However, mature cows grazing stockpiled forage required less hay to maintain an optimal body condition at calving (Allen et al., 1992; Hitz and Russell, 1998, Janovick et al., 2004) and had reduced production costs than cows fed hay throughout the winter (D'Souza et al., 1990; Adams et al., 1994; Schoonmaker et al., 2003). Heifers grazing stockpiled forage required minimal supplementation of corn gluten feed to meet a target BW compared with the hay and corn gluten feed required to maintain heifers in dry lots during winters with minimal snowfall (Clark, 2003).

Nutritional requirements of NE_m and protein increase in pregnant cows in the last 90 d of gestation (NRC, 1996). Heifers and young cows have additional nutrient requirements for growth and may lose BCS during their first lactation (Patterson et al., 2003; Freetly et al., 2005). Little research has been done with young cows in a system to minimize production costs. It was hypothesized that young cows grazing stockpiled forage could maintain adequate BW and body condition to ensure subsequent reproduction with minimal energy supplementation even in winters with greater snowfall than previously evaluated if provided an adequate forage allowance.

The objective of this study was to determine the effects of stocking rate and corn gluten feed supplementation on quantity and composition of pasture forages and the BW and BCS of bred 2-yr-old cows grazing stockpiled, tall fescue-red clover pastures.

[1]This project was funded, in part, by the Iowa Agric. and Home Econ. Exp. Sta., Ames, and a grant from the Leopold Center for Sustainable Agriculture, Iowa State Univ., Ames.
[2]Corresponding author: jrussell@iastate.edu
Received July 14, 2006.
Accepted February 1, 2007.

MATERIALS AND METHODS

All protocols for animal use were reviewed and approved by the Institutional Animal Care and Use Committee at Iowa State University.

Treatment Overview

In a winter feeding experiment, 2 forage systems (hay feeding or grazing stockpiled forage) were compared. Within the grazing treatments, 2 stocking rates and 2 levels of corn gluten feed supplementation were compared.

Pastures

Two 12.2-ha pastures of Fawn, endophyte-free, tall fescue (*Festuca arundinacea* L.) and red clover (*Trifolium pratense* L.) were established in 2000 at the Iowa State University Beef Nutrition Farm near Ames, IA. Pastures were frost-seeded with red clover in March yearly at a rate of 4.5 kg/ha. Hay was harvested from the pastures on May 28 and August 8, 2003 (yr 1) and on June 6 and August 7, 2004 (yr 2). Hay was packaged as large round bales and stored indoors. After the hay was removed in August, urea was applied at a rate to supply 50.5 kg of N/ha to initiate stockpiling on August 15 and 19 in yr 1 and 2, respectively. Each pasture was divided into two 2.53- and 3.54-ha pastures for high- and low-stocking rates, respectively, that were further subdivided into 8 paddocks for strip-grazing. Grazing was initiated on 22 and 20 October in yr 1 and 2, respectively, and continued for 147 d.

The length of the grazing period of each paddock was calculated from the estimated forage available for grazing, assuming 50 and 70% removal of the initial forage mass for the low- and high-stocking rates and forage DMI of 2.5% BW. Initial forage mass was determined by hand-clipping forage from two 0.25-m^2 locations per paddock. Samples were composited by pasture, weighed, and dried at 65°C for 48 h to calculate forage DM mass. Cattle were allowed to graze a new paddock every 19 d each year. Grazing of the last paddock was terminated at 14 d so cows could be relocated before calving.

Cows

In yr 1, 32 Angus-Simmental crossbred (initial BW = 542 ± 49 kg; initial BCS = 4.92 ± 0.44; initial age = 31 ± 0.3 mo) and in yr 2, 32 Angus (initial BW = 518 ± 43 kg; initial BCS = 5.0 ± 0.23; initial age = 29 ± 0.3 mo) spring-calving cows in their second gestation were blocked by BW and BCS. Three cows were allotted to each of the 8 pastures to graze at a low- (0.84 cow/ha) or high- (1.19 cow/ha) stocking rate, and 4 cows were allotted to each of 2 dry lots. Before allotment and at the conclusion of the experiment, cow BW were measured after the cows consumed hay at ad libitum levels for 3 d in a drylot to equalize ruminal fill. During the experiment, the cows were weighed every 14 d without a shrink and were visually scored for body condition on a 9-point scale (1 = thin, 9 = obese; Neuman and Lusby, 1986) weekly by the same 2 experienced individuals. Cows were bred to begin calving on April 1. At calving, calf birth weights were recorded as were calving ease scores on a scale of 1 to 4, with 1 = no assistance, 2 = assistance without mechanical help, 3 = use of a mechanical aid, and 4 = use of a mechanical aid and with resultant calf loss.

Feeds

Tall fescue-red clover hay harvested from the pastures was fed as large round bales in hay feeders to cows in the 2 dry lots for ad libitum consumption, except when their average BCS increased to > 5. If average BCS were > 5, no corn gluten feed was fed and hay feeding was restricted. Corn gluten feed was group-fed to cows in 2 pastures at each stocking rate and each drylot to maintain a mean BCS of 5 (high supplementation level) as predicted by the Cornell Net Carbohydrate and Protein System (CNCPS V. 5.0, Cornell University, Ithaca, NY). To prevent excessive loss of BCS, cows in the remaining pastures would have been fed corn gluten feed if BCS dropped to an average BCS of 4.3 (low supplementation level); however, this BCS limit was never reached in either year. However, all cows grazing and supplemented at the low and high levels were fed at least minimal amounts of corn gluten feed when excessive snow prevented grazing.

Water and a mineral and vitamin mixes (15% Ca; 8% P; 14.5% NaCl; 1% Mg; 1% K; 1,100 ppm Cu; 1,300 ppm Mn; 28 ppm Se; 1,700 ppm Zn; 884,000 IU of vitamin A/kg; 221,000 IU of vitamin D_3/kg; and 442 IU of vitamin E/kg; Kent Feeds Inc., Muscatine, IA) were provided for ad libitum intake by all cows.

Forage Sampling

Before grazing or a killing frost, the pastures were sampled by hand-clipping to a height of 2.5 cm at sixteen 0.25-m^2 locations per pasture. The samples were hand-separated for botanical composition into grass, legume, broadleaf weed, and dead material, weighed, and dried to determine the proportions of DM. Forage samples from the pastures were taken at the initiation of grazing and every 28 d thereafter by hand-clipping at two 0.25-m^2 locations per paddock, with samples composited within grazed or ungrazed paddocks in each pasture. Because of large amounts of snow cover in February (yr 1) and January (yr 2), forage samples were not taken during these months. One 0.5-m^2 grazing exclosure was placed in each paddock before grazing to determine weathering loss at the termination of grazing. At the termination of grazing, the ungrazed pasture samples were hand-clipped from a 0.25-m^2 area within each grazing exclosure. Each hay bale fed to cows in the dry lots was weighed and core-sampled to a depth of 73 cm before feeding.

In November and March, forage selected during grazing or hay consumption was sampled by ruminal evacuation of one ruminally fistulated steer per pasture or drylot within a block after a minimum of 5 d of adaptation to the treatment. On 2 consecutive days, ruminal contents were removed by hand and with a vacuum, the rumens were rinsed with water, and the steers were allowed to graze or consume hay for 2 h. After grazing, ruminal masticate was removed, subsampled, and frozen. Ruminal contents were placed back into respective steers. These procedures were subsequently repeated within the second block of pastures or dry lots.

Selection indices were calculated as the ratio of the concentration of each chemical component in the forage selected by the fistulated steers to the concentration of each chemical component in the available forage that was hand-clipped from the pastures at the same time as the ruminal evacuations or in the hay core-sampled before feeding.

Chemical Analyses

All forage samples were frozen until drying could be initiated. Forage samples were dried in a forced-air oven (Blue M Electric Co., Blue Island, IL) at 65°C for 48 h, and ruminal masticate samples were freeze-dried (Virtis SupraChamber 24, Virtis Co. Inc., Gardiner, NY). Forage composition values of ruminal masticate samples were averaged across both sampling days and analyzed as repeated measures. Dried samples were ground to pass through a 1-mm screen in a Thomas Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA). Dried forage and freeze-dried ruminal masticate samples were analyzed for IVDMD with a 48-h incubation in ruminal fluid with NC-64 phosphate buffer and a 24-h incubation in HCl and pepsin (Marten and Barnes, 1979). Crude protein was determined by Kjeldahl N (AOAC, 1990) multiplied by 6.25. Residue remaining after ADF analysis was removed from the fiber bags, weighed, and analyzed for N content with the micro-Kjeldahl procedure to determine ADIN (Goering and Van Soest, 1970).

Economic Analysis

An economic analysis was conducted on the data to estimate the production costs associated with winter grazing. A partial budgeting model (Clark, 2003) was used to determine the costs for cows grazing at different stocking rates and supplementation levels or wintered in a drylot, using the amounts of hay and corn gluten feed fed in the project. The costs of pasture establishment (Barnhart et al., 2004), perimeter and cross fences (Mayer, 1999), and watering systems (Wells, 1995) were estimated. Allocation of annual rental and pasture establishment costs to grazing of stockpiled forages was based on the proportion of the total annual forage production harvested as hay or stockpiled for winter grazing. The number of hectares necessary for winter grazing per cow was calculated from the initial forage mass and utilization rate. Prices were assumed to be \$82.69/t for corn gluten feed, \$57.88/t of hay, \$148/ha annual pasture rent, \$10/h labor charges, \$0.20·cow^{-1}·d^{-1} drylot yardage, and \$0.04·cow^{-1}·d^{-1} veterinary expenses.

Statistical Analysis

To account for repeated measurements over time, PROC MIXED (SAS Inst. Inc., Cary, NC) was used to analyze the data with a split-split-plot design, with pasture as the experimental unit for all analyses. An AR(1) correlation structure within pastures was used to analyze the forage data, and the Kenward Rogers approximation was used to calculate the degrees of freedom for each test. Forage mass was analyzed using linear and quadratic effects of day and the day × grazing interaction and was tested for stocking rate and supplementation level. Forage composition of the hay and ungrazed stockpiled forage was analyzed using linear effects of month, forage, and the month × forage interaction.

Components of ruminal masticate samples and selection indices of steers were analyzed within season (November or March) for the treatment effects of forage system and stocking rate, supplementation level, and the stocking rate × supplementation level interaction within stockpile grazing. Body weight and BCS of cows were analyzed by week and for the treatment effects of forage system and stocking rate, supplementation level, and the stocking rate by supplementation level interaction within stockpile grazing. The total amounts of corn gluten feed fed, calf birth weights, and calving ease scores were analyzed for the treatment effects of forage system and stocking rate, supplementation level, and the stocking rate × supplementation level interaction within stockpile grazing. Data were analyzed between and within years.

RESULTS

Weather

Mean temperatures from October to March during the project were comparable in yr 1 (1.5°C) and 2 (1.8°C) of this project, being an average of 0.7 and 1.0°C above the 30-yr average for the location (NOAA, 2003, 2004, 2005). Total snowfalls during the grazing season were 115 and 67 cm in yr 1 and 2, respectively, compared with the 30-yr average of 92 cm. Year 1 and 2 had 64 and 34 d with snow cover greater than 2.54 cm.

Forage Mass

There were no main effects or interactions of stocking rate and supplementation level on grazed or ungrazed forage mass, and therefore, forage masses of grazed and

Table 1. Predicted values (SE) of forage composition for ungrazed, stockpiled, tall fescue-red clover forage[1] (n = 8) and hay (n = 2) fed to cows in dry lots

	Month						Significance[2]		
Item	October	November	December	January	February	March	F	M	F × M
Year 1									
CP, % of DM									
Stockpiled	10.0 (0.26)	10.0 (0.26)	9.2 (0.26)	8.9 (0.26)	—	10.0 (0.26)	<0.001	0.16	0.49
Hay	12.1 (0.45)	12.3 (0.45)	12.2 (0.45)	11.8 (0.45)	11.8 (0.45)	12.0 (0.45)			
IVDMD, % of DM									
Stockpiled	55.0 (0.74)	53.8 (0.65)	52.5 (0.62)	51.4 (0.65)	—	47.7 (1.02)	0.71	<0.001	0.15
Hay	56.2 (1.11)	55.6 (0.86)	55.0 (0.69)	54.4 (0.69)	53.8 (0.86)	53.2 (1.11)			
ADIN, % N									
Stockpiled	9.0 (0.55)	9.6 (0.49)	10.2 (0.45)	10.8 (0.45)	—	12.6 (0.63)	0.39	0.95	0.001
Hay	6.7 (0.95)	6.1 (0.75)	5.5 (0.62)	4.9 (0.62)	4.4 (0.75)	3.8 (0.95)			
Year 2									
CP, % DM									
Stockpiled	10.8 (0.25)	9.3 (0.25)	8.7 (0.25)	—	8.9 (0.25)	9.8 (0.25)	0.006	0.001	0.01
Hay	10.5 (0.39)	10.2 (0.39)	10.2 (0.39)	10.7 (0.39)	10.2 (0.39)	10.2 (0.39)			
IVDMD, % of DM									
Stockpiled	59.0 (0.92)	57.2 (0.79)	55.4 (0.70)	—	51.7 (0.72)	48.1 (0.97)	0.01	0.002	0.005
Hay	54.4 (1.73)	54.3 (1.40)	54.2 (1.14)	54.1 (1.14)	54.0 (1.36)	53.8 (1.73)			
ADIN, % N									
Stockpiled	6.2 (0.29)	6.8 (0.38)	7.7 (0.24)	—	8.6 (0.27)	9.9 (0.36)	0.05	0.003	0.001
Hay	6.9 (0.49)	6.8 (0.26)	6.8 (0.31)	6.7 (0.31)	6.6 (0.38)	6.6 (0.49)			

[1]Means of samples collected for pastures stocked at 2 rates and 2 supplementation levels.
[2]F = forage; and M = month effects.

ungrazed forages were pooled between stocking rates and supplementation levels in yr 1 and 2, respectively. Forage disappeared at a faster rate ($P < 0.001$) in grazed paddocks (forage mass, kg/ha = 3,601.3 − 35.30 d + 0.13 d^2) than ungrazed paddocks (forage mass, kg/ha = 3,601.3 − 21.22 d + 0.13 d^2) in yr 1. In yr 2, forage also disappeared at a faster rate ($P < 0.001$) in grazed paddocks (forage mass, kg/ha = 3,807.6 − 49.70 d) than ungrazed paddocks (forage mass, kg/ha = 3,807.6 − 34.24 d); however, the quadratic coefficient was not significant.

Forage allowance (expressed as kg of forage DM/100 kg of cow BW) was calculated from ungrazed stockpiled forage mass at high- and low-stocking rates in yr 1 and 2, respectively. Therefore, these values represent changes in forage mass as affected by weathering adjusted for the stocking rate but do not consider forage removal by grazing. As designed, forage allowance was greater ($P = 0.001$) for cows grazing at the low-stocking rate (forage allowance, kg of forage DM·100 kg BW^{-1}·d^{-1} = 4.63 − 0.012 d) than the high-stocking rate (forage allowance, kg of forage DM·100 kg BW^{-1}·d^{-1} = 3.32 − 0.012 d) in yr 1. Similarly, in yr 2, forage allowance was greater ($P < 0.001$) for cows grazing at the low-stocking rate (forage allowance, kg of forage DM·100 kg BW^{-1}·d^{-1} = 5.68 − 0.010 d) than the high-stocking rate (forage allowance, kg of forage DM·100 kg BW^{-1}·d^{-1} = 3.91 − 0.010 d). Greater forage masses and lighter cow BW in yr 2 than yr 1 resulted in greater ($P = 0.002$) forage allowance in yr 2 than yr 1. Forage allowances ranged from 2.06 kg of DM/100 kg of BW at the end of grazing at the high-stocking rate in yr 1 to 5.67 at the initiation of grazing at the low stocking rate in yr 2. These allowances may have limited cow performance because forage allowances less than 5 kg of DM/100 kg of BW (NRC, 1996) and 10 kg of DM/100 kg of BW (Marsh, 1979) may limit daily intake and decrease daily gains in growing animals.

Forage utilization percentages, based on forage masses at the initiation and the conclusion of grazing, did not differ between stocking rates or supplementation levels in or between years. Although stocking rates were designed to remove 50 and 70% of the forage DM at low- and high-stocking rates, actual forage utilization percentages for the low- and high-stocking rates were 63.2 ± 6.1 and 71.3 ± 7.9% in yr 1, and 62.1 ± 18.0 and 76.4 ± 3.5% in yr 2, respectively. Forage disappearances from excessive lodging of tall fescue (Singer et al., 2003) and weathering were 28 (yr 1) and 11% (yr 2) in ungrazed forage, possibly increasing apparent forage utilization.

Composition of Available and Selected Forages

There were no main effects or interactions of stocking rate and supplementation level on the botanical composition of the pastures in October of yr 1 or 2, respectively. Before grazing, stockpiled pastures had a greater ($P = 0.01$) proportion of dead material in the total forage DM in yr 1 (17.1%) than yr 2 (10.9%). The proportions of grass ($P = 0.04$) and legume ($P = 0.03$) in the live DM were 90.0 and 6.4% in yr 1 and 83.0 and 13.1% in yr 2, respectively. The proportions of broadleaf weeds in the live DM averaged 3.8% for the 2 yr and did not differ ($P = 0.82$) between years.

Table 2. Mean composition (SE) of forage selected by steers grazing stockpiled, tall fescue-red clover (n = 8) or consuming hay (n = 2) in dry lots

Month and item	Forage system: Hay	Forage system: Grazing	Significance
Year 1			
November			
CP, % of DM	11.9 (0.51)	10.6 (0.25)	0.04
IVDMD, % of DM	65.3 (1.35)	62.6 (0.68)	0.09
ADIN, % N	4.8 (0.59)	8.7 (0.29)	<0.001
March			
CP, % of DM	9.8 (0.48)	9.5 (0.24)	0.65
IVDMD, % of DM	54.2 (0.97)	57.0 (0.49)	0.02
ADIN, % N	5.0 (0.79)	10.6 (0.39)	<0.001
Year 2			
November			
CP, % of DM	10.7 (0.41)	10.8 (0.20)	0.86
IVDMD, % of DM	52.4 (1.66)	57.8 (0.83)	0.01
ADIN, % N	7.4 (0.59)	6.5 (0.30)	0.17
March			
CP, % of DM	8.1 (0.34)	8.7 (0.17)	0.10
IVDMD, % of DM	52.4 (1.53)	53.6 (0.77)	0.49
ADIN, % N	6.9 (1.56)	8.6 (0.28)	0.01

Mean concentrations of CP in hay over the winter feeding season were greater ($P < 0.001$) than ungrazed stockpiled forage in yr 1 (Table 1). However, mean IVDMD concentrations of hay and stockpiled forage did not differ ($P = 0.71$) in yr 1. In yr 2, CP concentrations in hay were greater ($P = 0.006$) than stockpiled forage from November through March, but the mean concentrations of IVDMD were greater ($P = 0.01$) in stockpiled forage than hay from October to December. Concentrations of CP and IVDMD decreased at faster rates in stockpiled forage than hay in yr 2 (forage × month, $P < 0.01$). Mean concentrations of ADIN did not differ between forages in yr 1 but were greater ($P = 0.05$) in stockpiled forage than hay in yr 2. When years were combined across months, concentrations of CP in hay were greater ($P < 0.0001$) than stockpiled forage, but concentrations of IVDMD were greater ($P = 0.02$) for stockpiled forage than hay.

Steers consuming hay in dry lots selected forage with greater concentrations of CP ($P = 0.04$) and IVDMD ($P = 0.09$), and lower concentrations of ADIN ($P < 0.001$) in November of yr 1 than steers grazing stockpiled forage (Table 2). However, in March, steers grazing stockpiled forage selected forage with greater ($P = 0.02$) concentrations of IVDMD than steers fed hay. Similarly, in yr 2, steers grazing stockpiled forage selected forage with greater ($P = 0.01$) concentrations of IVDMD in November and greater ($P = 0.10$) concentrations of CP in March than steers fed hay.

Differences in the composition of forage selected by grazing and hay-fed steers resulted from increased selectivity by the grazing steers. Selection indices for steers grazing stockpiled forage were greater ($P < 0.04$) for CP and IVDMD in November and March of both years than steers consuming hay (Table 3). The selection indices for CP in forage selected by steers grazing stockpiled forage were 38 and 15% greater ($P < 0.06$) than steers consuming hay in March of yr 1 and 2. Similarly, the selection indices for IVDMD in forage selected by steers grazing stockpiled forage were 36 and 14% greater ($P < 0.02$) than steers fed hay in March of yr 1 and 2, respectively. Although grazing steers consumed forage with greater ($P < 0.01$) concentrations of ADIN than steers in dry lots, smaller ($P < 0.01$) ADIN selection indices for grazing steers than steers consuming hay indicated that steers grazing stockpiled forage were more selective against ADIN than steers fed hay.

In March of yr 1, steers grazing stockpiled forage at the low-stocking rate selected forage with greater ($P < 0.08$) concentrations of CP than steers grazing at the high-stocking rate (data not shown). This increased CP concentration resulted from the greater ($P = 0.08$) selectivity index at the low-stocking rate (1.22) than the high-stocking rate (1.09). Supplementation at the high level did not affect the concentration of CP consumed by steers grazing stockpiled forage in March of yr 1; however, steers grazing at the low-stocking rate and supplemented at the low level consumed forage with greater concentrations of CP than steers grazing at the high-stocking rate and supplemented at the low supplementation level (stocking rate × supplementation level, $P = 0.09$). In November of yr 1, steers grazing at the low-stocking rate consumed forage with lower ($P = 0.009$) concentrations of ADIN than steers grazing at the high-stocking rate. In yr 2, there were no effects of stocking rate, supplementation level, or stocking rate × supplementation level interactions in selection indices or in the composition of forage selected by steers grazing stockpiled forage.

Cow Body Condition and Weight

One cow grazing stockpiled forage aborted in each year. Because the abortions seemed unrelated to grazing treatments, BW and BCS data for those 2 cows were removed from the data set. In yr 1, there were no differences in BCS between stocking rates within weeks for cows grazing stockpiled forage; therefore, data of grazing treatments were pooled by supplementation level (Figure 1). Cows fed hay in dry lots had greater ($P < 0.10$) BCS than cows grazing stockpiled forage from wk 14 through the conclusion of the experiment. This difference in BCS occurred even though corn gluten feed was not fed and hay was limit-fed to cows in dry lots for the last 5 wk of the feeding period by leaving the hay feeder empty 1 d before feeding the next bale. Grazing cows at the high supplementation level had greater ($P = 0.08$) BCS at wk 4 than cows grazing at the low supplementation level.

In yr 2, cows in dry lots had greater ($P < 0.08$) BCS at wk 2 than cows grazing stockpiled forage (Figure 2). The BCS of cows grazing stockpiled forage at the high supplementation level were greater at wk 14 ($P = 0.08$),

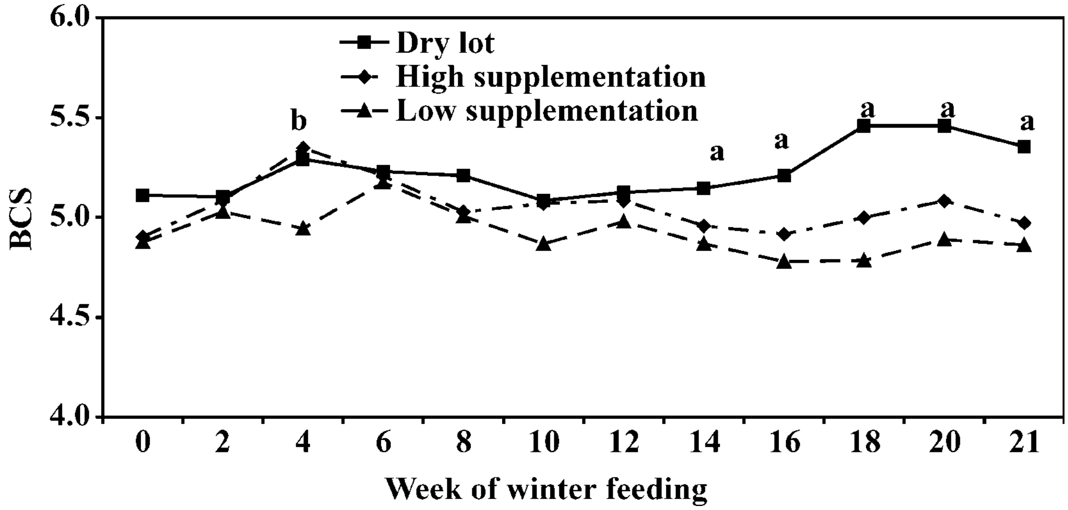

Figure 1. The BCS of cows grazing winter stockpiled, tall fescue-red clover or consuming hay in dry lots in yr 1. Treatment effects: a = a difference between drylot and grazing; and b = a difference between supplementation levels; $P < 0.10$. SEM (n = 10) for wk 0 = 0.07, 2 = 0.05, 4 = 0.08, 6 = 0.06, 8 = 0.07, 10 = 0.05, 12 = 0.07, 14 = 0.05, 16 = 0.08, 18 = 0.10, 20 = 0.07, 21 = 0.08.

16 ($P = 0.04$), and 18 ($P = 0.05$) than cows maintained at the low supplementation level. At the conclusion of the experiment, supplementation level did not affect BCS of cows grazing at the low-stocking rate, but supplementing corn gluten feed at the high level to cows grazing at the high-stocking rate improved BCS (stocking rate × supplementation level, $P = 0.07$).

Table 3. Selection indices[1] (SE) of steers grazing stockpiled, tall fescue-red clover (n = 8) or hay (n = 2) and rumen masticate samples in November and March

	Forage system		
Item	Hay	Grazing	Significance
Year 1			
November			
CP	0.99 (0.10)	1.29 (0.05)	0.01
IVDMD	1.11 (0.06)	1.27 (0.03)	0.02
ADIN	0.99 (0.07)	0.83 (0.04)	0.07
March			
CP	0.84 (0.06)	1.16 (0.03)	0.002
IVDMD	1.01 (0.05)	1.37 (0.02)	<0.001
ADIN	1.41 (0.12)	0.80 (0.06)	<0.001
Year 2			
November			
CP	1.04 (0.07)	1.22 (0.03)	0.03
IVDMD	0.97 (0.04)	1.07 (0.02)	0.04
ADIN	1.10 (0.07)	0.76 (0.03)	<0.001
March			
CP	0.85 (0.04)	0.98 (0.02)	0.004
IVDMD	0.99 (0.04)	1.13 (0.02)	0.002
ADIN	1.18 (0.06)	0.80 (0.03)	<0.001

[1]Selection indices were calculated as the ratio of the concentration of each chemical component in the forage selected by the fistulated steers to the concentration of each chemical component in the available forage that was hand-clipped from the pastures at the same time as the ruminal evacuations or in the hay core-sampled before feeding.

There was no difference in the BW of cows in the dry lots or cows grazing stockpiled forage in yr 1 (Figure 3). Body weights were greater for cows grazing at the low-stocking rate in wk 8 ($P = 0.04$), 16 ($P = 0.04$), and 18 ($P = 0.04$) than cows grazing at the high-stocking rate. Cows fed corn gluten feed at the high supplementation level had greater BW in wk 8 ($P = 0.07$), 18 ($P = 0.02$), and 20 ($P = 0.08$) and at the conclusion of grazing ($P = 0.04$) than cows fed at the low supplementation level. In yr 2, there were no effects of stocking rate or supplementation on BW of cows grazing stockpiled forage (Figure 4). There also were no differences in BW between cows in the 2 forage systems until the conclusion of the trial when cows in dry lots were heavier ($P = 0.06$) than cows grazing stockpiled forage. There were no significant stocking rate × supplementation level interactions in BW for cows grazing stockpiled forage in yr 1 or 2, respectively.

Birth weights of calves did not differ between cows in the 2 forage systems or between stocking rate or supplementation level for cows grazing stockpiled forage in yr 1 or 2, respectively. Calving ease scores for all births were 1 on a 4-point scale.

Supplemental Feeds

Cows in the dry lots were fed 2,564 and 2,157 kg of hay DM/cow through winter feeding in yr 1 and 2, respectively. All cows grazing stockpiled forage received corn gluten feed supplementation for a minimum of 6 and 11 d in yr 1 and 2, respectively, when snow cover prevented grazing. Although there was greater snowfall in yr 1, excessive snow cover and cold temperatures persisted longer in yr 2, requiring a longer period of supplementation. When weather prevented grazing in wk 14 and 15 in yr 1 and wk 12 and 13 in yr 2, all cows

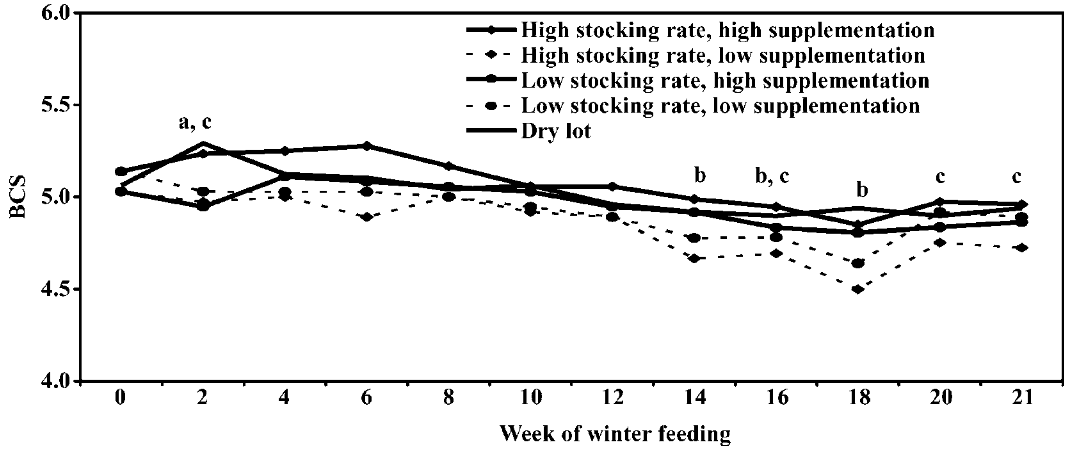

Figure 2. The BCS of cows grazing winter stockpiled, tall fescue-red clover or consuming hay in dry lots in yr 2. Treatment effects: a = a difference between drylot and grazing; b = a difference between supplementation levels; c = a stocking rate × supplementation level interaction; $P < 0.10$. SEM (n = 10) for wk 0 = 0.06, 2 = 0.05, 4 = 0.07, 6 = 0.07, 8 = 0.05, 10 = 0.04, 12 = 0.03, 14 = 0.06, 16 = 0.04, 18 = 0.06, 20 = 0.04, 21 = 0.04.

grazing stockpiled forage received a minimum 0.9 kg of corn gluten feed·cow^{-1}·d^{-1}. In yr 1, the mean ± SD amount of corn gluten feed fed was 46.3 ± 70.3 kg/cow and did not differ ($P = 0.33$) between forage systems at the high level of supplementation or between stocking rate of the stockpiled grazing treatments at both levels of supplementation. Within stockpiled grazing, there was a trend ($P = 0.14$) to feed greater amounts of corn gluten feed to cows at the high (106.1 ± 82.3 kg/cow) than low (8.2 ± 2.4 kg/cow) supplementation level. Similarly, in yr 2, greater ($P = 0.07$) amounts of corn gluten feed were fed to cows grazing stockpiled forage at the high (112.6 ± 58.5 kg/cow) supplementation level than low (9.1 ± 0 kg/cow) level, whereas cows in the dry lots received 60.7 ± 65.3 kg of corn gluten feed/cow. The lack of greater differences in the amounts of corn gluten feed fed to cows between treatments was likely caused by the large variation of corn gluten feed fed within

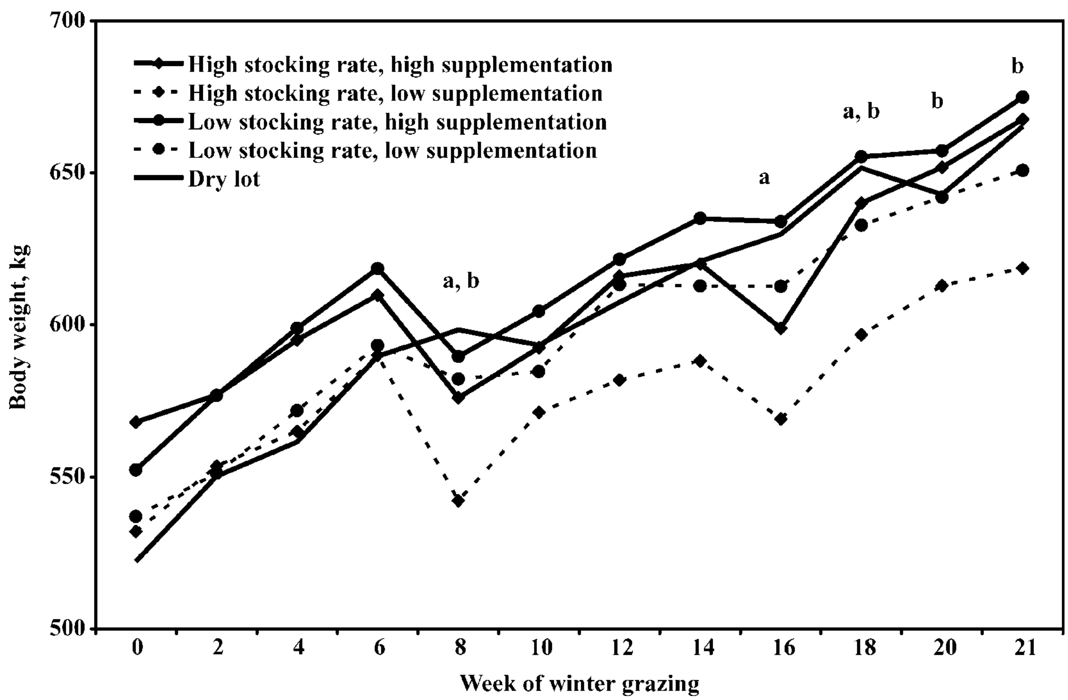

Figure 3. Body weight of cows grazing winter stockpiled, tall fescue-red clover or consuming hay in dry lots in yr 1. Treatment effects: a = a difference between stocking rates; and b = a difference between supplementation levels; $P < 0.10$. SEM (n = 10) for wk 0 = 8.2, 2 = 7.5, 4 = 7.0, 6 = 7.8, 8 = 8.3, 10 = 6.5, 12 = 8.1, 14 = 8.8, 16 = 10.9, 18 = 9.6, 20 = 8.7, 21 = 9.9.

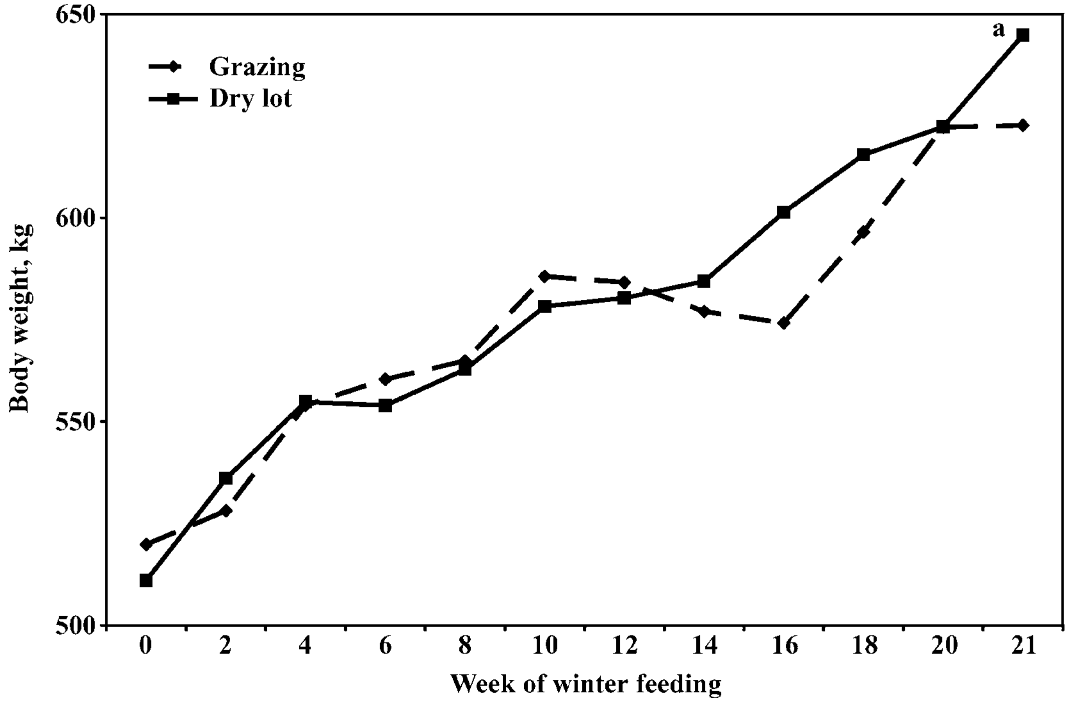

Figure 4. Body weight of cows grazing winter stockpiled, tall fescue-red clover or consuming hay in dry lots in yr 2. Treatment effects: a = a difference between drylot and grazing; $P < 0.10$. SEM (n = 10) for wk 0 = 7.1, 2 = 6.3, 4 = 5.7, 6 = 5.4, 8 = 6.0, 10 = 5.7, 12 = 6.2, 14 = 8.4, 16 = 8.5, 18 = 7.0, 20 = 7.0, 21 = 5.4.

treatments and the small number of cows and replications. By visual observation, this large variation is likely caused, in part, by 1 cow in a pasture stocked at the low stocking rate and high supplementation level that refused corn gluten feed supplementation in yr 2. Therefore, the average BCS of this group did not improve and greater amounts of corn gluten feed was fed to improve BCS, thereby resulting in oversupplementation of the remaining cows in that pasture.

Winter Production Costs

Using the partial budgeting model of Clark (2003), winter production costs for winter feeding were estimated (Table 4). Cows fed hay in dry lots had higher estimated costs of production in yr 1 and 2 (\$1.37 and \$1.32·cow^{-1}·d^{-1}, respectively) than cows grazing stockpiled forage. Estimated production costs of grazing cows were \$0.96, \$0.92, \$1.30, and \$1.35·cow^{-1}·d^{-1} in yr 1 and \$0.87, \$0.83, \$1.19, and \$1.12·cow^{-1}·d^{-1} in yr 2 for cows grazing at the high-stocking rate with high supplementation, high-stocking rate with low supplementation, low-stocking rate with high supplementation, and low-stocking rate with low supplementation, respectively. Lower production costs for cows grazing at the high-stocking rate than the low-stocking rate are likely caused by lower land costs per cow. Because the partial budgeting model was designed to adjust the number of acres required for winter grazing based on available forage, greater BW of cows and lower forage production in yr 1 than yr 2 likely caused greater production costs in yr 1 because more acres were required for winter grazing. A sensitivity analysis showed that the cost of maintaining cows in a drylot was more sensitive to a 20% increase or decrease in hay price than a 20% increase or decrease in land rent for grazing cows.

DISCUSSION

Throughout the Midwest, hay is often fed during winter months when pastures are dormant. Production and harvest costs associated with feeding hay can cost between \$55 (Brees, 2003) and \$77/t (Duffy and Smith, 2005). The harvested forages fed to beef cows represent 33% of the total feed cost per cow (Strohbehn, 2001). Implementation of forage systems whereby cattle continue to graze throughout the winter have reduced production costs for beef cows and maintained acceptable BCS for subsequent reproduction (D'Souza et al., 1990; Hitz and Russell, 1998; Janovick et al., 2004).

In previous experiments, winter grazing of stockpiled forage reduced the amount of stored feeds required to maintain cows. Heifers consumed 13.6 kg of hay DM·heifer^{-1}·d^{-1} and 0.8 kg of DM corn gluten feed·heifer^{-1}·d^{-1} in dry lots, whereas heifers grazing stockpiled forage were supplemented 0.1 kg of corn gluten feed·heifer^{-1}·d^{-1} (Clark, 2003). By grazing stockpiled forage, cows were fed 14.4 kg of DM less supplement cow/d than was fed to cows consuming hay (Schoonmaker et al., 2003). Spring-calving cows grazing stockpiled forages were fed 64% (Hitz and Russell, 1998) and 74% (Janovick et al., 2004) less hay to maintain optimal

Table 4. Estimated winter production costs ($\$\cdot cow^{-1}\cdot d^{-1}$) for cows grazing stockpiled, tall fescue-red clover or fed hay in dry lots and supplemented with corn gluten feed

	Stocking rate				
	High[1]		Low		
	Supplementation level				
Item	High[2]	Low	High	Low	Drylot
Yr 1					
Drylot yardage	0.00	0.00	0.00	0.00	0.20
Pasture rent	0.38	0.38	0.53	0.53	0.00
Pasture maintenance	0.53	0.53	0.71	0.71	0.00
Corn gluten feed	0.05	0.01	0.06	0.01	0.01
Hay	0.00	0.00	0.00	0.00	1.16
Total	0.96	0.92	1.30	1.35	1.37
20% increase/decrease in pasture rent	±0.08	±0.08	±0.11	±0.11	0.00
20% increase/decrease in hay price	0.00	0.00	0.00	0.00	±0.23
Yr 2					
Drylot yardage	0.00	0.00	0.00	0.00	0.20
Pasture rent	0.34	0.34	0.47	0.47	0.00
Pasture maintenance	0.48	0.48	0.64	0.64	0.00
Corn gluten feed	0.05	0.01	0.08	0.01	0.04
Hay	0.00	0.00	0.00	0.00	1.08
Total	0.87	0.83	1.19	1.12	1.32
20% increase/decrease in pasture rent	±0.07	±0.07	±0.10	±0.10	0.00
20% increase/decrease in hay price	0.00	0.00	0.00	0.00	±0.22

[1]High stocking rate = 1.19 $cow\cdot ha^{-1}$; and low stocking rate = 0.84 $cow\cdot ha^{-1}$.
[2]Cows supplemented at the high and low levels were fed corn gluten feed to a maintain BCS of 5.0 and 4.33, respectively.

condition for subsequent reproduction during winter grazing than cows fed hay in a drylot. Similarly, in the present experiment, no hay was fed to cows grazing stockpiled forage compared with an average 16.1 kg of hay DM $fed\cdot cow^{-1}\cdot d^{-1}$ to cows in dry lots.

Reducing the amount of stored feeds fed by allowing cattle to graze stockpiled forage has reduced feed costs (D'Souza et al., 1990; Adams et al., 1994; Schoonmaker et al., 2003). Estimated daily production costs for heifers grazing stockpiled forage at stocking rates of 1.17 and 0.84 heifer/ha were \$0.64 and $\$0.87\cdot heifer^{-1}\cdot d^{-1}$, while production costs for heifers managed in dry lots were $\$1.17\cdot heifer^{-1}\cdot d^{-1}$ (Clark, 2003). In the present experiment, estimated winter production costs of cows were also decreased 8 and 21%/cow by grazing stockpiled forage at low- (0.84 cow/ha) and high-stocking rates (1.19 cow/ha), respectively, compared with cows maintained in dry lots. Production costs for cows in this experiment were greater than heifers in previous experiments (Clark, 2003) because lower hay production in the present experiment resulted in a greater proportion of the land rental charge being assigned to stockpiled forage. Furthermore, a higher price of corn gluten feed, greater forage intakes of larger cows, and greater amounts of corn gluten feed fed during winter grazing may have inflated production costs in the present experiment. Differences between forage systems may have been greater if the costs of manure removal and application were included for the drylot treatment. Also, because grazing at the stocking rate of 1.19 cow/ha had relatively small effects on cow body condition and supplemental feed needs, it seems that the stocking rate for the stockpiled forage could have been increased even more to reduce land costs by increasing corn gluten feed supplementation and reducing forage intake with minor increases in the total production costs.

In conclusion, 2-yr-old cows fed hay in dry lots had less loss of body condition and greater BW gains than cows grazing stockpiled forage because forage available to cows in the dry lots was of greater digestibility in both years. Although cows grazing stockpiled tall fescue-red clover had lower BW and BCS than cows maintained in dry lots, BCS of cows grazing stockpiled forage were at or exceeded target BCS at the conclusion of the study with no hay fed. As a result of requiring less harvested feeds, winter production costs were lower for grazing cows than cows maintained in dry lots in spite of snowfall that challenged grazing in both years. Decreasing the stocking rate increased the amount of forage available per cow per day to ensure adequate forage availability. Supplementing cows to maintain moderate BCS improved cow BW and condition compared with cows fed minimal supplementation.

LITERATURE CITED

Adams, D. C., R. T. Clark, S. A. Coady, J. B. Lamb, and M. K. Nielsen. 1994. Extended grazing systems for improving economic returns from Nebraska sandhills cow/calf operations. J. Range Manage. 47:258–263.

Allen, V. G., J. P. Fontenot, D. R. Notter, and R. C. Hammes, Jr. 1992. Forage systems for beef production from conception to slaughter: I. Cow-calf production. J. Anim. Sci. 70:576–587.

AOAC. 1990. Official Methods of Analysis. 15 ed. Assoc. Off. Anal. Chem., Arlington, VA.

Barnhart, S., M. Duffy, and D. Smith. 2004. Estimated costs of pasture and hay production. http://www.extension.iastate.edu/Publications/AG96.pdf Accessed Feb. 20, 2005.

Brees, M. 2003. Cool season hay cost return budgets for Northern Missouri. University of Missouri Extension Publication, Columbia, MO. FBM 2201.

Clark, J. T. 2003. Evaluating efficacy and limitations of winter grazing systems for beef cattle on animal production and soil properties. MS Thesis Iowa State University, Ames.

CNCPS. 2000. Cornell Net Carbohydrate and Protein System. 5th ed. Cornell University, Ithaca, NY.

D'Souza, G. E., E. W. Maxwell, W. B. Bryan, and E. C. Prigge. 1990. Economic impacts of extended grazing systems. Am. J. Alt. Agric. 5:120–125.

Duffy, M., and D. Smith. 2005. Estimated costs of crop production in Iowa – 2005. http://www.extension.iastate.edu/Publications/FM1712.pdf Accessed July 18, 2005.

Freetly, H. C., C. L. Ferrell, and T. G. Jenkins. 2005. Nutritionally altering weight gain patterns of pregnant heifers and young cows changes the time that feed resources are offered without any differences in production. J. Anim. Sci. 83:916–926.

Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). Agric. Handbook No. 379. ARS, USDA, Washington, DC.

Hitz, A. C., and J. R. Russell. 1998. Potential of stockpiled perennial forages in winter grazing systems for pregnant beef cows. J. Anim. Sci. 76:404–415.

Janovick, N. A., J. R. Russell, D. R. Strohbehn, and D. G. Morrical. 2004. Productivity and hay requirements of beef cattle in a Midwestern year-round grazing system. J. Anim. Sci. 82:2503–2515.

Marsh, R. 1979. Effect of herbage DM allowance on the immediate and longer term performance of young Friesian steers at pasture. J. Agric. Res. 22:209–219.

Marten, G. C., and R. F. Barnes. 1979. Prediction of energy digestibility of forages with in vitro rumen fermentation and fungal enzyme systems. Pages 61–71 in Proc. Int. Workshop Standardization of Analytical Methodology for Feeds. Int. Dev. Res. Center Int. Union Nutr. Sci., Ottawa, Canada.

Mayer, R. 1999. Estimated costs for livestock fencing. Iowa State University Extension Publication, Ames, IA. FM 1855.

Neuman, A. L., and K. S. Lusby. 1986. Page 117 in Beef Cattle. 8th ed. Wiley, New York, NY.

NOAA. 2003. Climatological Data: Annual Summary; Iowa. United States Natl. Oceanic and Atmospheric Administration, Asheville, NC.

NOAA. 2004. Climatological Data: Annual Summary; Iowa. United States National Oceanic and Atmospheric Administration, Asheville, NC.

NOAA. 2005. Climatological Data: Annual Summary; Iowa. United States National Oceanic and Atmospheric Administration, Asheville, NC.

NRC. 1996. Nutrient Requirements of Beef Cattle. 7th rev. ed.: Update 2000. Natl. Acad. Press, Washington, DC.

Patterson, H. H., D. C. Adams, T. J. Klopfenstein, R. T. Clark, and B. Teichert. 2003. Supplementation to meet metabolizable protein requirements of primiparous beef heifers: II. Pregnancy and economics. J. Anim. Sci. 81:563–570.

SAS Institute. 1999. The SAS systems for Windows. 8.2 ed. SAS Inst. Cary, NC.

Schoonmaker, J. P., S. C. Loerch, J. E. Rossi, and M. L. Borger. 2003. Stockpiled forage or limit-fed corn as alternatives to hay for gestating and lactating beef cows. J. Anim. Sci. 81:1099–1105.

Singer, J. W., R. L. Hintz, K. J. Moore, M. H. Wiedenhoeft, and E. C. Brummer. 2003. Tall fescue response to nitrogen and harvest date for stockpiled grazing in the upper Midwest. Crop Manage. September 4, 2003.

Strohbehn, D. R. 2001. 2000 Beef cow record summary. Iowa State University Extension Publication, Ames, IA. File B1–47.

Wells, B. 1995. Watering systems for grazing livestock. Iowa State University Extension Publication, Ames, IA. PM 1604.