Synchronization of estrus in suckled beef cows for detected estrus and artificial insemination and timed artificial insemination using gonadotropin-releasing hormone, prostaglandin $F_{2\alpha}$, and progesterone[1]

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ABSTRACT: We determined whether a fixed-time AI (TAI) protocol could yield pregnancy rates similar to a protocol requiring detection of estrus, or estrous detection plus TAI, and whether adding a controlled internal device release (CIDR) to GnRH-based protocols would enhance fertility. Estrus was synchronized in 2,598 suckled beef cows at 14 locations, and AI was preceded by 1 of 5 treatments: 1) a CIDR for 7 d with 25 mg of PG $F_{2\alpha}$ (PGF) at CIDR removal, followed by detection of estrus and AI during the 84 h after PGF; cows not detected in estrus by 84 h received 100 μg of GnRH and TAI at 84 h (control; n = 506); 2) GnRH administration, followed in 7 d with PGF, followed in 60 h by a second injection of GnRH and TAI (CO-Synch; n = 548); 3) CO-Synch plus a CIDR during the 7 d between the first injection of GnRH and PGF (CO-Synch + CIDR; n = 539); 4) GnRH administration, followed in 7 d with PGF, followed by detection of estrus and AI during the 84 h after PGF; cows not detected in estrus by 84 h received GnRH and TAI at 84 h (Select Synch & TAI; n = 507); and 5) Select Synch & TAI plus a CIDR during the 7 d between the first injection of GnRH and PGF (Select Synch + CIDR & TAI; n = 498). Blood samples were collected (d –17 and –7, relative to PGF) to determine estrous cycle status. For the control, Select Synch & TAI, and Select Synch + CIDR & TAI treatments, a minimum of twice daily observations for estrus began on d 0 and continued for at least 72 h. Inseminations were performed using the AM/PM rule. Pregnancy was diagnosed by transrectal ultrasonography. Percentage of cows cycling at the initiation of treatments was 66%. Pregnancy rates (proportion of cows pregnant to AI of all cows synchronized during the synchronization period) among locations across treatments ranged from 37% to 67%. Pregnancy rates were greater ($P < 0.05$) for the Select Synch + CIDR & TAI (58%), CO-Synch + CIDR (54%), Select Synch & TAI (53%), or control (53%) treatments than the CO-Synch (44%) treatment. Among the 3 protocols in which estrus was detected, conception rates (proportion of cows that became pregnant to AI of those exhibiting estrus during the synchronization period) were greater ($P < 0.05$) for Select Synch & TAI (70%; 217 of 309) and Select Synch + CIDR & TAI (67%; 230 of 345) cows than for control cows (61%; 197 of 325). We conclude that the CO-Synch + CIDR protocol yielded similar pregnancy rates to estrous detection protocols and is a reliable TAI protocol that eliminates detection of estrus when inseminating beef cows.

Key words: beef cow, synchronization, timed artificial insemination

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INTRODUCTION

Synchronization of estrus has the potential to shorten the calving season, increase calf uniformity, and enhance the possibilities for using AI. The primary obstacle in synchronizing estrus and achieving optimum pregnancy rates in suckled beef cows is overcoming postpartum anestrus. Numerous estrous synchronization protocols using $PGF_{2\alpha}$ (**PGF**), GnRH, and/or a progestin have been developed that induce cyclicity and successfully synchronize estrus in suckled beef cows (Thompson et al., 1999; Lamb et al., 2001, Stevenson et al., 2003b).

To further enhance the use of estrous synchronization by beef producers, the protocols need to limit time and labor, which can be achieved by using 1 of 2 strategies: 1) systems that minimize the number and frequency of handling cows through the cattle-handling facility; and 2) protocols that minimize or eliminate detection of estrus by employing fixed-time AI (**TAI**). The development of TAI protocols (Geary et al., 2001; Lamb et al., 2001; Bader et al., 2005), which eliminates detection of estrus, is an attractive reproductive management tool.

The CO-Synch protocol, in which PGF is administered 7 d after GnRH followed by a second GnRH injection and TAI at 48 h (Geary et al., 2001), yielded pregnancy rates of 52% compared with 54% for the Ovsynch protocol, which is similar to CO-Synch, but the second GnRH injection occurs at 48 h after PGF, and the TAI occurs 12 to 24 h later. When a controlled internal device release (**CIDR**; Pfizer Animal Health, New York, NY) was added to the protocol (Lamb et al., 2001; Stevenson et al., 2003b), pregnancy rates to AI increased from 48 to 59%. However, the efficacy of CIDR-based TAI protocols has not been evaluated concurrently with protocols requiring detection of estrus or estrous detection followed by TAI in suckled beef cows.

Therefore, the objectives of this study were to determine 1) whether a TAI protocol could yield pregnancy rates similar to a protocol requiring detection of estrus; and 2) whether inclusion of a CIDR to GnRH + PGF-based protocols would enhance fertility.

MATERIALS AND METHODS

Locations and Animals

During the spring breeding season (April 1 to June 30) 2003, beef cattle used in this study were managed at 1 of 14 locations in 7 states. Herd size ranged from 91 to 305 cows. A total of 2,626 suckled beef cows were initially submitted for treatment; however, 28 cows were eliminated from the study because they either died, were culled, became ill, or their calf died or became ill prior to the first pregnancy diagnosis. Breed types of cows were British (n = 1080), Continental (n = 533), British × Continental (n = 891), or undetermined (n = 69). The mean number of days postpartum was 68.5 with a range of 17 to 125 d. Average parity was 3.0 ± 1.4 (mean ± SD) with a range of 1 to 12. Body condition scores (scale of 1 to 9; Whitman, 1975) were determined on d −17 relative to PGF, with a mean BCS of 5.4 ± 0.8 (mean ± SD) and a range of 3 to 9. Individual location data are summarized in Table 1.

Treatments

The Institutional Animal Care and Use Committee of the University of Minnesota approved animal-related procedures. Within location, all eligible cattle were inseminated artificially after being assigned randomly to 1 of 5 treatments (Figure 1): **1**) cows received a CIDR containing 1.38 g of progesterone (Pfizer Animal Health) for 7 d with 25 mg of PGF (Lutalyse, dinoprost tromethamine; Pfizer Animal Health) on the day of CIDR removal, followed by detection of estrus and AI during the 84 h after PGF; cows not detected in estrus by 84 h received 100 μg of GnRH (Fertagyl, gonadorelin, Intervet, Inc., Millsboro, DE) and TAI (control; n = 506); **2**) cows received 100 μg of GnRH followed in 7 d with 25 mg of PGF (d 0), followed in 60 h by a second injection of GnRH and TAI (**CO-Synch**; n = 548); **3**) CO-Synch plus a CIDR during the 7 d between the first injection of GnRH and PGF (**CO-Synch + CIDR**; n = 539); **4**) cows received 100 μg of GnRH, followed in 7 d with 25 mg of PGF, followed by detection of estrus and AI during the 84 h cows not detected in estrus received a 100 μg of GnRH and TAI at 84 h (**Select Synch & TAI**; n = 507); and, **5**) Select Synch & TAI plus a CIDR during the 7 d between the first injection of GnRH and PGF (**Select Synch + CIDR & TAI**; n = 498).

For the control, Select Synch & TAI, and Select Synch + CIDR & TAI treatments, a minimum of 3 daily visual observations (at least 45 min each) for estrus began on d 0 and continued for a minimum of 72 h. Cows were determined to be in estrus when they would stand to be mounted by other cows. Inseminations were performed using the AM/PM rule and were performed 9 to 14 h after the first detected estrus.

Pregnancy was diagnosed by transrectal ultrasonography (5-MHz or 7.5-MHz intrarectal transducer, Aloka 500V, Corometrics, Wallingford, CT) between 30 and 35 d after AI or TAI to determine the presence of a viable fetus, thereby assessing AI pregnancy rates. A second pregnancy diagnosis was performed at 9 locations (IL-1, IL-2, IN, MN-2, MN-3, MT, OH-2, OH-3, and OH-4) between 80 and 100 d after AI or TAI to determine overall pregnancy rates. Exposure to live bulls (clean-up bulls) was not initiated until a minimum of 10 d after AI or TAI to ensure a detectable difference between pregnancies initiated by AI from those resulting from natural matings by clean-up bulls.

At 12 locations, subsequent calving data were recorded resulting in 1,752 total births. Of the total births, 994 were the result of AI after initial treatments, whereas 758 births were the result of pregnancies initiated by clean-up bulls. Duration of gestation and sex ratios were assessed.

Table 1. Characteristics of cows at each location including number of cows treated, breed composition, days postpartum, parity, minutes, cycling percentage, and number of AI technicians and sires

Location[1]	N	Breed origin	Days postpartum,[2] mean and range	Parity, mean and range	BCS,[3] mean and range	Cyclicity,[4] %
IL-1	116	British	73.0	3.1	5.8	83
			37 to 104	1 to 9	4.0 to 7.5	
IL-2	91	Continental	74.1	2.2	6.2	81
			32 to 98	1 to 9	4.5 to 7.5	
IN	149	British, British × Continental	57.3	4.9	5.2	90
			38 to 77	2 to 11	4.0 to 7.0	
KS-1	291	British × Continental	75.8	3.7	5.3	63
			49 to 108	2 to 9	3.0 to 6.5	
KS-2	258	British × Continental	69.1	1.9	4.6	68
			23 to 112	1 to 2	3.0 to 6.3	
MN-1	172	Continental	61.1	—	5.3	76
			24 to 116		4.0 to 7.0	
MN-2	131	Continental	64.7	3.0	5.0	91
			26 to 125	1 to 9	4.0 to 6.0	
MN-3	159	British × Continental	62.2	—	5.3	49
			27 to 92		4.5 to 6.0	
MT	299	Continental, British × Continental	61.1	3.7	5.3	48
			17 to 80	1 to 11	3.0 to 7.0	
OH-1	118	British, British × Continental	80.2	—	6.2	—
			37 to 120		4.0 to 9.0	
OH-2	172	British × Continental	76.2	1.4	5.7	—
			49 to 108	1 to 2	4.0 to 7.0	
OH-3	144	British, Continental	70.8	3.3	4.8	40
			29 to 105	1 to 11	3.0 to 7.0	
OH-4	193	British × Continental	66.8	2.6	5.7	38
			29 to 100	1 to 3	3.0 to 8.0	
TN	305	British, British × Continental	69.5	4.6	5.7	84
			37 to 90	2 to 12	4.0 to 7.0	

[1]Location abbreviations refer to each of 14 herds among 7 states.
[2]Days postpartum at initiation of the breeding season (d 0).
[3]BCS on 1 to 9 scale (1 = emaciated and 9 = obese; Whitman, 1975).
[4]Percentage of cows cycling at initiation of treatments (d –7).

Blood Collection and RIA

At 12 of the 14 locations (blood was not collected at the OH-1 and OH-2 locations because appropriate handling facilities were not available), blood samples were collected via venipuncture of either jugular or tail vein on d –17 and d –7 relative to the injection of PGF. Blood was centrifuged (3,000 × *g* for 10 min) and serum or plasma was recovered and stored at –20°C until RIA. Blood serum or plasma was analyzed for concentrations of progesterone in the laboratory of individual investigators, according the validation procedures of the progesterone RIA in each laboratory. Either serum or plasma was acceptable because the goal of assessing concentrations of progesterone was to determine estrous cycle status. When at least 1 of 2 blood samples had concentrations of progesterone ≥1 ng/mL, the cow was considered to be cycling at the initiation of treatments (Perry et al., 1991). The intraassay CV ranged from 2.8 to 7.2% among all locations, whereas the interassay CV ranged from 4.6 to 9.9% among all locations.

Definition of Terms

Clean-up TAI: after 72 h of estrous detection, cows that were not detected in estrus were inseminated at a fixed time. Conception rates: the proportion of cows that became pregnant to AI of those exhibiting estrus during the synchronization period. Pregnancy rates: the proportion of cows pregnant to AI of all cows synchronized during the synchronization period. Overall pregnancy rates: the proportion of all cows pregnant after AI and a period of bull exposure.

Statistical Analyses

Procedures GLM and CATMOD of SAS (SAS Inst. Inc., Cary, NC) were used to analyze all categorical data, and procedure GLM was used to analyze noncategorical data. Proportions of cows cycling at the onset of treatments were analyzed with location as a fixed effect and days postpartum and BCS as regression covariables. The model excluded the OH-1 and OH-2 locations because blood samples were not collected at those 2 locations.

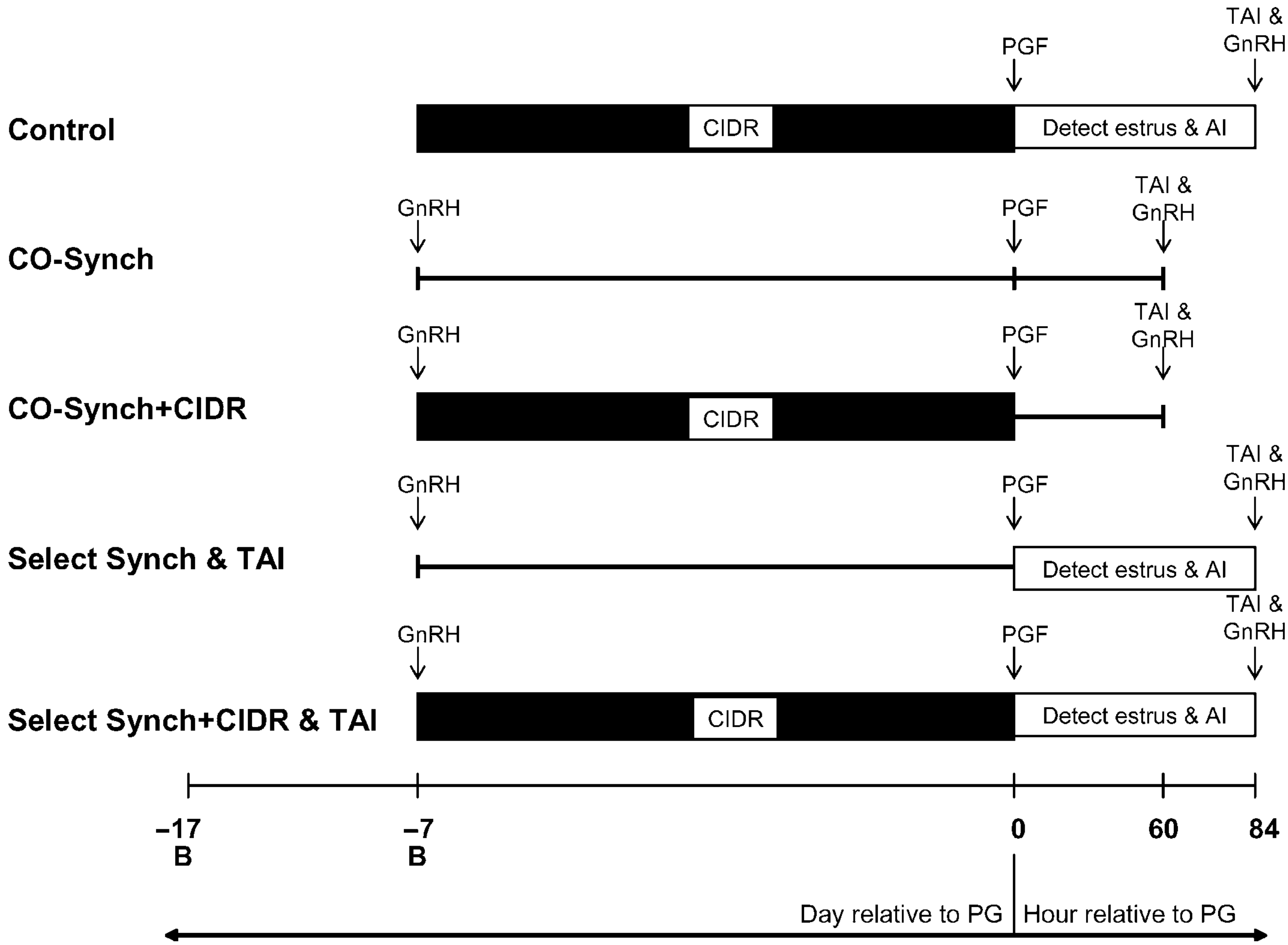

Figure 1. Experimental protocol for estrous synchronization treatments. Blood (B) samples were collected on d –17 and –7. PGF = prostaglandin $F_{2\alpha}$; CIDR = controlled internal device release; TAI = timed AI.

The model used to analyze pregnancy rates included treatment, location, and estrous cycle status assessed before the onset of treatment and all interactions with treatment, days postpartum and minutes as regression covariables. Eleven of the 14 locations used both primiparous and multiparous cows, and parity was included in the model for these cows, whereas cows from MN-1, MN-2, and OH-1 were excluded from this analysis. Because breed composition, AI sires, and AI technicians were confounded with location, they were not included in the model, but reasonable attempts were made to ensure that they were distributed evenly among treatments at each location.

Models used to analyze calving dates and sex ratios included treatment and location, plus the treatment × location interaction. Orthogonal contrasts were used to compare pregnancy rates, sex ratios, and duration of gestation between TAI (CO-Synch and CO-Synch + CIDR) and estrus-detected (control, Select Synch & TAI, Select Synch + CIDR & TAI) cows or CIDR-treated (control, CO-Synch + CIDR, and Select Synch + CIDR & TAI) and nonCIDR-treated (CO-Synch and Select Synch & TAI) cows.

The models used to analyze outcomes in which cows were observed for estrus and AI time included treatment, location, and estrous cycle status at the onset of treatment and all interactions with treatment. Because estrus was only detected as part of 3 treatment protocols, CO-Synch and CO-Synch + CIDR treatments were excluded from the model.

Within each model, analyses were conducted to ensure that no biases existed among treatments based on days postpartum, parity, BCS, and estrous cycle status.

RESULTS

Estrous Cycle Status

Blood samples collected from cows at each location at d –17 and –7 indicated that an average of 65.8% (1,455 of 2,212) of cows were cycling before treatment initiation. Proportions of cycling cows among locations ranged from 38 to 91% and were influenced by location, parity, and BCS (Table 1). A parity effect ($P < 0.001$) was detected in which 39.9% of the primiparous cows and 71.3% of multiparous cows were cycling. Percentages of cows cy-

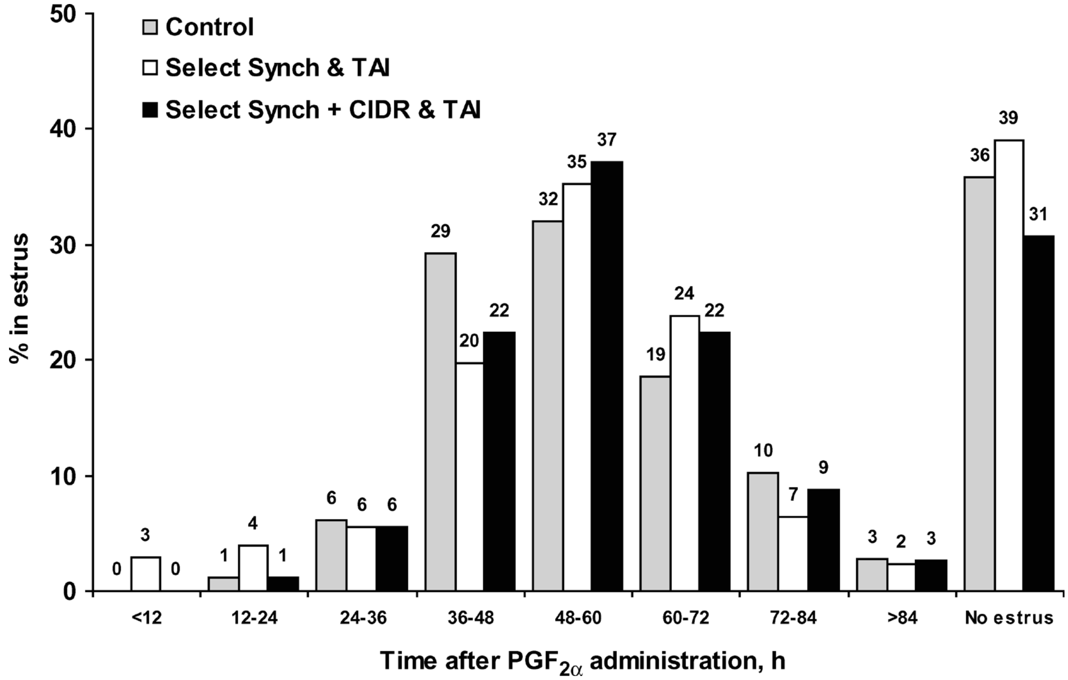

Figure 2. Distribution of estrus in control cows (shaded bars) and those treated with Select Synch & TAI (open bars), or Select Synch + CIDR & TAI (black bars). Numbers above bars represent the percentage of all females treated within each treatment.

cling were greater ($P < 0.05$) for cows with a BCS of 5 to 5.9 (66.7%) and those ≥6 (72.3%) than for cows with a BCS of <5 (53.4%). Pregnancy rates to AI also were greater ($P < 0.05$) for cycling (54.7%; 819 of 1,497) than for noncycling cows (45.9%; 350 of 762).

For every unit increase in BCS over the range 3.0 to 9.0, the proportion of cows cycling increased ($P < 0.001$) by 11.5 ± 3.2%. In a similar fashion, for every 10-d increase in days postpartum at the onset of the breeding season (range of 17 to 125 d), cyclicity increased ($P < 0.001$) by 5.5 ± 0.6%.

Characteristics of Estrus and AI

For cows in the control, Select Synch & TAI, Select Synch + CIDR & TAI treatments, estrus was detected during 84 h after the PGF injection, at which time all cows not detected in estrus were inseminated. A tendency ($P = 0.062$) occurred for a greater percentage of cows in the Select Synch + CIDR & TAI treatment (69.3%) to be detected in estrus than in the Select Synch & TAI treatment (60.9%), whereas the control cows (64.2%) were intermediate. No interaction was detected among location and treatment.

Time from PGF injection to estrus for those cows exhibiting estrus was similar among control (52.8 ± 0.9 h), Select Synch & TAI (51.5 ± 0.9 h), and Select Synch + CIDR & TAI (53.4 ± 0.8 h). Similarly, time from PGF injection to AI for those cows exhibiting estrus was similar among treatments (x = 63.5 h). Distribution of estrus between the injection of PGF and 84 h was similar among treatments (Figure 2). Regardless of treatment, interval from 48 to 60 h after PGF injection yielded the greatest estrous response. Of cows detected in estrus, 34.8% exhibited estrus during this interval.

Our goal was to ensure that the clean-up TAI in control, Select Synch & TAI, and Select Synch + CIDR & TAI treatments occurred at 84 h after PGF. Average interval to TAI was similar among the control, Select Synch & TAI, Select Synch + CIDR & TAI treatments (x = 83.9 h). Although no location × treatment interaction was detected, a location effect ($P < 0.05$) was apparent in which the shortest interval occurred at the IN location and the longest interval was at the IL-1 location (Table 2).

Similarly, in the 2 TAI treatments (CO-Synch and CO-Synch + CIDR), our aim was for the TAI to occur at 60 h after PGF. Average interval was 63.1 h for both treatments. No location × treatment interaction was detected, but a location effect ($P < 0.01$) was obvious in which the shortest interval to TAI occurred at the OH-1 location and the longest interval at the IL-1 location (Table 2).

Conception and Pregnancy Rates

Pregnancy rates to AI (Table 3) were similar among Select Synch + CIDR & TAI (58.0%), CO-Synch+CIDR (53.8%), Select Synch & TAI (53.0%), and the control (52.5%) treatments, but were greater ($P < 0.01$) than the CO-Synch (43.4%) treatment.

No location × treatment interaction was detected; however, when pregnancy rates among all treatments were combined within each location, a location effect ($P <$

Table 2. Location effects on interval from $PGF_{2\alpha}$ to timed AI (TAI) for cows assigned to TAI treatments (CO-Synch and CO-Synch + CIDR) and cows receiving a clean-up AI in estrous detection treatments (control, Select Synch & TAI, Select Synch + CIDR & TAI)[1]

	CO-Synch and CO-Synch + CIDR treatment		Control, Select Synch & TAI, Select Synch + CIDR & TAI	
Location[2]	No. of cows	Interval, h mean ± SEM and range	No. of cows	Interval, h mean ± SEM and range
IL-1	46	71.7 ± 0.33^{r} 70.6 to 72.8	39	92.2 ± 1.22^{x} 94.0 to 97.0
IL-2	36	62.1 ± 0.38^{s} 61.7 to 62.7	12	86.4 ± 2.59^{xy} 85.9 to 86.8
IN	58	61.0 ± 0.29^{t} 60.1 to 62.7	17	82.2 ± 1.89^{z} 80.4 to 82.9
KS-1	164	61.5 ± 0.18^{st} 57.8 to 64.9	64	82.3 ± 0.94^{z} 81.1 to 84.0
KS-2	101	63.5 ± 0.22^{u} 61.6 to 65.6	57	86.1 ± 0.99^{y} 85.6 to 87.4
MN-1	73	67.1 ± 0.26^{v} 62.3 to 71.8	28	85.4 ± 1.44^{yz} 87.0 to 90.0
MN-2	53	65.7 ± 0.31^{w} 63.3 to 68.0	39	83.8 ± 1.26^{z} 85.8 to 87.5
MN-3	64	60.1 ± 0.29^{tx} 57.8 to 63.5	17	86.4 ± 1.89^{y} 85.0 to 88.3
MT	119	65.6 ± 0.21^{y} 63.6 to 68.0	53	87.1 ± 1.05^{y} 86.6 to 90.3
OH-1	49	59.3 ± 0.33^{x} 59.5 to 61.0	13	87.9 ± 1.08^{y} 87.5 to 88.0
OH-2	69	59.6 ± 0.29^{x} 58.6 to 63.8	35	83.9 ± 1.06^{z} 83.0 to 85.2
OH-3	56	60.3 ± 0.31^{tx} 57.6 to 63.5	15	83.5 ± 2.20^{z} 82.4 to 85.2
OH-4	78	61.3 ± 0.25^{st} 59.5 to 63.5	30	83.9 ± 1.14^{z} 83.3 to 86.3
TN	121	64.8 ± 0.20^{z} 61.6 to 66.8	82	90.5 ± 0.84^{x} 85.4 to 93.1

[r–z]Means within a column without a common superscript letter differ, $P < 0.05$.
[1]CIDR = controlled internal device release. See experimental design of treatments in Figure 1.
[2]Location abbreviations refer to each of 14 herds among 7 states.

0.01) on AI pregnancy rates was observed (Figure 3). Pregnancy rates among locations ranged from 37% (MN-2 location) to 67% (IL-2 location), whereas those at the remaining 12 locations were intermediate. No difference in pregnancy rates occurred among treatments when cows were separated into 3 BCS groups: <5, from 5 to 5.9, and ≥6. However, conception rates were greater ($P < 0.05$) for cows that calved >50 d before the onset of the breeding season (53.3%), than for those that calved ≤50 d before the onset of the breeding season (46.0%). In addition, for every 10-d increase in days postpartum at the onset of the breeding season (range 17 to 125 d), conception rate increased ($P < 0.05$) by 1.1 ± 0.6%.

Of the 2,267 cows in which parity was known, 1,847 multiparous cows and 420 primiparous cows were treated. Multiparous cows (53.7%) tended ($P = 0.085$) to have greater AI pregnancy rates than primiparous cows (47.9%). No interaction was detected between parity and treatment.

Among the protocols in which estrus was detected (control, Select Synch & TAI, and Select Synch + CIDR & TAI), conception rates were greater ($P < 0.05$) for Select Synch & TAI (70.2%; 217 of 309) and Select Synch + CIDR & TAI (66.7%; 230 of 345) cows than for control cows (60.6%; 197 of 325). In contrast, conception rates for those cows that were not detected in estrus and inseminated at 84 h were greater ($P < 0.05$) for the Select Synch & TAI (38.6%; 59 of 153) and control (38.1%; 69 of 181) cows than for Select Synch + CIDR & TAI cows (26.3%; 52 of 198).

Among the 8 locations in which a second pregnancy diagnosis was performed, overall pregnancy rates did not differ among treatments with the control, CO-Synch, CO-Synch + CIDR, Select Synch & TAI, and Select Synch + CIDR & TAI treatments yielding overall average pregnancy rates of 92.2%. In addition, embryonic survival among the same 8 locations between the first and second diagnosis of pregnancy was similar among all treatments with an average survival rate of 96.7%.

Gestation and Sex Characteristics

Calving data during the subsequent calving season was assessed for 1,752 calves at 12 locations (Table 4).

Table 3. First-service AI pregnancy rates in suckled beef cows after estrous synchronization using $PGF_{2\alpha}$, GnRH, and (or) a controlled internal device release (CIDR)

Item	Treatment[1]					Overall
	Control	CO-Synch	CO-Synch + CIDR	Select Synch & TAI	Select Synch + CIDR & TAI	
	No. (%)					
Conception rates[2]						
At estrus	197/325 (61)	—	—	217/309 (70)	230/345 (67)	644/979 (66)
TAI	69/181 (38)	—	—	59/153 (39)	52/198 (26)	180/532 (34)
AI pregnancy rates[3]	266/506^x (53)	238/548^y (43)	290/539^x (54)	269/507^x (53)	289/498^x (58)	1352/2598 (52)
Estrous cycle status[4]						
Cycling	154/282 (55)	142/316 (45)	165/278 (59)	175/291(60)	170/288 (59)	806/1455 (55)
Noncycling	74/147 (51)	57/155 (37)	84/178 (47)	59/141 (42)	73/136 (54)	347/757 (46)
Parity[5]						
Primiparous	38/84 (45.2)	33/84 (39.3)	49/89 (55.1)	37/86 (43.0)	48/85 (56.5)	205/428^x (47.9)
Multiparous	196/365 (53.7)	178/400 (44.5)	222/394 (56.3)	205/362 (56.6)	207/355 (58.3)	1007/1876^y (53.7)
BCS						
<5	43/85 (51)	39/100 (39)	54/96 (56)	42/79 (50)	34/67 (51)	212/427 (50)
5 to 6	115/231 (50)	114/252 (45)	140/268 (52)	114/231 (49)	137/237 (58)	620/1219 (51)
≥6	105/183 (57)	80/182 (44)	93/163 (57)	108/182 (59)	110/181 (61)	496/891 (56)
Days postpartum						
≤50	36/85 (42)	29/90 (32)	46/89 (52)	42/91 (46)	53/93 (57)	206/448^x (46)
51 to 60	52/83 (63)	42/91 (46)	52/88 (59)	34/79 (43)	40/66 (61)	220/407^y (54)
61 to 70	50/100 (50)	45/108 (42)	57/107 (53)	56/98 (57)	60/104 (58)	268/517^y (52)
71 to 80	63/116 (54)	73/149 (50)	76/134 (57)	75/120 (63)	63/115 (55)	350/631^y (55)
>80	65/122 (53)	49/113 (43)	59/121 (49)	62/119 (52)	73/120 (61)	308/595^y (52)

^{x,y}Percentages within an item and row without a common superscript letter differ, $P < 0.05$.
[1]See experimental design of treatments in Figure 1.
[2]Conception rates for cows inseminated after a detected estrus or at TAI at 84 h. Conception rates = cows that became pregnant to AI over those exhibiting estrus during the synchronization period.
[3]Pregnancy rates = cows pregnant to AI over all cows synchronized during the synchronization period.
[4]Estrous cycle status excludes OH-1 and OH-2 locations.
[5]Parity data excludes MN-1, MN-3, and OH-1 locations.

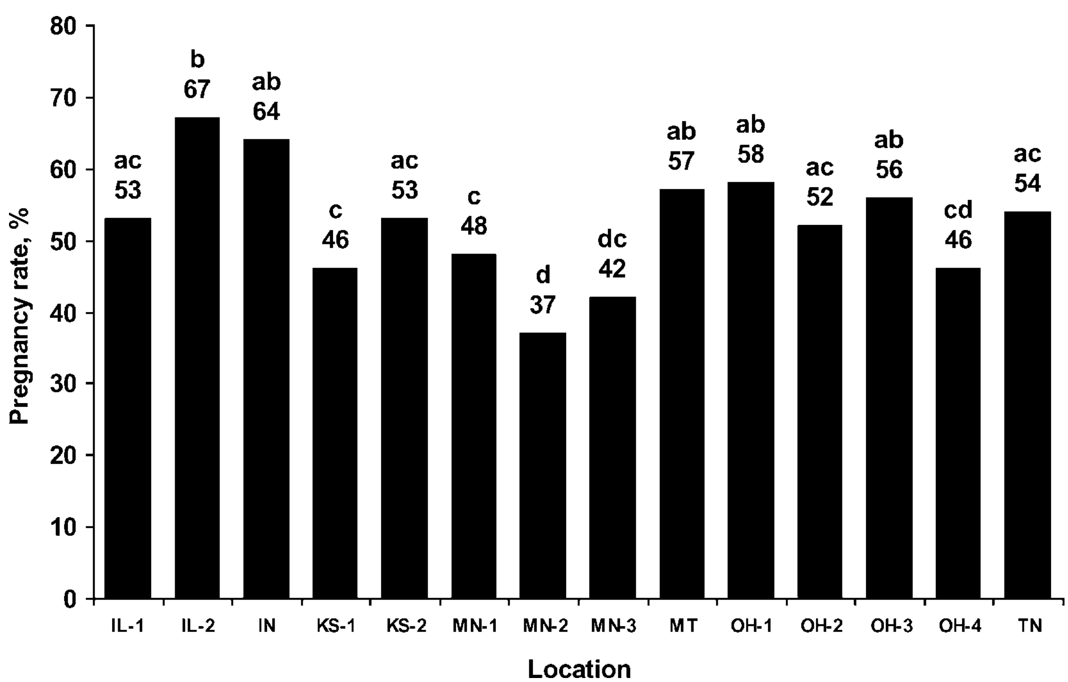

Figure 3. Overall first-service AI pregnancy rates among locations. Location abbreviations refer to each of 14 herds among 7 states. $^{a-d}$Location effect ($P < 0.05$).

Table 4. Calving and sex characteristics after estrous synchronization of suckled beef cows using $PGF_{2\alpha}$, GnRH, and (or) a controlled internal device release (CIDR)

Item	Treatment[1]						
	Control	CO-Synch	CO-Synch + CIDR	Select Synch & TAI	Select Synch + CIDR & TAI	Overall	*P*-value
Calving date	Days ± SE (no. of births)					Days ± SD	
Average gestation length of AI-sired calves[2]	281.8 ± 0.4 (185)	281.8 ± 0.4 (185)	282.2 ± 0.4 (217)	281.7 ± 0.3 (202)	281.9 ± 0.3 (205)	281.7 ± 5.2 (994)	0.882
Average calving interval after day 0[3]	298.8 ± 1.0 (335)	298.2 ± 1.0 (369)	297.5 ± 1.0 (356)	296.9 ± 1.0 (350)	296.4 ± 1.0 (342)	297.3 ± 17.7 (1752)	0.351
Sex ratio	Ratio (no. of calves)					Ratio (no.)	
Sex ratio for AI-sired calves[4]	0.54 (158)	0.49 (148)	0.50 (175)	0.57 (172)	0.53 (188)	0.53 (841)	0.887
Sex ratio for clean-up-bull-sired calves[5]	0.51 (136)	0.50 (141)	0.57 (112)	0.47 (129)	0.54 (116)	0.52 (635)	0.926

[1]See experimental design of treatments in Figure 1.
[2]Determined for cows pregnant after estrous synchronization, estrous detection and AI, or timed AI (TAI).
[3]Includes all cows calving during the subsequent calving season.
[4]Proportion of male calves born of those sired by AI after estrous synchronization.
[5]Proportion of male calves born of those sired by clean-up bulls.

Of the 1,752 calvings, 994 calves (56.7%) were the result of AI after estrus synchronization. Average duration of gestation among all AI-sired calves was 281.9 ± 5.2 d (× ± SD), and the range was 258 to 296 d. Duration of gestation was similar among treatments, but a location effect (P < 0.0001) was detected, which may have included breed, sire and managements differences. Cows at the IL-1 location had the shortest gestation period (279.4 ± 0.7 d), whereas those at MN-2 had the longest gestation period (287.1 ± 0.7 d). Period of gestation was greater (P < 0.001) for male (282.9 ± 0.2 d) than for female calves (280.9 ± 0.2 d), and single calves were carried 3.0 d longer (P < 0.05) than multiple calves.

For those cows from which calving data was recorded, the average interval from PGF injection (d 0 of the study) to calving among all cows was 297.3 d with a range of 258 to 373 d (Figure 4). Although average calving interval was similar among treatments, a (P < 0.001) location effect was detected. Average calving interval was shortest (P < 0.05) at the IN (293.4 ± 1.5 d) location, whereas the MN-2 (305.2 ± 1.7 d) location had the longest average calving interval from PGF.

At calving, sex was recorded in 1,490 calves; there were 770 (52.2%) male calves compared with 704 females. In addition, 15 sets of twins and a single set of triplets were recorded. Sex ratio of calves that conceived to AI at estrous synchronization favored (P < 0.01) bulls (i.e., 52.7% of 841 calves born were male). Similarly, of the 635 calves that conceived to clean-up bulls, 51.7% were male. No difference was detected in sex ratio for AI compared with natural-sired calves. Multiple birth rate for AI-sired calves [1.1% (9 of 850)] was similar (P > 0.05) to that of calves sired by clean-up bulls [0.9% (6 of 641)].

DISCUSSION

Estrous synchronization has the potential to shorten the calving season, increase calf uniformity, and enhance the possibilities for utilizing AI. Difficulty associated with detection of estrus is one of the primary reasons that many cattle producers do not use AI in their herds (NAHMS, 1994). Therefore, eliminating the need for detection of estrus should encourage AI use in beef management systems. To enhance further use of estrous synchronization by beef producers, the protocols need to reduce time and labor, which can be achieved by reducing the number of times cows are moved through a working facility and (or) by eliminating detection of estrus.

More recently developed TAI protocols (Geary et al., 2001; Lamb et al., 2001; Bader et al., 2005) have provided attractive reproductive management tools, which should stimulate producers to consider AI in their operations. An additional strategy that reduces the time and labor associated with detection of estrus is a brief period of estrous detection followed by TAI for cows that were not detected in estrus. Using this strategy, detection of estrus may be limited to fewer than 3 d, and all females will have been inseminated artificially. Therefore, we

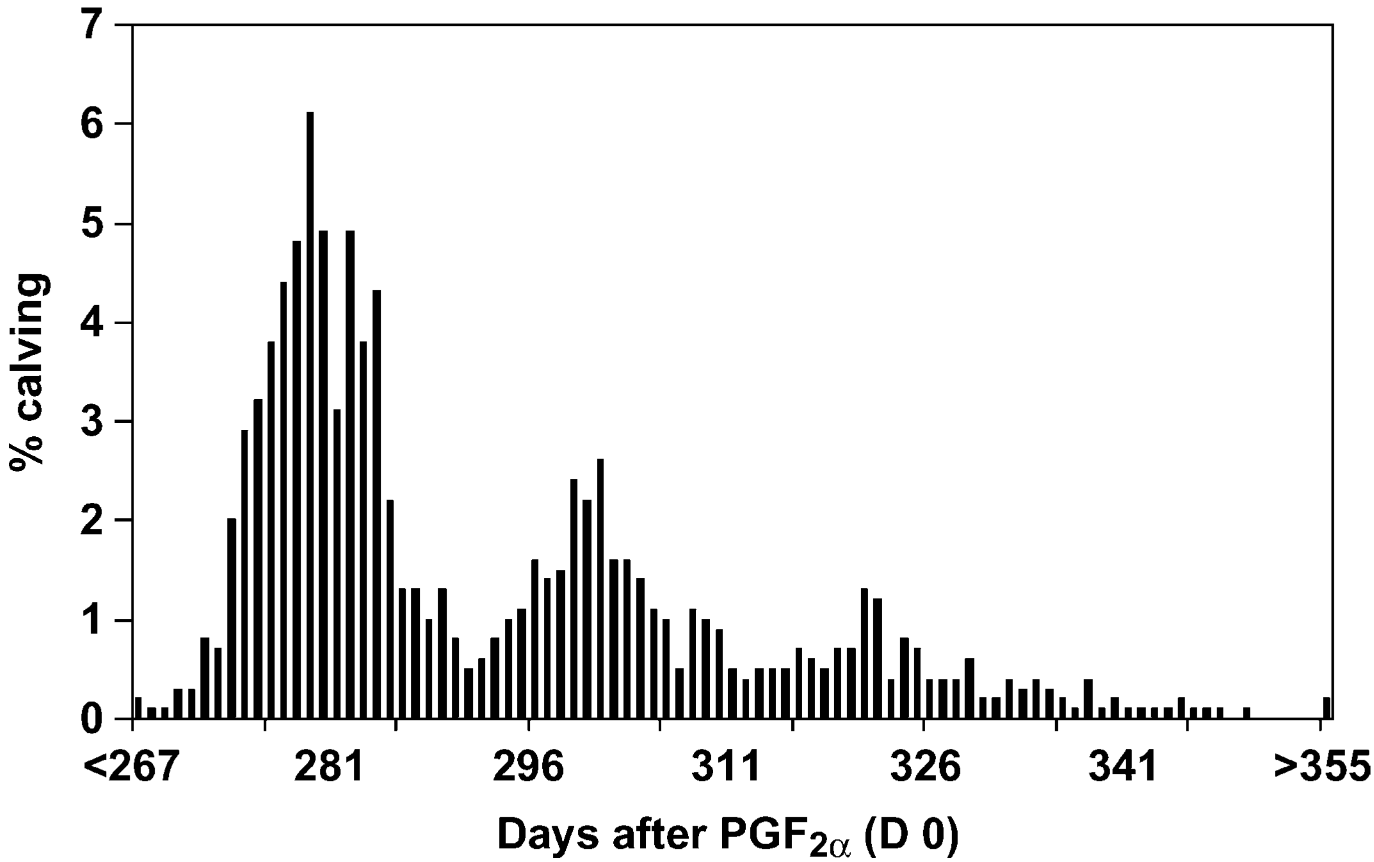

Figure 4. Frequency distribution of gestation length for all treated cows calving during the subsequent calving season.

hypothesized that a TAI protocol could yield pregnancy rates similar to a protocol requiring detection of estrus and that inclusion of a CIDR to GnRH + PGF based protocols might enhance fertility.

A primary obstacle in the success of synchronizing estrus and achieving optimum pregnancy rates in suckled beef cows is the fact that a large percentage of cows are anestrus at the onset of the breeding season. Cyclicity of cows in this study ranged from 38% to 91% at 12 locations. These results are consistent with previous studies (Stevenson et al., 2000, 2003b; Lamb et al., 2001), indicating the large variability in the percentage of cycling females among cattle operations. Numerous estrous synchronization protocols using PGF, GnRH, and (or) a progestin have been developed that induce cyclicity and successfully synchronize estrus in suckled beef cows (Stevenson et al., 2000; Lamb et al., 2001, Stevenson et al., 2003a). The current study confirms that AI-pregnancy and conception rates in cows that were cycling at the initiation of the breeding season are greater than those in cows that were not cycling at the beginning of the breeding season.

Comparison of the CO-Synch and CO-Synch + CIDR treatments indicated that addition of a CIDR to provide supplemental progesterone improved pregnancy rates after a TAI. Herein, pregnancy rates in CO-Synch and CO-Synch + CIDR averaged 43 and 54%, respectively. In 2 earlier reports, pregnancy rates for CO-Synch were 52 (Geary et al., 2001) and 48% (Lamb et al., 2001), respectively. The apparently poor pregnancy rates for CO-Synch in this study could be partially explained by differences in intervals from PGF to TAI. The interval from PGF to AI for CO-Synch in previous studies was 48 h, whereas that interval in the current study was 60 h. Addition of progesterone to the CO-Synch protocol (CO-Synch + CIDR) potentially prevents the premature occurrence of estrus prior to or following PGF (Twagiramungu et al., 1995; Kojima et al., 2000; Geary et al., 2001). Cycling cows with low concentrations of progesterone at the time of PGF without the CIDR could have been in proestrus or in estrus shortly before or immediately after PGF (Lamb et al., 2001). Therefore, a decrease in pregnancy rates may occur as a result of altering the interval from PGF to TAI from 48 to 60 h. An alternative explanation could be that the positive effect of the CIDR-inducing cyclicity in noncycling cows, resulting in a greater proportion of cows having an opportunity to become pregnant at TAI (Lamb et al., 2001).

Surprisingly, BCS of cows did not seem to enhance fertility, despite an increase in BCS of just one unit resulting in an 11.5% increase in the proportion of cows cycling at the onset of the breeding season. In our previous report (Lamb et al., 2001), we noted that an increase in BCS of a single unit resulted in a 23% increase in the proportion of cows pregnant to AI after ovulation synchronization. All treatments in this study either used

GnRH and (or) a CIDR. The ability of these products to induce cycling activity may attenuate the negative effects associated with lower body condition. For example, Thompson et al. (1999), using ultrasonography, scanned the ovaries of 40 early postpartum, suckled beef cows before, during, and after treatments of GnRH and (or) norgestomet and reported that luteal structures were induced from dominant follicles in 75% of the noncycling cows, resulting in elevated progesterone after 7 d. In contrast, Stevenson et al. (2000) reported that the rates of induced ovulation for noncycling cows treated with GnRH 7 d before $PGF_{2\alpha}$ (Select Synch) were 38% and 49%, respectively, in two experiments, whereas the rates of induced ovulation for noncycling cows treated with Select Synch plus a norgestomet implant were 17% and 28% in 2 experiments.

During the period of estrous detection (from the PGF injection to TAI), the 3 estrous detection treatments (control, Select Synch & TAI, and Select Synch + CIDR & TAI) had similar intervals to first detected estrus. However, during that 84-h period, 9% fewer Select Synch & TAI cows were detected in estrus than Select Synch + CIDR & TAI cows. A disadvantage of the Select Synch & TAI protocol is that approximately 10 to 20% of suckled beef cows exhibit estrus prior to and immediately after the PGF injection (Stevenson et al., 2000; DeJarnette et al., 2001a,b). Unless these cows are detected in estrus and inseminated, most will fail to become pregnant when inseminated later at a fixed TAI. Addition of progesterone in the Select Synch + CIDR & TAI protocol potentially prevents premature occurrence of estrus prior to or following PGF. Presynchronizing estrus in suckled beef cows with melengestrol acetate (Stegner et al., 2004) or lactating dairy cows with a CIDR (Xu and Burton, 1998) increased the percentage of beef cows expressing estrus after PGF and shortened the interval from the start of the breeding season to conception in dairy cows.

Pregnancy rates to the clean-up AI in the 3 estrous detection treatments ranged from 26.3 to 38.6%. This resulted in an increase of 9 to 11% in pregnancy rates that would not have been accounted for had cows not been inseminated. Although pregnancy rates were relatively low in comparison to conception rates, clean-up TAI is essential to achieve pregnancy rates similar to those achieved by the CO-Synch+CIDR & TAI protocol, which requires no estrous detection.

Gestation length is influenced by numerous factors including; breed, parity, sex of the calf, year of birth, and single vs. multiple progeny (Gregory et al., 1979; Bourdon and Brinks, 1982; Azzam and Nielsen, 1987; Cundiff et al., 1998). In the current study, gestation length was similar among treatments and averaged 282 d among all AI-sired calves and was similar to previous reports (Bourdon and Brinks, 1982; Azzam and Nielsen, 1987). Average gestation length, however, was shorter than the 286 d (Cundiff et al., 1998) and 287 d (Reynolds, et al., 1990) reported in earlier studies. Shorter gestation periods in the current study might have resulted from the genetic origin of the cows and potentially from using AI sires selected for calving ease. A majority of the females in our study were of British or British × Continental origin and tend to have shorter gestation periods than Continental cows and those of *Bos Indicus* origin (Gregory et al., 1979; Cundiff et al., 1998).

Sex ratio at calving revealed no differences among treatments. Overall, 53% of calves sired by AI were born male, and 52% of clean-up-bull sired calves were born male. The sex ratio favored male calves regardless of whether cows conceived to AI after estrus synchronization or after natural mating. These results confirm previous studies (Gardner, 1950; Ballinger, 1970; Foote, 1977) indicating that sex ratio was not altered by time of insemination and that a greater proportion of male calves was born.

Comparison of CO-Synch and CO-Synch + CIDR treatments indicated that addition of a CIDR to provide elevated concentrations of progesterone improved pregnancy rates after a fixed TAI at 60 h. Comparison among control, Select Synch & TAI, and Select Synch + CIDR & TAI revealed that addition of a CIDR likely reduced the incidence of premature expression of estrus prior to the PGF injection and thereby enhanced the percentage of cows detected in estrus after PGF. A combination of estrus detection before a TAI at approximately 84 h proved effective in reducing the time and labor associated with this estrous synchronization protocol. In addition, the CO-Synch + CIDR treatment yielded pregnancy rates similar to estrous detection before an 84 h TAI treated cows, indicating that a TAI protocol in the absence of estrous detection appears to be a suitable option for synchronization of estrus in beef cows. Our results, however, also indicated that factors associated with individual location, which could include differences in pasture and diet, breed composition, body condition, postpartum interval, and geography, might affect the success of estrous synchronization with PGF, GnRH, and (or) a CIDR.

IMPLICATIONS

Optimal pregnancy rates in beef cattle require more than compliance to a sound estrous synchronization protocol. Estrous cyclicity is a major factor affecting fertility. Body condition, parity, and days postpartum can greatly affect the proportion of cows cycling at the initiation of an estrous synchronization protocol. We have demonstrated that producers can effectively use 2 strategies to enhance the ease and efficiency of implementation of estrous synchronization and also optimize pregnancy rates in beef production systems: 1) a strategy that reduces detection of estrus by combining estrous detection with a clean-up fixed-time artificial insemination; and 2) a fixed fixed-time artificial insemination protocol that includes a controlled internal device release eliminates detection of estrus with all cows inseminated artificially at a single predetermined time. Both strategies are of short duration (less than 10 days) and limit the frequency that cows are handled, allowing artificial insemination to be used as a suitable reproductive management tool for producers.

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