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Statement of Purpose

Roundup is the major beef cattle education and outreach event sponsored by the Agricultural Research Center–Hays. The 2018 program is the 104th staging of Roundup. The purpose is to communicate timely, applicable research information to producers and extension personnel.

The research program of the Agricultural Research Center–Hays is dedicated to serving the people of Kansas by developing new knowledge and technology to stabilize and sustain long-term production of food and fiber in a manner consistent with conservation of natural resources, protection of the environment, and assurance of food safety. Primary emphasis is on production efficiency through optimization of inputs in order to increase profit margins for producers in the long term.

Contents

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Effects of Early or Conventional Weaning on Beef Cow and Calf Performance in Pasture and Drylot Environments

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Introduction

During widespread drought, pasture availability and productivity are reduced. This, coupled with increasing land prices and lease rates, has prompted the evaluation of alternative management strategies that decrease grazing pressure on perennial pasture or reduce feed and pasture costs. Weaning early and moving cows from pasture to a drylot environment is used commonly for reducing grazing pressure on perennial pastures. A premature end to lactation reduces cow nutrient requirements and reduces grazing pressure. Removal of the calf further reduces grazing pressure, as calves are significant consumers of forage dry matter (DM) during mid and late lactation. The combination can be used to extend grazing by 0.4 d for each d weaning is executed earlier than normal. Early weaning may result in calves having less value at weaning compared to calves weaned at conventional ages. Retaining ownership of young calves through backgrounding can be useful for increasing their value. Limit-feeding non-lactating cows or cow-calf pairs in confinement can also reduce grazing pressure on pastures, while maintaining cow body condition score (BCS) or body weight (BW). Previous research conducted at the location of this study found that limit-feeding non-lactating cows at 1.9% BW achieved acceptable gains in BW, BCS, and rump fat. Therefore, the objective of our study was to evaluate the performance of beef cows and calves subject to a 56-d early or conventional weaning period in either pasture or drylot environments.

Experimental Procedures

Animals

Spring-calving Angus-cross cows (n = 167; initial BW = 1321 ± 120.2 lb; 5 ± 2.4 yr; initial BCS = 5.5 ± 0.54) and calves (n = 167; initial BW = 450 ± 58.9 lb; 153 ± 15 d of age) were used in this study. By approximately 60 d of age, all calves were vaccinated against clostridial diseases (Ultrabac 7; Pfizer Animal Health, Exton, PA) and steers were castrated. At the initiation of the study on August 19, cow-calf pairs were stratified by calf age, cow BW, and cow BCS and assigned randomly to 1 of 4 weaning treatments with 4 pen or pasture replicates/treatment. Treatments were as follows: weaning at 153 d of age followed by 56 d of limit feeding in confinement for both cow and calf (E-D), confinement of cow and calf together for a 56-d period of limit feeding followed by weaning at 209 d of age (C-D), weaning at 153 d of age followed by a 56-d grazing period for both cow and calf (E-P), and a 56-d grazing period with cow and calf together followed by weaning at 209 d of age (C-P).

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Drylot Treatments

Cows and calves assigned to E-D and C-D were placed into the feedlot for 56 d. Calves assigned to E-D were separated from their dams and placed in feedlot pens (n = 4, minimum area = 215 ft^2/calf; bunk space = 1.5 ft/calf) and provided ad libitum access to water via concrete tanks. Calves were fed a weaning diet (Table 1) formulated to promote a 2.2 lb average daily gain (ADG) at a dry matter intake (DMI) of 2.5% of BW. Bunks were evaluated each morning at 6:30 am, and feed was delivered once daily at 7:00 am. Bunks were managed using a slick-bunk management method to minimize feed refusals. If all feed delivered to a pen was consumed, delivery at the next feeding was increased to approximately 102% of the previous delivery. Diet samples were collected from bunks weekly and frozen at -4°F. Samples were composited by weight at the conclusion of the study and submitted to a commercial laboratory (SDK Laboratories, Hutchinson, KS) for analysis of DM, CP, neutral detergent fiber (NDF), and acid detergent fiber (ADF) (Table 1). Diet net energy (NE) values were calculated from detergent fiber analyses using equations.

Cows assigned to E-D were separated from their calves and placed in earth-floor pens (n = 4, minimum area = 1,000 ft^2/cow; linear bunk space = 2.13 ft/cow) and provided ad libitum access to water via concrete tanks. Cows were limit-fed a roughage-based diet at 1.6% of initial BW (Table 2). Feed was delivered once daily at 7:00 am. Diet samples were collected from bunks weekly and frozen (-4°F). Diet samples were composited by weight at the conclusion of the study and submitted to a commercial laboratory (SDK Laboratories, Hutchinson, KS) for analysis of DM, CP, NDF, and ADF (Table 2). Diet NE values were calculated from detergent fiber analyses using equations.

Cows and calves assigned to C-D were placed as pairs into feedlot pens (n = 4, minimum area = 1,000 ft^2/cow; bunk space = 2.13 ft/cow) and provided ad libitum access to water via concrete tanks. Cows were limit-fed a forage-based diet at 2.0% of initial BW that was formulated to meet nutrient requirements of pregnant cows in late lactation. Calves assigned to C-D were offered the same diet fed to E-D (Table 1) at a daily DM allowance of 2.0% of initial BW. Creep panels were used to allow calves undisturbed access to the weaning diet. Cow and calf bunks were evaluated each morning at 6:30 am and feed was delivered once daily at 7:00 am. Diet samples were collected from bunks weekly and frozen (-4°F). Samples were composited by weight and nutrient composition was analyzed as previously described.

Pasture Treatments

Cows and calves assigned to E-P and C-P were placed onto the native pastures for 56 d. Calves assigned to E-P were separated from their dams and placed in feedlot pens for 4 d (n = 4, minimum area = 215 ft^2/calf; bunk space = 1.5 ft/calf) and provided ad libitum access to water via concrete tanks. Calves were fed native prairie hay ad libitum. Hay was delivered once daily at 7:00 am. On the afternoon of d 4, calves were released into 1 of 4 assigned pastures. Each pasture (27 ± 1.0 acres) provided continual access to surface water and was stocked at 2.0 acres/calf for 56 d.

Two permanent 328-ft transects were established in each pasture at the onset of the study in order to estimate forage quality and aboveground forage biomass. Pasture forage quality and biomass were estimated by clipping all plant material from within randomly-placed sampling frames (2.69 ft^2; n = 10/pasture) at a height of 0.39 inch on

8/19, 9/16, and 10/14. Range forage samples were dried in a forced-air oven (122°F; 96 h) and weighed to estimate biomass availability. Samples were subsequently composited by sampling date on an equal-weight basis at the conclusion of the experiment and submitted to a commercial laboratory (SDK Laboratories, Hutchinson, KS) for analysis of DM, CP, NDF, and ADF (Table 3).

Cows assigned to E-P were separated from their calves and placed in feedlot pens for 4 d (n = 4, minimum area = 1,000 ft^2/cow; bunk space = 2.13 ft/cow) and provided ad libitum access to water via concrete tanks. Cows were fed the same prairie hay offered to E-P calves for ad libitum intake during this period. Hay was delivered once daily at 7:00 am. Cows were released into assigned pastures on the afternoon of d 4 and remained there 56 d. Each pasture (n = 4, 37 ± 1.0 acres) was stocked at 3.0 acres/cow and provided continual access to surface water. Pasture forage quality (Table 3) and total forage biomass (Table 4) were collected, as previously described, on 8/19, 9/16, and 10/14.

Cows and calves assigned to C-P were placed as pairs directly onto native range pasture (n = 4, 37 ± 1.0 acres) for 56 d. Pastures were stocked at 4.0 acres/pair and provided continual access to surface water. Pasture forage quality (Table 3) and total forage biomass (Table 4) were collected as previously described on 8/19, 9/16, and 10/14.

Final Phase
Following the 56-d study period, cows and calves were individually weighed. Animals assigned to E-P and C-P were transported to the feedlot. Cows and calves assigned to C-P and C-D were separated at that time and assigned to a new pen (n = 4 pens/treatment for cows, 4 pens/treatment for calves). To equalize gut-fill between treatments, all calves were fed a common diet (Table 1) at 2.0% of BW for 7 d and all cows were fed a common diet (Table 2) at 1.6% of BW for 7 d.

Data Collection
Calf BW was individually measured on d 0, 28, 56, and 63. Cows were weighed individually on d 0 and 63. Cows and calves were weighed at 6:00 am prior to feed delivery. Cow BCS was assigned by two trained observers using a 9-point scale (1 = emaciated, 9 = obese) on d 0 and 63. Also on d 0 and 63, rump fat thickness of cows was measured ultrasonically at the midpoint between the hip bone and pin bone using an Aloka 500V (Aloka Co., Ltd., Wllingford, CT) B-mode instrument equipped with a 3.5-MHz general purpose transducer array (UST 5021-12mm window). Cattle Performance Enhancement Company (CPEC, Oakley, KS) software was used to collect ultrasound images. Rump fat thickness was estimated with procedures that incorporated image analysis software integral to the CPEC software.

Results and Discussion
Forage Biomass
Available pasture forage biomass was greater ($P \leq 0.01$) for E-P calves than for either E-P cows or C-P cow-calf pairs for the duration of our study (Table 4). This was expected because of lesser grazing pressure afforded by calves compared with either cows or cow-calf pairs. There were no differences ($P \geq 0.21$) in available forage biomass

between pastures with C-P cow-calf pairs or E-P cows at any time during our study. Range-forage biomass declined in quantity throughout the study in all treatments.

Calf Performance

Calf BW was not different ($P \geq 0.06$) between treatments at the beginning of the study or on d 28 (Table 4). On d 63, there was an interaction ($P = 0.05$) between diet and weaning treatment. Calves managed in confinement, both weaned and non-weaned, had greater BW than calves managed on pasture. Calves suckling their dams had greater BW than weaned, unsupplemented calves grazing native pastures. Average daily gains were influenced by diet and weaning treatments (diet × weaning – $P \leq 0.03$). In general, calves managed in confinement and fed concentrate-based diets (i.e., E-D and C-D) had greater ADG than unsupplemented calves maintained on pasture (i.e., E-P and C-P). Weaned calves on pasture had lesser ($P < 0.01$) ADG than suckling calves on pasture from d 0 to 28 and from d 0 to 63.

Cow Performance

Cow BW, BCS, and rump-fat thickness were not different ($P \geq 0.36$) between treatments at the beginning of the study (Table 5). Cow BW on d 63 was greatest ($P < 0.01$) for non-lactating cows on pasture, intermediate for non-lactating cows fed in confinement and least for cows that continued to suckle calves. Overall BW change was influenced by both diet and weaning status (diet × weaning – $P = 0.05$). Non-lactating cows maintained on pasture had lesser BW loss than other treatments; BW loss by confined, non-lactating cows and lactating cows maintained on pasture was less than that by confined lactating cows. Cow BCS on d 63 and BCS change from d 0 to 63 were influenced ($P < 0.01$) by diet and weaning status. Non-lactating cows fed in confinement had lesser BCS on d 63 and greater BCS loss from d 0 to 63 than all other treatments.

Trends in BW and BCS may be interpreted to indicate that DMI of the cows assigned to the E-D treatment was not adequate to maintain BW or BCS; however, rump-fat data do not support this conclusion. Rump-fat depth on d 63 was greater ($P < 0.01$) for non-lactating cows maintained on pasture than for lactating cows in either pasture or drylot environments; non-lactating cows in confinement were intermediate to and not different from these treatments (Table 5). Similarly, change in rump-fat depth was greatest (diet × weaning - $P < 0.01$) for non-lactating cows on pasture and least for lactating cows in either pasture or drylot environments. Non-lactating cows maintained in confinement were intermediate to and different from these treatments.

Implications

Results were interpreted to indicate that early weaning spared cow BW and rump fat compared to weaning at conventional calf ages. Performance of cows was acceptable when either limit-fed under drylot conditions or maintained in a pasture environment. Conversely, calf performance was generally greater in confinement than on pasture.

Table 1. Composition of the diet fed to early-weaned calves in confinement

Ingredient composition	% DM
Sorghum silage	21.9
Dry rolled sorghum grain	63.4
Wet distillers grains	6.1
Soybean meal	5.1
Supplement[1]	3.4
Nutrient composition[2]	DM basis
CP, % DM	18.1
NE_m, Mcal/kg DM	1.81
NE_g, Mcal/kg DM	1.09

[1]Supplement contained ammonium sulfate, limestone, urea, salt, Rumensin 90 (300 mg/hd/d), Tylan 40 (90 mg/hd/d), and a trace-mineral premix.
[2]Nutrient analysis conducted by SDK Laboratories, Hutchison, KS.

Table 2. Composition of the diet fed to beef cows in confinement

Ingredient composition	% DM
Ground hay[1]	80.6
Dry rolled sorghum grain	10.4
Wet distillers grains	7.9
Calcium carbonate	0.30
Salt	0.30
Vitamin and mineral premix	0.30
Nutrient composition[2]	DM basis
CP, % DM	13.2
NE_m, Mcal/kg DM	1.68

[1]Native prairie hay blended with forage sorghum hay.
[2]Nutrient analysis conducted by SDK Laboratories, Hutchison, KS.

Table 3. Nutrient composition of range forage grazed by cows and calves

Sampling date	CP, % DM	NDF, % DM	ADF, % DM
		Calves, early weaned	
August 19	6.8	71.1	46.2
September 16	5.9	76.2	51.2
October 14	5.5	74.9	51.6
		Cows, early weaned	
August 19	6.2	71.6	45.8
September 16	5.5	76.7	51.1
October 14	4.6	77.2	52.4
		Cow-calf pairs, conventionally weaned	
August 19	5.8	70.4	44.6
September 16	5.2	74.9	49.3
October 14	5.4	75.1	50.5

Table 4. Forage biomass available to weaned calves, non-lactating cows, and cow-calf pairs during a 56-d grazing period

Date	Weaned calves[1]	Non-lactating cows[2]	Cow-calf pairs[3]	SEM
	------------------ lb forage DM/ 100 lb BW ------------------			
August 19	812.3[a]	443.3[b]	356.2[b]	65.65
September 16	806.5[a]	389.9[b]	317.9[b]	54.04
October 14	661.1[a]	345.2[b]	345.2[b]	49.07

[1]Calves were early weaned in a pasture environment and not supplemented for 56 d (4 pastures; 12 or 13 calves/pasture).
[2]Dams of early-weaned calves in a pasture environment and not supplemented for 56 d (4 pastures; 12 or 13 cows/pasture).
[3]Cow-calf pairs grazed together in a pasture environment and not supplemented for 56 d (4 pastures; 8 or 9 pairs/pasture).
[a,b]Within a row, means without a common superscript differ ($P \leq 0.01$).

Table 5. Performance of beef calves that were weaned early or paired with dams in either confinement or pasture environments

Item	Weaned calves, confined[1]	Non-weaned calves, confined[2]	Weaned calves, pasture[3]	Non-weaned calves, pasture[4]	SEM	*P*-value Diet	Weaning	Diet × weaning
Initial BW, lb	459	452	456	450	4.1	0.83	0.50	0.99
d 28 BW, lb	534	538	500	536	4.6	0.07	0.06	0.16
d 63 BW, lb	611	628	498	560	5.0	< 0.01	< 0.01	0.05
ADG d 0-28, lb	2.65	3.09	1.54	3.09	0.05	< 0.01	< 0.01	< 0.01
ADG d 28-63, lb	2.20	2.65	-0.66	0.66	0.04	< 0.01	< 0.01	0.03
ADG d 0-63, lb	2.43	2.87	0.66	1.76	0.04	< 0.01	< 0.01	< 0.01

[1]Calves were weaned in a drylot environment and fed a growing diet 56 d (4 pens; 8 or 9 calves/pen).
[2]Cow-calf pairs confined together in a drylot environment fed complete diets for 56 d (4 pens; 8 or 9 pairs/pen).
[3]Calves were weaned in a pasture environment and not supplemented for 56 d (4 pastures; 12 or 13 calves/pasture).
[4]Cow-calf pairs grazed together in a pasture environment and were not supplemented for 56 d (4 pastures; 12 or 13 pairs/pasture).
[a,b,c,d]Within a row, means without a common superscript differ ($P \leq 0.01$).

Table 6. Performance of pregnant beef cows in confinement and pasture environments either post-weaning or while suckling calves

Item	Post-weaning, confined[1]	Suckling, confined[2]	Post-weaning, pasture[3]	Suckling, pasture[4]	SEM	*P*-value Diet	Weaning	Diet × weaning
BW, lb								
d 0	1351	1329	1316	1329	19.0	0.37	0.85	0.36
d 63	1285	1224	1314	1257	18.7	<0.01	<0.01	0.93
Change, d 0-63	-66.1	-106.7	-2.2	-74.3	7.89	< 0.01	< 0.01	0.05
BCS								
d 0	5.5	5.4	5.5	5.5	0.08	0.56	0.78	0.47
d 63	4.5[a]	5.0[b]	5.1[b]	5.0[b]	0.07	<0.01	<0.01	<0.01
Change, d 0-63	-1.0[a]	-0.4[b]	-0.4[b]	-0.6[b]	0.70	<0.01	<0.01	<0.01
Rump fat depth, mm								
d 0	5.43	5.67	4.91	5.44	0.054	0.49	0.48	0.78
d 63	6.69[ab]	6.05[a]	8.33[b]	5.89[a]	0.057	0.19	< 0.01	0.12
Change, d 0-63	1.262[b]	0.393[c]	3.411[a]	0.449[c]	0.030	< 0.01	< 0.01	< 0.01

[1]Cows were weaned in a drylot environment and fed a growing diet 56 d (4 pens; 8 or 9 cows/pen).
[2]Cow-calf pairs confined together in a drylot environment fed complete diets for 56 d (4 pens; 8 or 9 pairs/pen).
[3]Cows were weaned in a pasture environment and not supplemented for 56 d (4 pastures; 12 or 13 cows/pasture).
[4]Cow-calf pairs grazed together in a pasture environment and were not supplemented for 56 d (4 pastures; 12 or 13 pairs/pasture).
[a,b,c]Within a row, means without a common superscript differ ($P \leq 0.01$).

Effects of Frequency of Protein Supplementation on Performance by Beef Calves Grazing Dormant Native Range

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Introduction

Stocker calves that graze forages before entering a feedlot account for more than 75% of the beef calves raised in the United States each year. A large proportion of those will be calves born in the spring and weaned in the fall. Modest growth rates are expected when the quality of fall and winter forages is poor. Growing calves in confinement systems during fall and winter typically allows for greater average daily gain (ADG) than grazing low-quality forages; however, modest overall costs associated with grazing perennial, dormant forages may be competitive during times when feed prices are relatively high.

Providing supplemental protein to beef cows grazing dormant, warm-season, native forages (i.e., ≤ 6% crude protein [CP]) has been demonstrated to increase body condition score (BCS), body weight (BW), improve dry matter digestibility (DMD), and forage dry matter intake (DMI). Furthermore, beef cows grazing low-quality forages and supplemented with protein either daily, every third day, or every sixth day had similar BW and BCS.

Reducing the frequency of supplement delivery can reduce labor costs and equipment depreciation without negatively affecting animal performance; however, this practice has variable success when used with growing beef cattle. In previous research, steers supplemented with cottonseed cake 3 times weekly had similar BW gain during winter compared to steers supplemented daily. Conversely, in another study, steers grazing winter range and supplemented with dried distillers grain daily had greater ADG than steers supplemented 3 times weekly. Therefore, the objective of this study was to evaluate the performance of young, lightweight stocker calves grazing dormant, native tallgrass pastures and supplemented with protein either daily or 3 times weekly throughout the winter.

Experimental Procedures

Angus × Hereford steer and heifer calves (n = 233; initial BW = 408 ± 61.9 lb; initial age = 162 ± 21 d) originating from the commercial cow-calf herd at Kansas State University in Manhattan, KS, were used in our study. At approximately 60 d of age, male calves were surgically castrated; all calves were vaccinated against clostridial diseases (Ultrabac 7; Pfizer Animal Health, Exton, PA) at that time, and, where applicable, surgical dehorning was performed. Following weaning in October, calves were confined to a single, dormant, native tallgrass pasture at the Kansas State University Commercial Cow-Calf Unit and were assigned randomly to 1 of 2 treatments related to protein-supplementation frequency: daily (7×) or thrice weekly (3×).

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Upon separation from their dams, calves were weighed individually and given initial vaccinations against viral respiratory pathogens (Bovi-Shield Gold 5; Pfizer Animal Health, Exton, PA) and clostridial pathogens (Ultrabac 7; Pfizer Animal Health, Exton, PA). Calves were also given an injection of trace minerals (Multimin 90; Multimin USA Inc., Fort Collins, CO), and treated for internal and external parasites (Dectomax Injectable; Zoetis Inc., Kalamazoo, MI). In addition, steer calves were given a growth-promoting implant (Ralgro; Intervet Inc., Merck Animal Health, Summit, NJ) at that time. Calves were re-vaccinated against viral respiratory pathogens and clostridial pathogens 14 d after maternal separation.

Immediately following separation from dams, calves were confined to a single earth-floor pen (minimum area = 215 ft^2/calf) and allowed ad libitum access to native tallgrass prairie hay (88.9% DM, 8.71% CP) via 6 ring feeders (diameter = 9.8 ft) for 4 d. Calves were released into the pasture designated for the study on the afternoon of d 4. The previously non-grazed, burned, native tallgrass pasture (321 acres) provided continual access to surface water and was stocked at 1.38 acres/calf for the duration of the study.

Pasture forage quality was estimated by clipping all plant material from within randomly-placed sampling frames (2.69 ft^2; n = 2/pasture) at a height of 0.4 inches on 10/03, 10/31, 11/28, 01/02, 01/28, and 03/09. Samples were composited by sampling date at the conclusion of the experiment and submitted to a commercial laboratory (SDK Laboratories, Hutchinson, KS) for analysis of DM, CP, NDF, and ADF. Nutrient composition was fairly consistent over the period of our study (Table 1).

Pelleted sunflower meal (SFM; 93% DM, 32.1% CP), purchased from Archer Daniels Midland in Goodland, KS, was used as the supplemental CP source for our study. All calves were fed 15.4 lb of SFM weekly, with supplementation frequency depending on treatment group. Once released on pasture, calves were sorted daily into either 3× or 7× treatment groups and confined to two separate pens. Both treatments were group-fed in concrete bunks (18 inches of linear bunk space/calf). Calves assigned to 7× were fed 2.2 lb SFM/calf daily (DM basis). Calves assigned to 3× were sorted and confined in a pen daily but were supplemented with 5.1 lb SFM/calf on Monday, Wednesday, and Friday only.

Sunflower meal pellets were delivered at approximately 6-wk intervals during our study in four separate truckloads. Grab samples were collected from each truckload and frozen at -4°F. Samples were composited by weight at the conclusion of the experiment and submitted to a commercial laboratory (SDK Laboratories, Hutchinson, KS) for analysis of DM, OM, CP, NDF, ADF, Ca, and P (Table 2).

Calves were individually weighed at 28-d intervals over the 157-d study (Table 3). To attempt to reduce the influence of gut fill on BW, calves were penned without access to feed for 24 h before BW measurements. Calves were monitored daily for symptoms of respiratory disease and conjunctivitis. Calves with clinical signs of BRD, as judged by animal caretakers, were removed from pastures and evaluated. Calves were assigned a clinical-illness score (scale: 1 to 4; 1 = normal, 4 = moribund), weighed, and assessed for febrile response. Calves with a clinical illness score > 1 and a rectal temperature > 104°F were treated with therapeutic antibiotics according to label directions (first incidence =

Baytril, Bayer Animal Health, Shawnee Mission, KS; second incidence = Resflor Gold, Merck Animal Health, Summit, NJ). Calves were evaluated 72 h following treatment and re-treated if clinical signs of BRD persisted. Calves showing signs of conjunctivitis (i.e., pinkeye) were treated using oxytetracycline (LA 200; Zoetis Inc., Kalamazoo, MI). Calves were evaluated 14 d following treatment and re-treated if clinical signs of conjunctivitis persisted.

Results and Discussion

Calf BW was not different ($P \geq 0.31$) between treatments at any time during the study. Likewise, calf BW change over the course of the study was not influenced ($P = 0.49$) by supplementation frequency. Calf ADG was not different ($P \geq 0.22$) between treatments from d 0 to 28, d 29 to 56, d 57 to 91, or d 118 to 157; moreover, ADG from d 0 to 157 was not different ($P = 0.48$) between treatments. For a brief period between d 92 and 117, calves assigned to 7× had greater ($P < 0.01$) ADG than calves assigned to 3×; however, this result was inconsequential to overall ADG. Calf BW changes during our study were modest but typical of winter grazing operations in the tallgrass prairie region of Kansas. Poor forage quality likely limited performance (Table 2).

Dormant-season grazing with calves is common for ranchers in the tallgrass prairie region of Kansas. Calves are purchased in the late fall when seasonal price discounts are relatively high, and then grown at modest rates on dormant, native tallgrass range until spring. From approximately April 15 to July 15, calves then graze actively-growing native tallgrass range and can achieve an ADG that exceeds 2 lb. Although winter BW gains are modest in this system, subsequent summer BW gains are thought to offset poor winter performance.

The contracted price of SFM at the initiation of our study was \$235.38/ton; feed cost per calf was estimated at \$41.45 for the 157-d period of our study (i.e., 2.4 lb SFM × 157 d × \$0.11/lb; as-fed basis). Feed delivery cost for 7× was estimated at \$39.25/calf (i.e., 157 d × \$0.25/calf), whereas feed delivery cost for 3× was only \$16.25/calf for the 157-d period (i.e., 65 d × \$0.25/calf).

Implications

Daily protein supplementation did not improve growth performance relative to thrice-weekly protein supplementation when total weekly CP delivery was held constant between treatments. Supplementing CP to stocker calves thrice weekly saved 59% (\$23.00/calf) in feed-delivery cost throughout the winter compared with daily CP supplementation.

Table 1. Nutrient composition of range forage

Sampling date	CP, % DM	NDF, % DM	ADF, % DM
October 3	4.4	67.4	46.8
October 31	4.1	69.9	49.6
November 28	3.7	71.2	50.9
January 2	3.6	72.8	51.5
January 28	3.6	73.7	51.9
March 9	3.9	69.1	47.6

Table 2. Nutrient composition of sunflower meal

Nutrient composition	
DM %	93.0
OM, % DM	25.6
CP, % DM	32.1
NDF, % DM	44.2
ADF, % DM	31.3
Ca, % DM	0.37
P, % DM	0.96

Table 3. Post-weaning growth of calves supplemented with sunflower meal (SFM) either daily (7×) or thrice (3×) weekly while grazing dormant native tallgrass range during winter

Item	7×[1]	3×[2]	SEM	*P*-value
Weaning BW, lb	403	410	8.2	0.42
BW on d 28, lb	425	434	8.6	0.31
BW on d 56, lb	443	452	9.5	0.44
BW on d 91, lb	443	452	9.3	0.33
BW on d 117, lb	454	456	9.3	0.84
BW on d 157, lb	465	467	9.3	0.68
BW change 0 to 157 d, lb	59.5	56.4	4.37	0.49
ADG d 0 to 28, lb	0.73	0.82	0.077	0.28
ADG d 29 to 56, lb	0.64	0.60	0.086	0.70
ADG d 57 to 91, lb	0.00	0.02	0.075	0.64
ADG d 92 to 117, lb	0.44	0.15	0.082	< 0.01
ADG d 118 to 157, lb	0.24	0.31	0.042	0.22
ADG d 0 to 157, lb	0.37	0.35	0.029	0.48

[1]Calves were supplemented with 2.2 lb SFM (DM basis) daily for 157 d.
[2]Calves were supplemented with 5.1 lb SFM (DM basis) thrice weekly for 157 d.

Gonadotropin-Releasing Hormone Increased Pregnancy in Suckled Beef Cows Not Detected in Estrus and Subjected to a Split-Time Artificial Insemination Program

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Introduction

Estrus-synchronization programs allow insemination of all females in a herd at one fixed time on the first day of the breeding season. Inseminating cows after they have expressed estrus increases pregnancy rate (PR) compared with cows that do not display estrus in a timed AI (TAI) program. Identification of estrus status can be facilitated by using estrus-detection patches. Varying AI timing according to estrus status has increased PR in some previous studies. Reducing the number of injections in a TAI program decreases labor requirements, stress on cows, and overall cost of the program. Previous studies have demonstrated that PR is not compromised in cows displaying estrus when the GnRH injection administered at AI is eliminated. A split-time AI program decreases the time between estrus expression and insemination compared with a single fixed-time AI when the first AI occurs before the recommended standard 60- to 66-h fixed time. Previous research has demonstrated that delaying AI results in approximately 50% more cows displaying estrus when compared with a single insemination time. Eliminating the GnRH injection at AI for cows displaying estrus in a split TAI program can reduce the number of GnRH injections required and the program cost. The objective of this study was to test the hypothesis that GnRH injection concurrent with split TAI program improves PR only in cows not displaying estrus.

Experimental Procedures

A total of 1,236 mixed-parity suckled beef cows at 12 locations in 3 states (Colorado, Kansas, and North Dakota) were enrolled in the experiment. Body condition scores ((BCS) 1 = thin and 9 = obese) were assigned (d −17) before the start of the TAI program by a trained evaluator (Figure 1). Characteristics of suckled beef cows enrolled by location including breed, parity, days postpartum at split TAI, and BCS at the onset of the synchronization program are summarized (Table 1). All cows were injected intramuscularly with 100 µg GnRH (2 mL Factrel; Zoetis Inc., Florham Park, NJ) 7 d before 25 mg $PGF_{2\alpha}$ on d 0 (5 mL Lutalyse; Zoetis Inc.). A new progesterone-impregnated controlled internal drug release (CIDR) insert (Zoetis Inc.) containing 1.38 g progesterone was placed intravaginally at the time of the GnRH injection (d −7). Progesterone inserts were removed and $PGF_{2\alpha}$ was injected at 6:00 pm on d 0 to allow for AI

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to begin 65 h later at 11:00 am. The 84-h time was selected to begin the late AI time as soon as daylight would allow (6:00 am) and to allow insemination of cows approximately 5- to 13-h before ovulation induced by GnRH 19 h earlier. Ovulation occurs between 24 and 32 h after exogenous GnRH in cattle.

On d 0, concurrent with CIDR insert removal, estrus-detection patches (Estrotect, Spring Valley, WI) were affixed to the tail head of all cows according to the manufacturer's recommendation. Patches were evaluated at 65 h after CIDR insert removal, and estrus was defined to have occurred when an estrus-detection patch was >50% colored (activated). Cows with activated patches were assigned by random chute order to either receive 100 μg GnRH and early AI at 65 h (E+G) or AI only at 65 h (E−G). Remaining nonestrus cows received either 100 μg GnRH at 65 h and late AI at 84 h (L+G) or AI only at 84 h (L−G). An additional evaluation of patch activation status was also conducted at 84 h to determine if activation had occurred between 65 and 84 h.

Pregnancy Diagnosis

Cows were either observed for estrus and reinseminated on subsequent estrus or were exposed to cleanup bulls beginning 10 to 12 d after split TAI. At 35 d after split TAI, PR was confirmed by transrectal ultrasonography (Aloka 500V, 5 MHz transrectal transducer, Wallingford, CT). A final pregnancy diagnosis was determined via transrectal ultrasonography or palpation per rectum no sooner than 35 d after the end of the breeding season (range of 35 to 42 d). Pregnancy loss was defined as those cows pregnant 35 d after split TAI but not at the appropriate stage of pregnancy at the time of the final pregnancy diagnosis.

Estrus-Cycle Status

Blood samples were collected via puncture of a caudal blood vessel from cows (n = 427) at 8 of the 12 locations on d -17 and -7. Concentrations of progesterone in blood serum were measured. Cows with a serum progesterone concentration ≥ 1.0 ng/mL at either d -17 or -7 were defined to have resumed estrous cycles. All other sampled cows with concentrations of progesterone < 1.0 ng/mL were considered to have been anestrous at the onset of the ovulation synchronization program (Table 1).

Results and Discussion

Pregnancy Rate

Cows detected in estrus and inseminated at 65 h had greater PR than the cows inseminated at 84 h regardless of GnRH treatment (Figure 2). Pregnancy rate was not improved ($P = 0.68$) by administration of GnRH in cows that were in estrus by 65 h (61.9 and 60.4% for E+G and E−G, respectively). For cows inseminated at 84 h, PR was greater ($P = 0.001$) in cows that received GnRH at 65 h (L+G) compared with their herd mates not receiving GnRH at 65 h (41.7 and 30.8% for L+G and L−G, respectively).

Four cows were eliminated from the analysis of PR because patch data were not available at 84 h. Administration of GnRH at 65 h increased ($P < 0.01$) PR in cows not detected in estrus by 84 h (Figure 3). In contrast, administration of GnRH did not impact PR ($P = 0.60$) in cows expressing estrus during the interval from 65 to 84 h. Pregnancy rate for cows inseminated at either time was not affected ($P \geq 0.10$) by BCS, parity, or days postpartum at AI. Final PR assessed at least 35 d after the end of the breeding season for E+G, E−G, L+G, and L−G cows were 87.4, 89.0, 84.5, and 78%, respectively. Final PR of L−G cows differed from E+G ($P = 0.02$) and E−G cows ($P = 0.004$). Body condition score did not affect final PR. An interaction ($P = 0.05$) was detected between days postpartum and parity when considering the final PR. Primiparous cows that were ≤82 d postpartum had a lesser ($P = 0.003$) final PR than primiparous cows >82 d (70.9 vs. 87.6%, respectively). Final PR of primiparous cows ≤82 d postpartum also differed ($P = 0.01$) from that of multiparous cows ≤82 d and multiparous cows >82 d (87.8 and 89.7%, respectively).

Occurrence of Estrus
Activated estrus-detection patches were observed in 61.3% (758/1,236) of cows at 65 h after insert removal. Of the remaining cows, 42.2% (200/474) had activated estrus-detection patches at 84 h, indicating estrus had occurred between 65 and 84 h. In total, 77.5% (958/1,236) of cows were observed with activated estrus-detection patches by 84 h.

The proportion of cows expressing estrus by 65 h was not impacted ($P > 0.10$) by BCS, parity, days postpartum (Table 2), or their respective interactions. Likewise, the proportion of cows expressing estrus during the interval from 65 to 84 h was not influenced ($P > 0.10$) by BCS, parity, days postpartum, or their respective interactions. A greater proportion of cows >82 d postpartum tended ($P = 0.09$) to express estrus by 84 h compared with cows ≤82 d postpartum (79.8 vs. 75.5%, respectively).

Estrus-cycle status based on concentrations of progesterone was examined for its effect on occurrence of estrus in the subset of 427 cows for which that information was available. Analysis of the impact of estrus-cycle status on estrus expression revealed that similar ($P > 0.26$) proportions of cycling and anestrous cows were detected in estrus in each of the 3 observation periods (51 vs. 58% by 65 h, 25 vs. 28% between 65 and 84 h, and 65 vs. 70% by 84 h for cycling and anestrous cows, respectively). The proportion of cows that had resumed estrous cycles (32.3%; 138/427) was influenced by neither BCS nor days postpartum. Primiparous cows, however, were more ($P < 0.01$) likely to be anestrous than their multiparous herd mates (94.6 vs. 63.6%, respectively).

Implications
Injection of GnRH at AI improved PR only in those cows that were not detected in estrus before time of AI. Cows that exhibited estrus, regardless of GnRH treatment, had better PR than cows that did not display estrus. Insemination at a predetermined time in beef cows can reduce the time and labor associated with a conventional single standard fixed-time AI program. The split-time AI program serves as a compromise between conventional AI after detection of estrus and a standard one fixed-time AI program. Depending on the cost of GnRH (range of US $2.22 to $3.10 per dose) and 60% of cows in estrus by 65 h, the economic trade-off of using estrus-detection patches in a split-time AI program is favorable and saved $0.33 to $0.86 per cow. However, it does not account for the extra time and cow–calf handling invested to carry out the second AI at 84 h. The cost of semen and sire selection for cows detected in estrus having a greater PR compared with those not detected in estrus and lesser PR could provide other favorable options and economic advantages for using a split-time AI program.

Table 1. Selected characteristics of suckled beef cows enrolled in the experiment

Location[1]	Breed[2]	n	2-year-old	Day postpartum at AI	BCS[3]	Estrus cycle status[4]	Pregnancy rate[5]
			%			------------- % -------------	
CO-1	A	333	26	83 ± 1.0	4.6 ± 0.02	-[6]	58.9
CO-2	A	80	23	81 ± 1.9	5.5 ± 0.08	-[6]	68.8
KS-1	H	39	28	78 ± 2.9	5.6 ± 0.08	33	66.7
KS-2	A × H	40	25	82 ± 2.6	5.7 ± 0.10	53	45.0
KS-3	A × H	77	31	84 ± 1.7	5.4 ± 0.07	61	49.4
KS-4	A × H	61	26	83 ± 1.8	5.4 ± 0.09	49	55.7
KS-5	A × H	64	86	78 ± 2.6	5.5 ± 0.08	6	23.4
KS-6	A × H	98	0	69 ± 1.8	5.7 ± 0.06	18	46.9
KS-7	A × H	29	0	49 ± 3.8	5.8 ± 0.07	14	51.7
KS-8	A × H	19	0	69 ± 4.2	5.3 ± 0.18	5	21.1
ND-1	A × H	190	0	72 ± 1.4	4.4 ± 0.04	_[6]	68.9
ND-2	A × H	206	32	83 ± 1.2	4.3 ± 0.04	_[6]	62.6

[1]Cows at 12 locations in 3 states were enrolled. CO = Colorado; KS = Kansas; and ND = North Dakota.
[2]A = Angus and H = Hereford.
[3]Mean ± SE.
[4]Based on progesterone concentrations measured in 2 blood samples collected 10 d apart before the onset of the experimental protocol in 427 cows (cut point for determining if cows were having estrus cycles was ≥1 ng/mL).
[5]Assessed at 35 d after AI.
[6]Blood samples were not collected to assess estrus cycle status.

Table 2. Estrus expression by 65 h, between 65 and 84 h, and by 84 h after controlled internal drug release insert removal as affected by BCS, parity, days postpartum, and GnRH

Item	Estrus by 65 h		Estrus between 65 and 84 h		Estrus by 84 h	
	n	%	n	%	n	%
Days postpartum						
≤82	596	61.1	229	37.9	596	75.5[a]
>82	640	65.8	245	41.6	640	79.8[b]
BCS						
≤5	689	64.3	269	41.8	689	79.3
>5	547	62.6	205	37.7	547	76.1
Parity						
Primiparous	287	64.2	119	37.5	287	77.1
Multiparous	949	62.7	355	42.0	949	78.4
GnRH at 65 h	---	---	249	40.9	---	---
No GnRH at 65 h	---	---	225	38.6	---	---

[a,b]Means within estrus category with different superscript letters tend ($P < 0.10$) to differ.

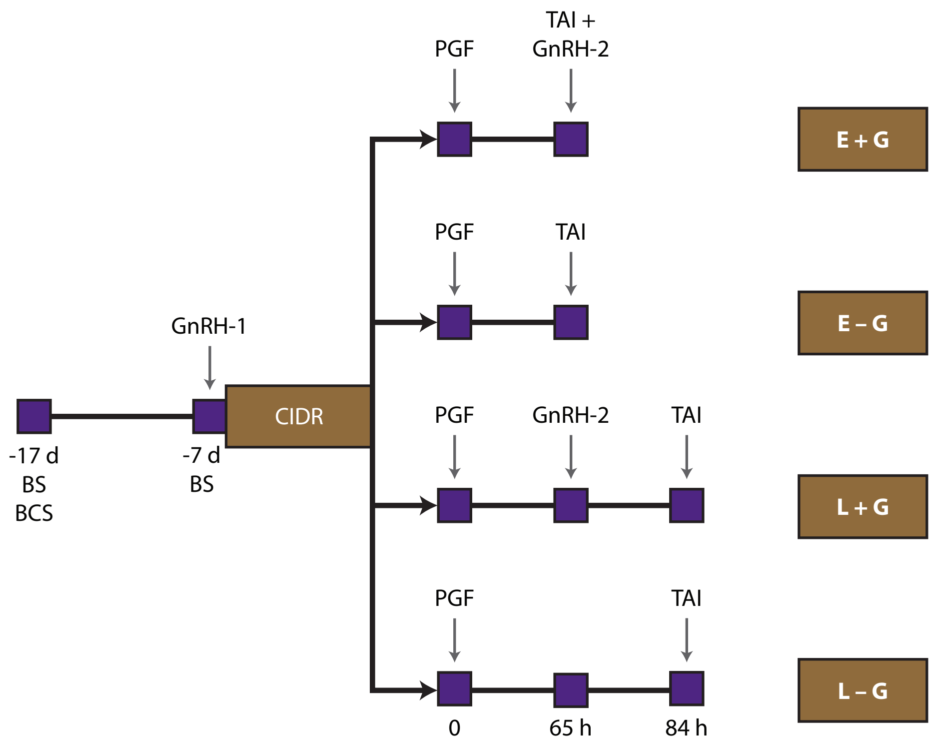

Figure 1. Experimental design of treatments. All cows (n = 1,236) received intramuscularly 100 μg GnRH (GnRH-1) and a controlled internal drug release (CIDR) insert containing 1.38 g of progesterone followed in 7 d by 25 mg $PGF_{2\alpha}$ (PGF) and CIDR removal (d 0). Cows with patches >50% activated were defined to be in estrus and treatment assignments were made at 65 h. The 100 μg GnRH and early AI at 65 h (E+G) cows (n = 373) received 100 μg GnRH (GnRH-2) and insemination at 65 h. The AI only at 65 h (E-G) cows (n = 385) received no GnRH and were inseminated at 65 h. The 100 μg GnRH at 65 h and late AI at 84 h (L+G) cows (n = 252) received GnRH at 65 h and were inseminated at 84 h. The AI only at 84 h (L-G) cows (n = 226) received no GnRH and were inseminated at 84 h. Body condition scores (BCS; 1 = thin and 9 = obese) were assigned (d –17) before the start of the TAI program. Blood samples (BS) were collected on d -17 and -7 from a subset of cows (n = 427) at 8 of 12 locations. TAI = timed AI.

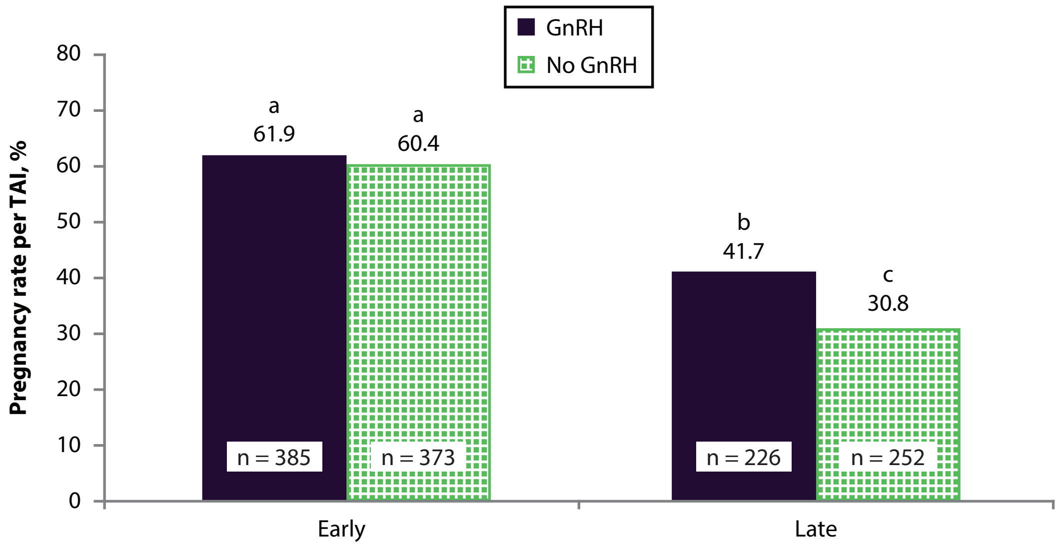

Figure 2. Pregnancy rate (PR) per timed AI (TAI) by treatment. The early cows were detected in estrus by 65 h, inseminated, and either received GnRH at 65 h (E+G) or did not receive GnRH (E-G). The remaining cows were allocated to 2 late treatments: 1) injected with GnRH at 65 h and inseminated at 84 h (L+G) or 2) no GnRH at 65 h and inseminated at 84 h (L-G).

[a,b,c]Bars with different letters differ ($P < 0.05$). Values at the base of each bar represent the number of cows per treatment.

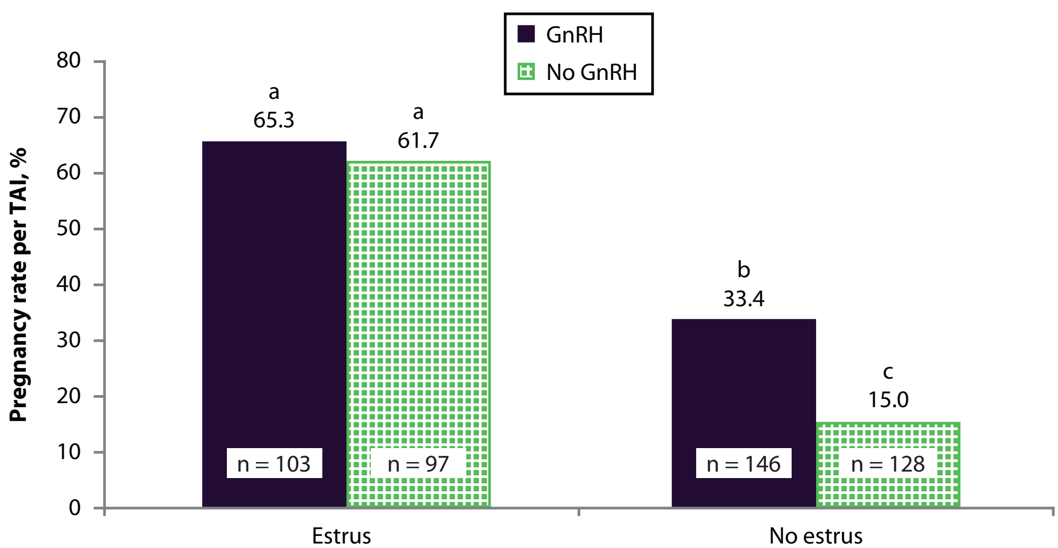

Figure 3. Pregnancy rate (PR) per timed AI (TAI) for cows inseminated at 84 h. Based on whether the estrus-detection patch was >50% activated between 65 and 84 h after controlled internal drug release insert removal, cows were classified at estrus or no estrus.

[a,b,c]Bars with different letters differ ($P < 0.05$). Values at the base of each bar represent the number of cows per treatment.

Two Split-Time Artificial Insemination Programs in Suckled Beef Cows

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Introduction

Successful programs to manipulate estrus and ovulation to maximize pregnancy outcomes in suckled beef cattle have been developed to limit animal handling and to eliminate the need to detect estrus, thereby providing more opportunity to incorporate AI to start the breeding season. The most successful and consistent synchronization scheme employs an intravaginal progesterone insert (controlled internal drug release, CIDR) in place for 7 d concurrent with GnRH treatment, and, upon removal of the insert, injection of $PGF_{2\alpha}$, followed by timed AI at 60 to 66 h concurrent with a second dose of GnRH (CO-Synch + CIDR).

Inseminating cows after expressed estrus increases pregnancy rate compared with cows that do not display estrus in a timed AI program. Identification of estrus can be accomplished easily by using estrus-detection patches, thus facilitating timing of AI to meet herd-specific situations. Varying AI timing has increased pregnancy rate in some, but not all studies.

Rather than using 1 planned fixed-time AI for all cows, we tested split-time AI intervals, and used detection of estrus to optimally time AI relative to detected estrus. In previous research, in 2 separate experiments, estrus was detected by using estrus-detection patches at either 60 or 65 h after $PGF_{2\alpha}$ and AI was conducted for cows in estrus. Remaining cows received a fixed-time AI at either 75 or 84 h, respectively. Administering GnRH to cows already detected in estrus at 60 or 75 h did not improve pregnancy rate. Additionally, administering GnRH at 60 or 75 h to cows not yet in estrus only improved pregnancy rate in cows that did not come into estrus during the interim before timed AI occurred at 75 or 84 h, respectively.

Our objective was to determine which time combination for split-time AI would maximize pregnancy rate in suckled beef cows: 55 h (AI cows in estrus) + 75 h (receive GnRH at 55 h and AI at 75 h) or 65 h (AI cows in estrus) + 85 h (receive GnRH at 65 h and AI at 85 h).

Experimental Procedures

Suckled beef cows (n = 1,062) of mixed parity at 12 locations in 4 states were enrolled in the experiment. Characteristics by location including breed composition, proportion of primiparous cows, days postpartum at artificial insemination (AI), and body condi-

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tion score (BCS) are summarized (Table 1). Cows grazed native pastures during the treatment and AI period.

Cows were placed in a CO-Synch program plus an intravaginal insert which was impregnated with progesterone (1.38 g) (CIDR; Zoetis, Florham Park, NJ): GnRH + CIDR on d -7, CIDR insert removal + $PGF_{2\alpha}$ on d 0 at which time estrus-detection patches (Estrotect, Spring Valley, WI) were affixed to the tail head of all cows according to manufacturer's recommendations. The dose of GnRH was 100 µg (2 mL Factrel i.m.; Zoetis). The dose of $PGF_{2\alpha}$ was 25 mg (2 mL Lutalyse HighCon i.m.; Zoetis). Body condition scores (1 = thin; 9 = obese) were assigned on d −7 by trained evaluators in all but 2 locations.

The study was designed as a completely randomized experiment of 2 treatment combinations. Within location and balanced for parity (primiparous vs. multiparous), cows were assigned randomly to 2 treatment times (55 vs. 65 h after CIDR insert removal; Figure 1). At 55 or 65 h, estrus-detection patches were assessed. Estrus was defined to have occurred if patches were > 50% colored. Cows determined to be in estrus were inseminated at either 55 or 65 h, whereas the remaining nonestrous cows in both treatment times received GnRH at 55 or 65 h and were inseminated 20 h later at 75 or 85 h, respectively. To facilitate inseminations (AI based on estrus or at a fixed time) at only 2 times, CIDR inserts, $PGF_{2\alpha}$ injection, and application of estrus-detection patches in the 65-h treatment were removed 10 h before those in the 55-h treatment. The 2 treatment combinations, therefore, consisted of the 55 + 75-h and the 65 + 85-h combinations with inseminations based on estrus occurring at either 55 or 65 h and their peer herd mates not in estrus at 55 or 65 h were inseminated 20 h later at 75 or 85 h, respectively.

Activated patches were removed from cows in estrus at 55 or 65 h after the time of AI. Patches on remaining cows were assessed at 75 or 85 h when cows received their timed AI, thus allowing a determination of the number of cows showing estrus during the 20-h period after GnRH was administered compared to nonestrous cows before they were inseminated at 75 or 85 h.

No sooner than 1 wk after AI, cows were exposed to natural service sires for a total breeding season of 45 to 60 d. A positive pregnancy outcome via transrectal ultrasonography required presence of an embryo with a visible heart beat at 36 d after AI (mean = 36.0 ± 0.1 d; range of 32 to 45 d). A final pregnancy diagnosis was determined via transrectal ultrasonography or transrectal palpation no sooner than 35 d after the end of the breeding season. Pregnancy loss was defined as those cows pregnant at 36 d after AI, but not at the appropriate stage of pregnancy at the time of the final pregnancy diagnosis.

Results and Discussion

Location Characteristics

Summarized in Table 1 are location characteristics of 1,046 cows enrolled at the 12 locations in the 4 states where the experiment was conducted. The cows were Angus-based, including both purebreds and crosses of Angus. Cows at all locations calved during the spring, but at one location (CO-1), the spring-calving cows were moved to a fall-breeding program. As expected, resulting pregnancy rates varied ($P < 0.001$) among locations (Table 1). Actual insemination times were: 55 h (mean and range = 54.5 h; 53.6 to 55.8 h), 65 h (64.6 h; 63.7 to 66.0 h), 75 h (74.4 h; 73.6 to 75.5 h), and 85 h (84.7 h; 83.1 to 85.5 h).

Expression of Estrus

Expression of estrus was greater ($P = 0.001$) by 65 h after $PGF_{2\alpha}$ than by 55 h (Figure 2), and this proportion was influenced by parity (time × parity interaction; $P = 0.006$). By 55 h, fewer primiparous than multiparous cows were in estrus, whereas no differences in those proportions were detected between parity groups by 65 h. As a result, proportionally more ($P < 0.001$) cows received the timed AI at 75 than 85 h (59.4% vs. 40.6%). Similar proportions of cows not in estrus by 55 or 65 h were detected in estrus by 75 or 85 h (40.1% vs. 39.3%), respectively. As expected, the total proportion of cows in estrus by 75 h was less ($P < 0.001$) than that by 85 h (Figure 2). These proportions were affected by parity ($P = 0.045$), with more multiparous than primiparous cows showing estrus. No interaction of treatment and parity was detected ($P = 0.137$). Body condition did not affect ($P = 0.12$) expression of estrus in the current study.

Pregnancy Outcomes

Of cows in estrus (n = 500) by 55 or 65 h (inseminated at either 55 or 65 h), pregnancy rate was greater ($P < 0.001$; Table 2) compared with cows not in estrus (n = 549) by those times (inseminated at 75 or 85 h), respectively. Of cows not in estrus (n = 198) by 55 or 65 h, but showed estrus by 75 or 85 h, respectively, pregnancy rates were greater ($P < 0.001$) for cows expressing estrus than for cows not showing estrus (n = 302) during that 20-h period (66.7% vs. 42.7%), respectively. Overall, regardless of when estrus occurred, pregnancy rate was greater ($P < 0.001$) for cows that showed estrus (n = 747) than for those not showing estrus and receiving the timed AI (n = 302; 67.3% vs. 42.7%).

Both actual and adjusted mean proportions of cows pregnant at 36 d after AI, cows pregnant at the end of the breeding season (which included exposure to natural service sires), and intervening pregnancy loss are summarized in Table 2. Pregnancy rate at 36 d for estrous cows inseminated at 55 h did not differ from those estrous cows inseminated at 65 h. Although estrous cows inseminated at 55 h had a greater pregnancy rate than their nonestrous peers receiving the timed AI at 75 h, that did not hold true for estrous cows inseminated at 65 h compared with their nonestrous peers receiving the timed AI at 85 h (contrasts: 55 vs. 65 h [$P = 0.337$]; 55 vs. 75 h [$P = 0.029$]; 65 vs. 85 h [$P = 0.113$]; 75 vs. 85 h [$P = 0.127$]).

A more appropriate way to assess the programs is to examine the combined pregnancy rate for cows in the 55 + 75-h treatment combination with those in the 65 + 85-h treatment combination. Cows in the latter treatment combination had the greater pregnancy rate at 36 d than the former (Table 2). This difference in pregnancy rate is explained partly by the proportionally greater number of cows receiving the timed AI in the 55 + 75-h combination compared with those in the 65 + 85-h combination (59.4% vs. 40.6%), respectively. In other words, the greater pregnancy rate of the 65 + 85-h combination occurred because more cows were inseminated after having been detected in estrus and a tendency ($P = 0.127$) for greater pregnancy rate for cows receiving the timed AI at 85 h compared with 75 h.

Pregnancy rates at 36 d tended ($P = 0.067$) to be less in primiparous than multiparous cows, but no interaction was detected ($P = 0.192$) between treatment and parity (Figure 3). In 10 locations in which BCS was assessed, BCS did not significantly influence pregnancy rate at 36 d. Cows with longer postpartum intervals to AI had greater pregnancy rate. For every 10-d increase in days postpartum at AI, pregnancy rate at 36 d increased by 3.1 ± 0.1% ($P = 0.014$) or 3.5 ± 1.1% ($P = 0.026$) depending whether the model included all 4 insemination times or the 2 treatment combinations, respectively.

Final pregnancy rates tended ($P = 0.058$) to be less in cows that received the timed AI at either 75 or 85 h (Table 2). In contrast, when the treatment combinations were examined, final pregnancy outcomes did not differ. As expected, final pregnancy outcomes were less ($P = 0.001$) in primiparous than multiparous cows (Figure 4). Final pregnancy rates for primiparous cows increased ($P = 0.001$) by 3.4 ± 0.7% (4 AI times) or by 3.5 ± 0.7% (2 treatment combinations) for each 10-d increase in postpartum days to AI. Body condition score influenced final pregnancy risk in locations in which it was assessed. For every unit increase in BCS, final pregnancy rate increased ($P = 0.001$) by 4.1 ± 1.5% (4 AI times) to 4.4 ± 1.5% (2 treatment combinations).

Although small, pregnancy losses between AI and the end of the breeding season tended ($P = 0.058$) to differ among treatments, but they did not differ between the 2 treatment combinations (Table 2), averaging less than 4%. For every 10-d increase in days postpartum at AI, pregnancy loss decreased ($P < 0.001$) by -1.1 ± 0.5% (4 AI times) to -1.3 ± 0.5% (2 treatment combinations).

Implications

We conclude that employing a split-time AI program at 65 + 85 h produced more pregnancies than the 55 + 75 h program because more cows were in estrus at the 65- and 85-h insemination times and fertility was greater in estrous than nonestrous cows.

Table 1. Selected characteristic of suckled beef cows enrolled in the experiment

Location[1]	Breed[2]	n	2-year-old	Days post-partum at AI[3]	BCS[3]	Pregnancy rate[4]
			%			%
CO-1	A, H	75	31	156 ± 23	5.2 ± 0.8	62.7
CO-2	A	150	27	77 ± 9	-	61.3
CO-3	A	169	44	73 ± 24	-	63.3
KS-1	A × H	45	20	82 ± 16	5.7 ± 0.5	46.7
KS-2	A × H	44	27	83 ± 14	5.4 ± 0.4	29.5
KS-3	A × H	64	62	77 ± 15	6.0 ± 0.8	43.7
KS-4	A × H	75	16	69 ± 16	5.4 ± 0.5	65.8
KS-5	A × H	61	28	75 ± 17	5.1 ± 0.5	63.9
KS-6	A × H	101	0	75 ± 18	6.0 ± 0.8	54.3
MT-1	A	108	24	75 ± 15	4.8 ± 0.6	69.2
WA-1	A cross	70	0	59 ± 10	6.2 ± 1.1	71.4
WA-2	A	100	0	59 ± 10	6.2 ± 0.7	63.0

[1]Cows at 12 locations in 4 states were enrolled.
[2]A = Angus and H = Hereford.
[3]Mean ± SD.
[4]Assessed at 33 to 45 d (average = 36 d) after AI.

Table 2. Pregnancy rate (PR) at 36 d after artificial insemination, final pregnancy rate at the end of the breeding season, and intervening pregnancy loss

	Treatment[1]					Program[1]		
	55	65	75	85	*P*-value	55 + 75	65 + 85	*P*-value
PR at 36 d								
n	223	326	302	198		525	524	
Actual,[2] %	66.8	68.6	49.7	56.1		57.7	62.8	
Adjusted,[3] %	58.8	64.7	46.3	55.0	0.002	51.4	61.0	0.015
Final PR[4]								
n	223	326	307	199		530	525	
Actual, %	94.8	92.8	87.9	87.4		90.0	92.0	
Adjusted, %	92.3	93.9	86.8	88.0	0.058	88.7	91.7	0.185
Loss								
n	153	217	149	110		302	327	
Actual, %	2.0	0.9	2.7	8.2		2.3	3.4	
Adjusted, %	2.0	0.9	2.7	8.2	0.068	2.3	3.4	0.599

[1]Cows were enrolled in a CO-Synch + controlled-internal drug release insert (CIDR) program (GnRH + CIDR on d -7, CIDR insert removal + $PGF_{2\alpha}$ + fitted with estrus-detection patches on d 0). Cows were assigned to have their patches assessed (>50% activation) at either 55 or 65 h after CIDR insert removal. Cows with activated patches were then inseminated at either 55 or 65 h. The remaining nonestrous cows in both groups received GnRH at 55 or 65 h but were inseminated at 75 or 85 h, respectively.
[2]Unadjusted raw mean percentages.
[3]Adjusted mean percentages resulting from logistic regression analysis. Contrasts: 55 vs. 65 h ($P = 0.337$); 55 vs. 75 h ($P = 0.029$); 65 vs. 85 h ($P = 0.113$); and 75 vs. 85 h ($P = 0.127$).
[4]Six cows not present for the first pregnancy diagnosis (PR at 36 d) were present for the final pregnancy diagnosis.

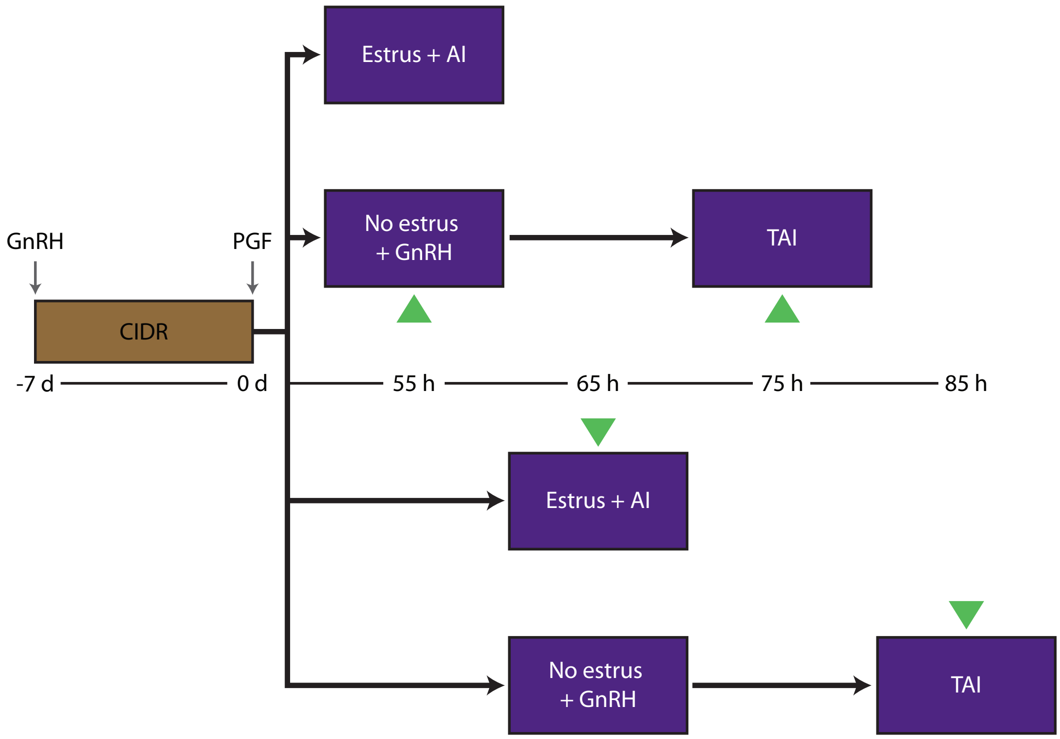

Figure 1. Experimental design of treatments employed in the experiment. Cows were enrolled in a CO-Synch + CIDR program (GnRH + CIDR on d -7, CIDR insert removal + $PGF_{2\alpha}$ + fitted with estrus-detection patches on d 0). Cows assigned to have their patches "read" (<50% activation) at either 55 or 65 h after CIDR insert removal. Cows with activated patches were then inseminated at either 55 or 65 h. The remaining cows in both groups received GnRH at 55 or 65 h but were inseminated at 75 or 85 h, respectively. CIDR = controlled internal drug release insert containing 1.38 g of progesterone; GnRH = gonadotropin-releasing hormone; PGF = prostaglandin $F_{2\alpha}$; and TAI = timed artificial insemination.

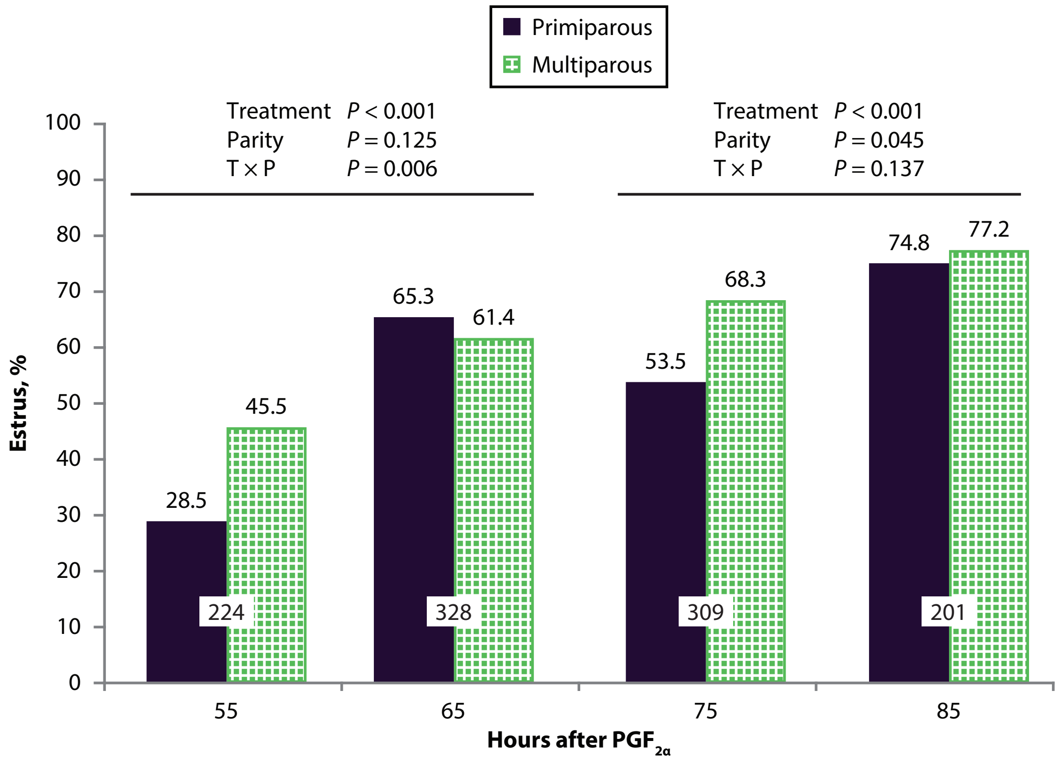

Figure 2. Proportions of cows interpreted to be in estrus by 55, 65, 75, or 85 h after removal of CIDR insert and injection of $PGF_{2\alpha}$ in primiparous and multiparous suckled beef cows. Cows in the 75- and 85-h times were treated with GnRH 20 h earlier, respectively.

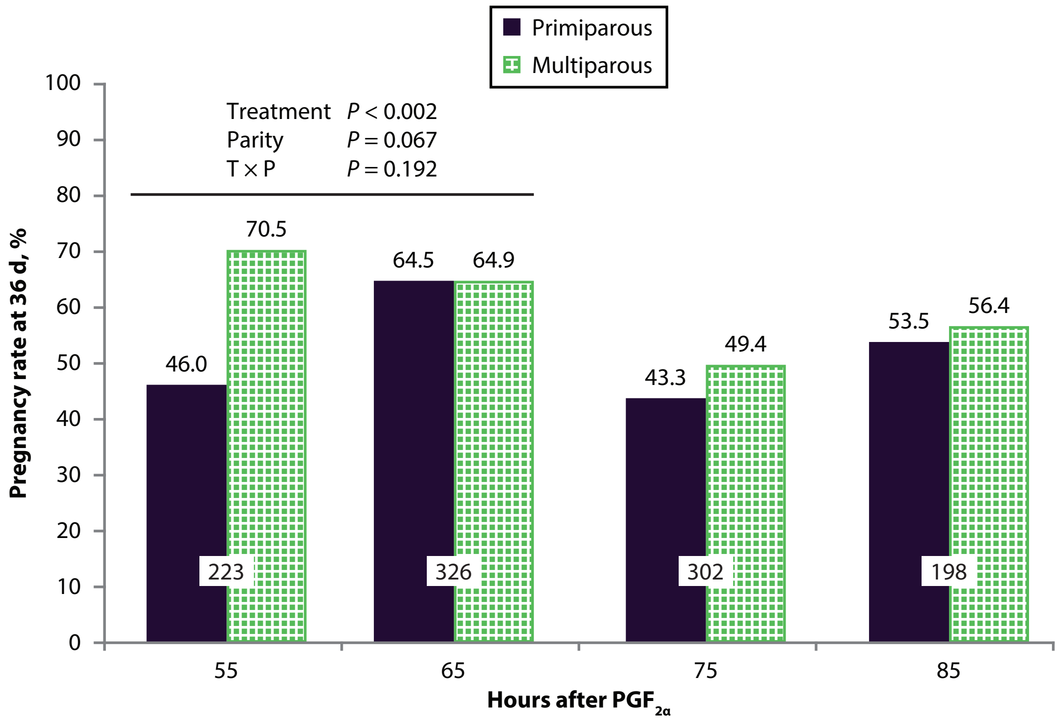

Figure 3. Pregnancy rate in primiparous and multiparous suckled beef cows at 36 d after artificial insemination by transrectal ultrasonography. Cows in the 55- and 65-h treatments were inseminated if estrus-detection patches were activated (>50%) by 55 or 65 h after removal of a CIDR insert and injection of $PGF_{2\alpha}$. The remaining nonestrous cows in both groups received GnRH at 55 or 65 h but were inseminated at 75 or 85 h, respectively. Thirteen cows were not present for this pregnancy diagnosis.

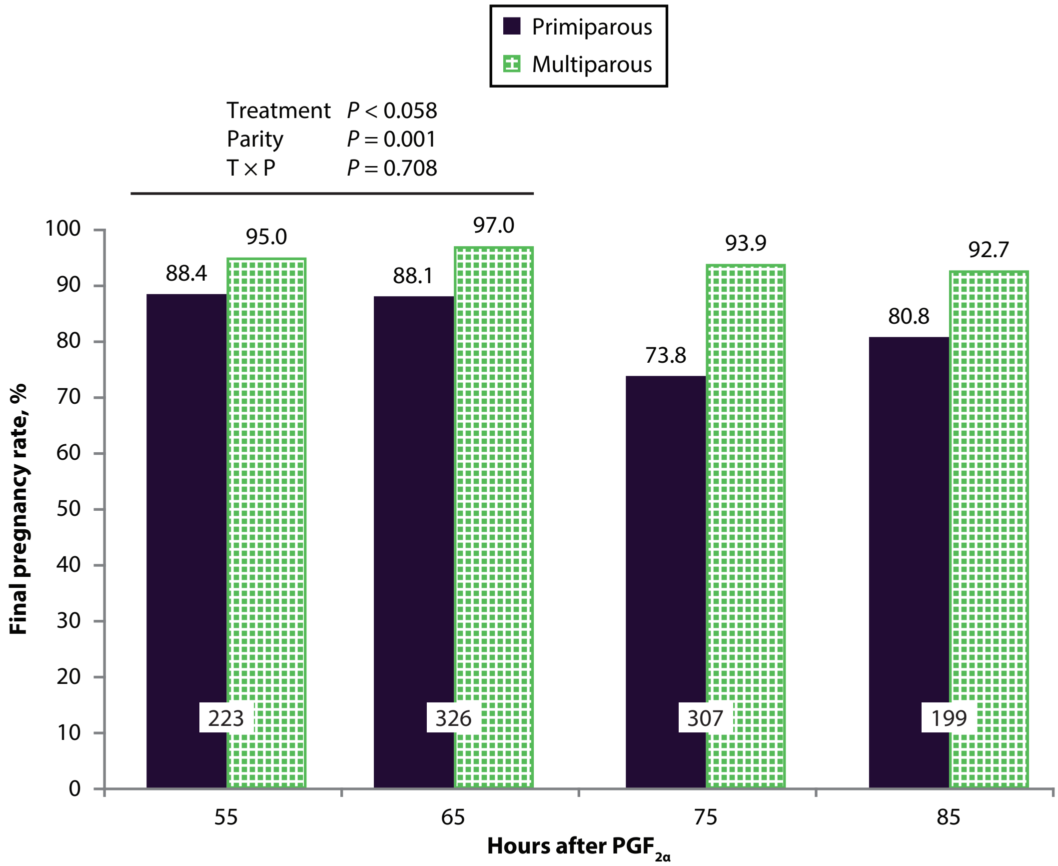

Figure 4. Final end of breeding season pregnancy rate in primiparous and multiparous suckled beef cows. Cows in the 55- and 65-h treatments were inseminated if estrus-detection patches were activated (>50%) by 55 or 65 h after removal of a CIDR insert and injection of $PGF_{2\alpha}$. The remaining nonestrous cows in both groups received GnRH at 55 or 65 h but were inseminated at 75 or 85 h, respectively. Cows were exposed to cleanup bulls beginning 10 d after AI.

Using Modified Intensive Early Stocking for Grazing Replacement Heifers

Keith Harmoney and John Jaeger

Introduction

Even though Kansas native rangelands often have steep slopes or shallow soils not conducive to many other uses other than livestock grazing, native rangeland and perennial grassland acres in Kansas have been declining. Cropland acreage over this same time frame has increased, and so has rangeland fragmentation into small ranchettes and urbanization. Producers may be looking to increase production efficiency on a shrinking forage land base. The use of intensive early stocking (IES) is one the most efficient stocking strategies to produce beef on rangeland acres. The IES strategy has been widely used in eastern Kansas and is capable of increasing beef production by 30-40% compared to continuous season long stocking (SLS). In western Kansas, IES and continuous SLS have resulted in similar beef production. However, a modified IES (MIES) system, which combines greater early season animal density on high-quality forage of IES, and late season individual animal selectivity for a high-quality diet of SLS, has increased beef production by 26% compared to continuous SLS alone on western Kansas rangelands. Even with this significant increase in production efficiency, stocker production is largely overshadowed by cow/calf production in terms of acres grazed in western Kansas. The question then arises, can the efficiencies of greater beef stocker production from modified IES be utilized with reproductive animals of the cow/calf production system? The purpose of this study was to compare the use of continuous SLS and MIES in a replacement heifer system for western Kansas.

Experimental Procedures

High percentage Angus and Angus crossbred replacement heifers were either stocked at 1.6× the typical stocking density May through July and at 1× for the rest of the season in a modified IES system, or at 1× for the entire season in a continuous SLS system. Pastures averaged 35 acres in size and consisted mostly of limy upland ecological sites. Stocking consisted of 8 heifers or 13 heifers per pasture in the SLS and MIES pastures, respectively. Heifers were checked by transrectal ultrasonography between 30 and 35 days after fixed time artificial insemination (AI) to determine pregnancy and were checked again at the end of the grazing season to determine final pregnancy. One bull was placed in each pasture 10 days after timed AI and remained on pasture for 35 days. Heifers determined not pregnant to artificial insemination in the 1.6× IES system were removed in mid-July while all heifers, regardless of pregnancy status, remained on pasture in the 1× continuous system. In cases when not enough AI pregnant heifers in the 1.6× IES system could be retained to meet the late 1× stocking density, the oldest non-AI pregnant heifers remained on pasture while the youngest were removed. Heifer body weight and body condition score (BCS) were collected in May at the start of the grazing season, in mid-July at mid-season, and again in October at the end of the grazing season. Standing available herbage biomass was also collected from pastures at the grazing season midpoint in July, and again at the end of the grazing season in October by sample estimates from a falling plate meter calibrated to clipped sample plots at each harvest. At midseason, a modified step-point sampling method was also used to estimate ground cover and vegetative species composition.

Results and Discussion

Heifer body weight and body condition score were not different between the two stocking treatments at any time during the grazing season (Table 1). However, early individual average daily gain (ADG) from May to July was slightly greater (1.84 vs 1.72 lb/day) for the continuous SLS group compared to the MIES group (Table 2). This difference disappeared during the last half of the grazing season, and animals had similar ADG for the last half of the grazing season and for the combined whole grazing season. Because animals were stocked at a greater density in the MIES pastures early in the season, the MIES treatment had greater total beef production during the first half of the growing season, and subsequently had 38% greater beef production per acre for the whole grazing season (Table 2). First service conception rate (FSCR) was not different between stocking treatments. Because heifers not pregnant to AI were removed from MIES pastures at mid-season, the MIES pastures had a higher percentage of AI-bred heifers remaining on pasture at the end of grazing, forming a more uniform and synchronized group.

Available herbage dry matter at mid-season in July was greater for the MIES pastures by 145 lb/acre, but available herbage dry matter was not different between stocking systems in October at the end of the growing season (Table 3). Both stocking systems averaged just over 1900 lb/acre of residual available herbage at the end of three growing seasons. Litter cover (Table 4) and species composition of most dominant and subdominant grasses and forbs were not different between stocking systems before or after initiation of the experiment. Two species did have significant composition changes after stocking treatments were imposed. Composition of sand dropseed (*Sporobolus cryptandrus*) and sedges (*Carex* sp.) significantly declined in the continuous SLS pastures but did not change in the MIES pastures (Table 4). Both of these species comprise only a small percentage of total vegetative composition, so these differences may have only small or minimal biological impact on the pasture system.

Implications

The MIES system appears to be ideally suited for the production of replacement heifers. The use of a synchronization protocol and early pregnancy detection with ultrasonography enables the removal of non-AI pregnant heifers at the grazing season mid-point. This creates a uniform group of heifers remaining on pasture at the end of the grazing season. Individual weight gain-trends and gains per acre of the MIES system with replacement heifers closely resembles the improved production efficiency of MIES observed in long-term stocker steer grazing research.

Table 1. Heifer body weights and condition scores in early May at the start of the grazing season, at mid-July at mid-grazing season, and at the end of the grazing season in early October, averaged over 2015-2017

Heifer stocking treatment	May weight	May BCS	July weight	July BCS	October weight	October BCS	Heifer FSCR	Pasture AI Remain
	lb		lb		lb		%	%
Continuous SLS	772	5.5	909	5.7	986	5.5	52	51
Modified IES	770	5.5	900	5.7	989	5.5	44	69

Heifer FSCR to timed AI and percent of heifers pregnant to AI left on pasture at the end of season is also included.

Table 2. Early grazing season, late grazing season, and total season individual ADG and total beef produced per acre for replacement heifers stocked with a continuous SLS system or a 1.6×+1 modified IES system averaged over three years, 2015-2017

Heifer stocking treatment	May-July ADG	July-October ADG	Total ADG	May-July beef	July-October beef	Total beef
	lb/hd	lb/hd	lb/hd	lb/acre	lb/acre	lb/acre
Continuous SLS	1.84*	1.03	1.42	34*	19	52*
Modified IES	1.72*	1.09	1.40	52*	20	72*

*Indicates statistically different values at the $P \leq 0.05$ level.

Table 3. Pasture available herbage dry matter (DM) yield determined by falling plate meter readings correlated with clipped frame samples in July and October of 2014 prior to grazing treatments and in 2015-2017 at mid-season and after grazing

	Heifer stocking treatment			
	July		October	
	Continuous SLS	Modified IES	Continuous SLS	Modified IES
	Available DM (lb/acre)			
2014 pretrial	1310	1428	1568	1754
2015	1866	1909	1558	1590
2016	2482	2195	2413	2359
2017	2112	1919	1857	1754
Average 2015-2017	2153*	2008*	1943	1901

*Indicates statistically different values at the $P \leq 0.05$ level.

Table 4. Pasture ground cover and species composition in 2017, and significant change in composition of sand dropseed (SPCR) and sedges *(Carex)* from 2014, prior to grazing treatments, to 2017

	Litter cover 2017	SPCR 2017	2014-2017 Change	*Carex* 2017	2014-2017 Change
			%		
Continuous SLS	88	3.0	-1.4*	5.1	-4.4*
Modified IES	84	2.3	0.0*	5.3	-0.1*

*Indicates statistically different values at the $P \leq 0.05$ level.

Can Modified Intensive Early Stocking Be Used in Cow/Calf Production?

Keith Harmoney and John Jaeger

Introduction

Intensive early stocking (IES) was introduced nearly a half century ago in eastern Kansas and has since been adopted as a major management tool to increase animal production, efficiency of production, and economic return on tallgrass rangelands. These increases have come almost exclusively by using IES with young stocker animals. Intensive early stocking and its gains have been proven effective repeatedly in published research. A similar modified IES (MIES) system has increased production efficiency of stocker animals on western Kansas rangelands. Perennial grassland acres for cattle production, as well as cattle numbers, are declining. Using management practices that mimic a MIES system to increase beef cattle stocking density for breeding herds may allow producers to maintain or increase cow numbers for beef production on fewer perennial grassland resources. The objective of this project is to compare cow and calf growth and performance in traditional continuous season-long stocking (SLS) and MIES beef production systems.

Experimental Procedures

On native mixed-grass rangelands, 211-225 total cow/calf pairs at two locations were stocked at either 1.45× the typical stocking density May through November, or at a typical 1× density during the growing seasons of 2015-2017. The grazing study occurred at the Saline Experimental Range in northeast Ellis County, and the HB Ranch in southern Trego County. Both stocking treatments were implemented at both locations. Calves from 1.45× cows were weaned mid-growing season in late July and were backgrounded in a feedlot, thus reducing pasture stocking rate and density for the last portion of the grazing season. Calves from 1× cows were weaned in October. Cow body weights and body condition scores (BCS) were measured at the start of grazing in May, at the grazing mid-point in late July, and at the end of the grazing season in October. Calf weights were also recorded at these times. Additional calf weights were measured at approximately 4 and 8 weeks after weaning time periods. Cows were synchronized for artificial insemination (AI) and pregnancy was determined 30-35 days following AI and at the end of the grazing season by using transrectal ultrasonography. All pastures were monitored for plant species composition, ground cover, and biomass along transects at representative ecological sites to compare rangeland health between MIES and continuous stocking systems. Available herbage dry matter (DM) was measured through a double sampling protocol of clipped sample plots calibrated to readings from a falling plate meter, while ground cover and species composition were estimated with a modified step-point technique along the same transects. Cows were intermingled during the winter, managed together, and had access to the same stockpiled winter rangeland and short-term feed resources until being sorted into their respective stocking treatments at grazing turnout in May.

Results and Discussion

Cow body weight (Table 1) was similar between grazing treatments at the start of each grazing season. Cow BCS (Table 2) was also similar for both grazing treatments at the start of the 2015 grazing season. Cow body weight and BCS were similar for both grazing treatments each year at the midpoint of the grazing season at the end of July (Table 1). Cow body weight and BCS were always greatest in October for cows from the MIES group. Even though MIES cows were stocked at a greater density, early-weaning calves in late July still allowed the MIES cows to gain condition each fall. The MIES cows retained some of this greater body condition through the winter and subsequently started with a greater body condition in both the 2016 and 2017 grazing seasons (Table 2). Cow grazing treatment did not affect cow first service conception rate (FSCR), but final conception rate was greater for the MIES grazing treatment (Table 1). Greater average cow BCS to start the grazing season in the MIES cow group may have benefitted final pregnancy rate. Averaged over all three years, calf body weight was not different for the two grazing treatments at any time during the growing season.

Total available herbage dry matter was similar between grazing treatments in the year prior to the study and was also similar between grazing treatments at the midpoint in late July and the end of grazing in October for each of the three study years (Table 3). Average total available herbage between the two stocking treatments was consistently within 150 lb/acre at all sampling dates. In three years, vegetative species composition had not changed significantly between the two grazing treatments for any of the species monitored (data not shown).

Implications

The use of an MIES system appears to be a suitable stocking strategy to increase cow/calf units while maintaining rangeland productivity. Cows in the MIES system with early weaning had similar or improved values for most production characteristics, including beginning and end of season BCS and final pregnancy rate. Returns from both systems, at present, are similar. At the current animal production level, the current variable cost pricing level, and current livestock pricing levels, a cost and returns budget showed that the MIES system provided an estimated return of $25.60/acre (including all costs of carrying more cows), while the continuous SLS system provided an estimated return of $24.87/acre.

Table 1. Cow body weights and BCS, and calf body weights at the start of the grazing season, at the end of July at mid-grazing season, and at the end of the grazing season

	Stocking treatment	
	Continuous SLS	Modified IES
Cow May weight, lb	1131	1169
Cow May BCS	5.09*	5.32*
Calf May weight, lb	188	189
Cow July weight, lb	1256	1270
Cow July BCS	5.31	5.40
Calf July weight, lb	377	376
Cow October weight, lb	1267*	1365*
Cow October BCS	5.22*	5.74*
Calf October weight, lb	555	568
Cow FSCR, %	45.5	54.9
Cow Final Conception Rate, %	86.0*	91.0*

*Indicates statistically different values between treatments at the $P \leq 0.05$ level.
Cow FSCR to timed AI and final conception rate is also included.

Table 2. Cow BCS at the start of grazing each year for 2015-2017, and the average over all three years

	Year			
Stocking treatment	2015	2016	2017	Average
Continuous SLS	5.17	5.26*	4.84*	5.09*
Modified IES	5.27	5.56*	5.13*	5.32*

*Indicates statistically different values between treatments at the $P \leq 0.05$ level.

Table 3. Pasture available herbage DM yield determined by falling plate meter readings calibrated with clipped frame samples in the fall of 2014 prior to grazing treatments, and in 2015 to 2017 at mid-season in July and after the growing season in October

	Cow stocking treatment			
	July		October	
	Continuous SLS	Modified IES	Continuous SLS	Modified IES
	Available DM (lb/acre)			
2014			1831	1861
2015	2298	2260	1997	1980
2016	2655	2526	2365	2279
2017	1970	2026	1579	1584
Average 2015-17	2308	2271	1980	1948

Interseeding Warm-Season Annual Grasses into Perennial Cool-Season Western Wheatgrass Pasture

Keith Harmoney and John Guretzky[1]

Introduction

Conversion of pastureland into cropland has occurred at a rapid rate on the central to northern Great Plains. A reduction in total acreage of pastureland from this conversion has resulted in a decline of total numbers of beef cows in the same region. One method to mitigate the decline in cow numbers is to increase carrying capacity of the remaining pastureland acres. Introducing warm-season annual grass species into perennial cool-season grass pastures to increase dry matter production during the mid-summer time period that perennial cool-season grasses would be most dormant is one strategy that may be able to boost production. An increase in production during this time period could result in an overall increase in total land area biomass production to be able to maintain or increase the number of cow units per acre of pastureland.

Experimental Procedures

Five warm-season annual grasses [forage sorghum (*Sorghum bicolor*), sudangrass (*Sorghum bicolor* ssp. *drummondii*), sorghum-sudangrass hybrid, pearl millet (*Pennisetum glaucum*), and corn (*Zea mays*)] were no-till-drilled into perennial cool-season western wheatgrass pasture within a randomized complete block design experiment with four replications. Western wheatgrass was harvested at a 4-inch height in late spring prior to annual warm-season grass seeding in 2015. Following wheatgrass harvest, warm-season annual grasses were no-till drilled in 12-inch row spacings at a seeding depth of one inch. At the time of emergence, plots were then broadcast fertilized with 60 lb of N/acre. Also, shortly after emergence, population density was measured in the center two rows of each subplot. Warm-season grasses were harvested at a 6-inch height for yield determination at 45 and 90 days after planting with a self-propelled flail harvester. Warm-season annual grasses harvested at 45 days were allowed to accumulate regrowth and were also harvested at 90 days to represent a 2-cut system, while annual grasses harvested one time at 90 days represented a 1-cut system. Western wheatgrass growing in plots the following year was harvested again in late spring to determine production effects of prior year warm-season grass interseeding. The experiment was repeated at a different field location in 2016.

Results and Discussion

Western wheatgrass yields prior to seeding warm-season annual grasses and the year after seeding warm-season annual grasses were not different among the annuals for either the 2015 or 2016 seeding. Therefore, seeding warm-season annuals had no effect on western wheatgrass yield the next year. The lack of rainfall in 2015 during the end of May and all of June reduced dry matter yield production potential of western wheatgrass. Following wheatgrass harvest in June, soil was dry, and lacked precipitation for germination of annual warm-season grasses until mid-July. In 2015, emergence and

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establishment of annual warm-season grasses was poor. Pearl millet was the only annual warm-season grass that established a population of more than 10,000 plants/acre. Annual warm-season grasses desiccated under continued dry conditions before harvest and resulted in 0 population at time of harvest. The 2016 seeded annual warm-season grasses, with more abundant precipitation resulting in excellent stands, had much greater emergence and survival than in 2015. Annual warm-season grass yields were greatest for sudangrass and sorghum-sudangrass in 2016, and yield from a 1-cut harvest system was typically greater than the total yield of the 2-cut harvest system. The lack of any effect on western wheatgrass yield following the 2015 warm-season annual grass seeding could be attributed to the lack of moisture and lack of any growth of the warm-season grasses during the summer of 2015 to affect western wheatgrass the next spring. However, in 2016, ample moisture was present for annual warm-season grasses to establish and to accumulate abundant yield. Even though more than 1-2 ton/acre of forage was produced by some warm-season annual grasses during 2016, this forage growth had no effect on subsequent western wheatgrass yield the next spring.

Implications

Summer precipitation had the greatest effect on the success or failure of warm-season annual grasses to provide extra forage when interseeded into cool-season grass pasture. With average summer precipitation, interseeding warm-season annual grasses from the sorghum family into semi-dormant western wheatgrass pasture provided abundant extra forage. During years of low summer precipitation, this management practice involves much greater risk.

Table 1. Western wheatgrass dry matter yield prior to planting warm-season annual grasses into wheatgrass stubble, and dry matter yield the year after seeding

Warm-season grass species	Western wheatgrass DM yield Seeding year 2015	2nd year 2016	Seeding year 2016	2nd year 2017
	------------------------------------ lb/acre ------------------------------------			
Sorghum-sudangrass	1351	5642	2357	3288
Sudangrass	1447	4755	2502	3614
Pearl millet	1384	5374	2918	3693
Corn	1257	4754	2548	3870
Forage sorghum	1604	4658	2733	3313
Non-seeded control	1463	4925	2740	3250

Within a column, no statistical differences were detected within any year.

Table 2. Annual warm-season grass early plant populations and total annual warm-season grass yields when seeded into western wheatgrass pasture

Warm-season grass species	2015	2016	One harvest 2016	Two harvests 2016
	------------- plants/acre -------------		------------- lb/acre -------------	
Sorghum-sudangrass	2668 bc	292911 b	4457 ay	2349 az
Sudangrass	5554 b	243955 b	3446 by	1688 abz
Pearl millet	11271 a	613206 a	1138 c	1158 bc
Corn	54 c	50616 c	709 c	848 bc
Forage sorghum	926 c	281295 b	2614 by	1239 bcz
Non-seeded control	0 c	0 c	282 c	570 c

a,b,c = within a year, different letters are significant between grasses at $P \leq 0.05$.
y,z = within a grass, different letters are significant between harvests at $P \leq 0.05$.

Roundup 2018

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