Strategies for Optimizing Reproductive Management of Dairy Heifers

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Take Home Messages

- The overall goal of a replacement heifer program is to rear heifers to reach a desired age and body weight early so that they initiate puberty, establish pregnancy, and calve easily at a minimal cost.
- The economic advantages of using AI to breed dairy heifers exceed those realized when using AI exclusively to breed lactating cows.
- The rate at which heifers become pregnant after reaching puberty is determined by an interaction between service rate and conception rate.
- The primary reason for synchronizing estrus in dairy heifers is to facilitate use of artificial insemination.
- New protocols for synchronization of ovulation and timed AI of dairy heifers are currently being developed.

Age at First Calving

The overall goal of a replacement heifer program is to rear heifers to reach a desired age and body weight early so that they initiate puberty, establish pregnancy, and calve easily at a minimal cost. Research has consistently supported that Lifetime milk yield, 305-day lactation yields, and lifetime profit of replacement heifers are maximized when heifers calve for the first time between 23 and 25 months of age. There are several reasons why age at first calving affects dairy farm profitability. On most farms, an investment of around $1,200 (US) is needed to raise heifers from birth to calving. Heifers that calve earlier spend a greater proportion of their life producing milk, and therefore returning profit to a dairy, whereas heifers that calve later spend more time in a nonproductive period before initiation of lactation.

In addition to delayed income and increased rearing costs, delaying the age at first calving results in a greater number of replacement females needed at any given time to maintain herd size (Table 1). For example, a 1,000-cow dairy with a 38% culling rate and an average age at first calving of 30 months could decrease the number of replacement heifers needed within the rearing system at any given time by 210 heifers and still have enough available replacements to maintain a constant herd size. Decreasing the number of heifers needed to maintain herd size dramatically reduces feed and housing costs associated with the heifer rearing system. Clearly, age at first calving has a profound effect on the profitability of a heifer rearing system. The economic importance of establishing an age at first calving of between 23 and 25 months of age is so great that all other aspects of a replacement heifer management system are oriented toward achieving this goal.

Table 1. Effect of cull rate and age at first calving on the number of replacement heifers needed per year to maintain herd size on a dairy with 100 mature cows* (Adapted from Fricke, 2003).

Cull rate	Age at first calving (mo)					
(%)	**24**	**26**	**28**	**30**	**32**	**34**
24	53	57	62	66	70	75
26	57	62	67	72	76	81
28	62	67	72	77	82	87
30	66	72	77	83	88	94
32	70	76	82	88	94	100
34	75	81	87	94	100	106
36	79	86	92	99	106	112
38	84	91	98	105	111	118
40	88	95	103	110	117	125

*Assumes a 10 % death loss from calving. Each day calving is delayed beyond 24 months of age costs $1.50 to $3.00 per heifer.

▪ Age at First Breeding

Age at first breeding coupled with reproductive efficiency to first and subsequent breedings determines age at first calving because gestation length is a fixed interval (~282 days) once conception occurs. Thus, the major reproductive challenge for breeding age heifers is to achieve conception by 14 to 16 months of age. Rearing heifers to initiate puberty by 11-13 months so that breeding can occur in a timely fashion is critical to the overall success of a heifer rearing program.

Age at onset of puberty is related to body weight, and Holstein heifers normally exhibit their first estrus at a body weight of between 550 to 650 pounds. Nutritional management resulting in poor body weight gain early during development causes reproductive problems because it delays onset of puberty, age at first breeding, and ultimately age at first calving. By contrast, research has consistently shown that nutritional management resulting in excessive prepubertal weight gain reduces milk yield during first and subsequent lactations due to subnormal development of mammary secretory tissue (Head, 1992). Thus, nutritional management of prepubertal heifers profoundly influences age at puberty, age at first breeding and hence age at calving.

Artificial Insemination

Artificial Insemination (AI) breeding programs have long been recommended for dairy producers that raise heifers for herd replacements because of the proven genetic and economic advantages of using AI compared with using natural service bulls for breeding dairy cattle. For example, research estimates a lifetime Net Merit Dollars advantage of $211 for a Holstein cow sired by an average (first-proof) AI bull when compared with a cow sired by an average, proven natural-service bull. This estimate is conservative because dairy managers often select semen from above-average AI bulls and because the genetic merit of an average, proven natural-service bull is greater than that of an average, unproven natural-service bull (Fricke, 1997).

Under most circumstances, the economic advantages of using AI to breed dairy heifers exceed those realized when using AI exclusively to breed lactating cows. On farms using AI, heifers represent the most advanced genetic population of females on the farm. Thus, the genetic merit of AI-sired calves from heifers is superior to that of AI-sired calves from older cows. Based on age, first lactation cows constitute the largest group of cows on a dairy (34%; AgSource/CRI, 2002). Heifer AI programs accelerate genetic progress because calves from heifers contribute proportionately greater numbers of offspring available for herd replacements compared with cows in older age groups. Semen costs per pregnancy and per replacement heifer produced also are lower for heifers because heifers exhibit higher conception rates than lactating cows (Pursley et al., 1997b) and, therefore, require fewer AI services per pregnancy. Lifetime milk yield, 305-day lactation yields, and lifetime profit of replacement heifers are maximized when heifers calve for the first time between 23 and 25 months of age (Head, 1992). Synchronized breeding protocols used in conjunction with AI allow dairy producers to more precisely manage age at first AI service and age at first calving in heifers. Finally, heifer AI programs allow for use of Holstein AI sires with proven calving-ease rather than using bulls of other breeds to avoid dystocia. Thus, the most effective method to accelerate genetic progress and maximize profitability on a dairy operation is to incorporate use of heifer AI breeding programs.

Industry Trends for Use of Artificial Insemination in Dairy Heifers

Despite the overwhelming economic advantages of using AI for breeding heifers, a paradoxical trend exists in the dairy industry. A national survey sponsored by the National Association of Animal Breeders (NAAB) revealed that, depending on herd size, only 55% to 63% of dairy heifers were serviced using AI (Erven and Arbaugh, 1987). A more recent NAAB survey showed that only 62 to 68% of dairy heifers receive at least one AI service (Hogeland and Wadsworth, 1995). Finally, a biannual market survey conducted by Hoard's Dairyman indicates that the reported use of natural service bulls for breeding dairy heifers increased by nearly 6% between 1990 and 1996 and was nearly 10% greater for dairy heifers than for lactating dairy cows (Hoards Dairyman, 1997). Based on these statistics, heifers continue to be the most underutilized genetic resource on dairy farms (Everett, 1989).

Several reasons for the lack of widespread use of AI to breed dairy heifers and for the trend toward increased use of natural service bulls for breeding dairy heifers have been cited. When asked to rank reasons for using natural service bulls to breed heifers, farmers listed "Heifers Not at a Convenient Location", "Inadequate Heat Detection for AI", and "Lack of Time to Supervise AI" among the most important factors contributing to this management practice (Erven and Arbaugh, 1987).

Deciding When to Breed

In general, breeding of dairy replacement heifers should be initiated when heifers reach 60 percent of their mature weight or height (Table 2). Using this benchmark, Holstein heifers are ready to breed at 397 kg or 127 cm. Heifers should be monitored for weight and or height to specifically determine when these criteria are met. Simply guessing at ages, heights and or weights of dairy heifers to determine their eligibility for first breeding is an unacceptable management practice.

Table 2. Breeding criteria for dairy heifers (Adapted from Fricke, 2003).

	Holstein & Brown Swiss		Ayershire & Guernsey		Jersey	
Age	**Weight**	**Wither height**	**Weight**	**Wither height**	**Weight**	**Wither height**
(months)	(kg)	(cm)	(kg)	(cm)	(kg)	(cm)
12	352	124	272	117	236	112
14	397	127	308	122	261	114
16	442	130	349	127	295	117
18	476	132	390	130	331	119

Age at first breeding coupled with reproductive efficiency at first and subsequent breedings determines the heifer's age at first calving. Gestation length is a fixed interval (around 282 days for Holsteins). Thus, the major reproductive challenge for breeding heifers is to achieve conception by 14 to 15 months of age to assure calving ages of 23 to 24 months of age. Age of first breeding of smaller dairy breeds, such as Jerseys, can be reduced by one month because smaller breeds mature earlier. Rearing Jersey heifers to initiate puberty by 11 to 12 months assures that first breeding can occur by 13 to 14 months.

▪ Measuring Reproductive Performance

When monitoring the success of your heifer reproductive program, focus on the following three areas:

1) Service Rate. This measures the proportion of eligible heifers serviced during a given 21-day period. Theoretically, each individual heifer within a group of nonpregnant, pubertal heifers should exhibit estrus once during a 21-day period. Thus, service rate and estrus-detection rate will be the same when breeding heifers based on signs of behavioral estrus. With good management conditions, producers should observe more than 90 percent of heifers in estrus in a 45-day period.

2) Conception Rate. To achieve high conception rates, heifers need to be gaining weight and have adequate body condition at the time of breeding. In addition, timing of AI in relation to behavioral estrus is critical for maximizing conception rate. Research with dairy heifers has shown that immediately breeding a heifer after a detected estrus or only conducting AI breeding once a day results in similar conception rates when compared to AM-PM programs (Gonzalez et al., 1985; Wahome et al., 1985). Provided good management

conditions, heifer raisers should expect conception rates to vary between 50 percent and 70 percent.

3) Pregnancy Rate. The rate at which heifers become pregnant after reaching puberty is determined by an interaction between service rate and conception rate. In general, pregnancy rate can be estimated by the equation:

Pregnancy Rate = Service Rate x Conception Rate

Although pregnancy rate is not always the mathematical product of conception rate and service rate, this equation approximates pregnancy rate in large groups of heifers. Thus, maximizing both conception and service rate provides opportunities for management control of reproduction and profitability in a heifer raising operation. A practical method for determining pregnancy rate is to observe the number of successful outcomes (pregnancies) that occur during periods when eligible heifers are at “risk” to become pregnant (21-day reproductive cycles). Pregnancy rate for groups of heifers can vary between 25 and 50 percent depending on the service and conception rate.

Although the stated goal for a heifer-rearing program is to achieve an average age at calving of between 23 and 25 months of age, heifer raisers should not use this average as a benchmark. Research has shown that delayed breeding causes heifers to become over-conditioned which creates a higher incidence of dystocia and metabolic problems at calving. Therefore, a calving age of 24 months should be considered a maximum age. Figure 1 shows how using an “average” calving age benchmark can be deceiving.

■ Reproductive Performance

The rate at which heifers become pregnant after reaching puberty is determined by an interaction between service rate and conception rate. Although the stated goal for a heifer rearing program is to achieve an average age at calving of between 23 and 25 months of age, measuring reproductive efficiency using an average age at first calving fails to account for the distribution or variation among individual heifers around that average. For many heifer rearing systems, a high proportion of heifers conceive too late and have an unacceptably high age at first calving despite the fact that the average age at first calving for all heifers within the rearing system is at or near the stated goal of between 23 and 25 months of age. This point can be best illustrated using the survival curves shown in Figure 1.

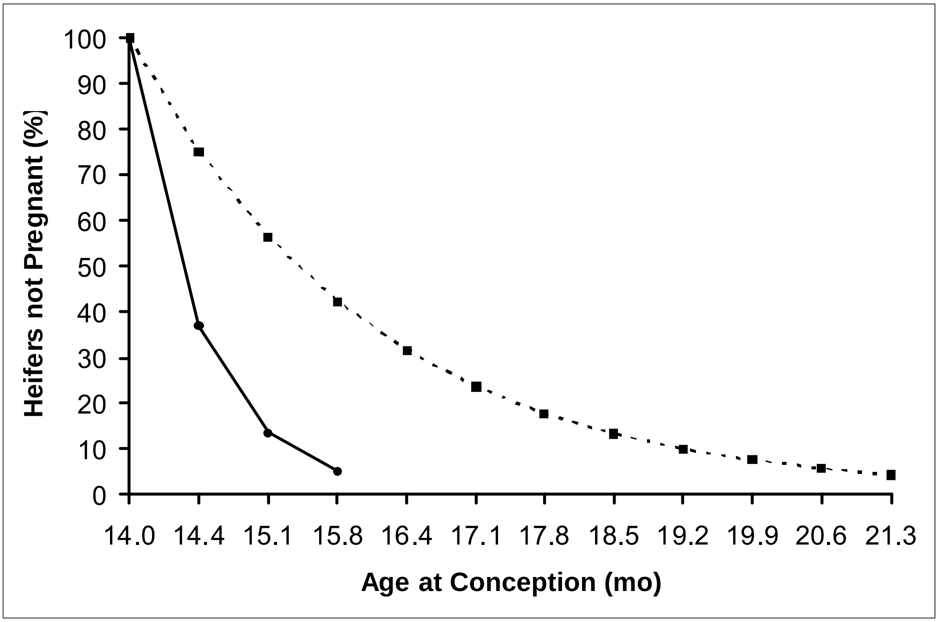

Figure 1. In this scenario, heifers are subjected to estrus detection at 14 months. The broken line shows the rate at which heifers become pregnant under poor reproductive management (a service rate of 40 percent and a conception rate of 50 percent). By contrast, the solid line shows the rate at which heifers become pregnant under excellent reproductive management (a service rate of 90 percent and conception rate of 70 percent). Although the average age at first calving is 25.4 months for the poor-management group of heifers, more than 25 percent of the heifers will not calve until after 26 months of age and 10 percent of the heifers will not calve until after 28 months of age. Clearly, the average age at calving does not reflect an underlying reproductive problem. For the solid line, average age at calving is 23.9 months. But, more important, 95 percent of heifers subjected to excellent reproductive management will calve before 25 months of age (Adapted from Fricke, 2003).

Average age at conception and average age at calving for heifers subjected to poor reproductive management are 16.1 and 25.4 months, respectively. Average age at conception and average age at calving for heifers subjected to excellent reproductive management are 14.7 and 23.9 months, respectively. It is important to understand that both aspects of reproductive management (e.g., service rate and conception rate) must be fully optimized to achieve an average age at calving of between 23 and 25 months as well as a tight distribution around this average age at calving.

■ Development of New Controlled Breeding Programs for Dairy Heifers

The primary reason for synchronizing estrus in dairy heifers is to facilitate use of AI (Xu and Burton, 1999). Effectiveness of current estrus synchronization strategies is limited because dairy producers must rely on visual estrus detection, which is inefficient on most farms, to accurately time AI. In support of this notion, "Inadequate Heat Detection for AI", and "Lack of Time to Supervise AI" were two important factors identified by dairy producers in a national survey as reasons for not using AI to breed dairy heifers (Erven and Arbaugh, 1987). We recently have conducted a series of experiments to develop timed AI protocols for dairy heifers. These research results are summarized in the two studies below.

Ovsynch was the first protocol developed to successfully synchronize ovulation in lactating dairy cows (Pursley et al., 1995). By using Ovsynch, dairy producers need not rely on estrus detection for timing of AI. Rather, cows receive a fixed-time AI in relation to a synchronized ovulation which results in conception rates similar to that of cows receiving AI to a detected estrus (Pursley et al., 1997a). Unfortunately, dairy heifers respond poorly to Ovsynch and fixed-time AI, exhibiting conception rates 20% to 40% lower than heifers receiving AI to a standing estrus (Pursley et al., 1997b; Schmitt et al., 1996). Although we have recommended against using Ovsynch for use in dairy heifers, certain modifications in management during the protocol and of the protocol itself may improve response of heifers to the protocol.

To develop and assess the effectiveness of hormonal breeding protocols for conducting timed AI in Holstein dairy heifers, we recently conducted two experiments on a large heifer growing operation in Wisconsin.

Experiment 1 (Rivera et al., 2004).

Nonlactating Holstein dairy heifers (n = 352) 13 mo of age were managed using a 42-d breeding period in which they were inseminated artificially (AI) after removed tail chalk evaluated once daily. Heifers were assigned randomly to either of two insemination schemes. At the onset of the breeding period (d 0), in one group of heifers ovulation was synchronized (100 µg GnRH, d 0; 25 mg $PGF_{2\alpha}$, d 6; 100 µg GnRH, d 8) before a timed artificial insemination (TAI; d 8); before and after TAI, inseminations were based on removed tail chalk for the entire AI breeding period (GPG; n = 175). A second group of heifers were inseminated during the entire AI breeding period (TC; n = 177) based solely on removed tail chalk.

Key results from this experiment are shown in Table 3. The interval from the onset of AI breeding period to first AI service was greater (p<0.01) for TC than for GPG heifers (9.9 ± 0.6 vs. 7.5 ± 0.1 d), whereas conception rate at 30 d post AI was similar between treatments (46.5% vs. 38.3%, for TC vs. GPG heifers, respectively). No treatment by AI technician interaction was detected (p=0.70); however, AI technician affected (p<0.01) conception rate (Table 4). Thus, the overall poor conception rates in this study can be attributed to differences due to AI technician rather than failure of the protocol itself. Pregnancy loss from 30 to 75 d post AI was 10.2% and was similar between treatments (Table 3).

Table 3. Effect of treatment on pregnancy rate per artificial insemination (PR/AI), pregnancy loss, and cumulative pregnancy rate of Holstein dairy heifers during the 42-d AI breeding period. (Adapted from Rivera et al., 2004).

Item	Treatment[1]		p-value
	TC	**GPG**	
PR/AI to 1st AI at 30 d after TAI[2]			
Overall, %	46.5	38.3	0.12
(no./no.)	(80/172)	(67/175)	
After TAI, %	-	38.2	-
(no./no.)		(55/144)	
After removed tail chalk, %	46.5	38.7	0.44
(no./no.)	(80/172)	(12/31)	
PR/AI to first AI at 75 d[2]			
Overall, %	41.8	34.3	0.15
(no./no.)	(72/172)	(60/175)	
Pregnancy loss, 30 to 75 d[2]			
Overall, %	10.0	10.4	0.98
(no./no.)	(8/80)	(7/67)	
PR/AI to 2nd and 3rd AI at 41 to 66 d after AI			
Overall, %	34.0	42.1	0.25
(no./no.)	(31/91)	(51/121)	
Cumulative pregnancy rate[3]			
Overall, %	58.2	63.4	0.38
(no./no.)	(103/177)	(111/175)	

[1]For GPG heifers, ovulation was synchronized before a timed artificial insemination; before and after TAI, inseminations were based on removed tail chalk during the entire AI breeding period. For TC heifers, inseminations occurred during the entire AI breeding period based solely on removed tail chalk.
[2]Due to variation in the interval from the start of the experiment to first AI among TC heifers, mean (± SEM) intervals for all heifers from first AI to the first and second pregnancy diagnosis were 31.5 ± 0.1 and 74.5 ± 0.3 d, respectively.

[3]Proportion of heifers diagnosed pregnant to AI during the 42 d AI breeding period.

Many heifers that failed to synchronize displayed estrus before the second GnRH injection of the protocol. For GPG heifers, 17.7% (31/175) received AI before the day 8 (Day 5.2 ± 0.2) and did not receive TAI. We have shown a similar response in low-producing lactating dairy cows managed in a grazing-based dairy in Wisconsin (Cordoba and Fricke, 2002). For GPG heifers receiving TAI, 90.9% (131/144) ovulated within 48 h after the second GnRH injection (double ovulation rate=4.9%, 7/144). Thus, heifers that did not display estrus during the protocol synchronized ovulations at a high rate to the second GnRH injection. Blood samples collected from GPG heifers at each injection were classified based on serum progesterone (P) concentrations as High (≥1.0 ng/ml) or Low (<1.0 ng/ml). The proportion of GPG heifers with a functional CL (High P) at $PGF_{2\alpha}$ was 91.6% (132/144), and 96.2% (127/132) of functional CL had regressed (Low P) by 48 h after $PGF_{2\alpha}$. Thus, luteal regression in response to $PGF_{2\alpha}$ was also high in this experiment.

Table 4. Effect of inseminator on pregnancy rate per artificial insemination (PR/AI) of Holstein dairy heifers receiving AI after removed tail chalk (TC) or synchronization of ovulation and timed artificial insemination (GPG). (Adapted from Rivera et al., 2004).

Treatment[1]	Inseminator		
	1	**2**	**3**
TC, %	30.2	33.3	62.6
(no./no.)	(16/53)	(12/36)	(52/83)
GPG, %	20.0	25.0	53.8
(no./no.)	(12/60)	(6/24)	(49/91)
Overall, %	24.8[a]	30.0[a]	58.0[b]
(no./no.)	(28/113)	(18/60)	(101/174)

[a,b]Within a row, percentages with different superscripts differ (P < 0.01). Treatment by inseminator interaction was not significant (P = 0.70).

[1]For GPG heifers, ovulation was synchronized before a timed artificial insemination; before and after TAI, inseminations were based on removed tail chalk during the entire AI breeding period. For TC heifers, inseminations occurred during the entire AI breeding period based solely on removed tail chalk.

We conclude that the GPG synchronization protocol assessed in the present study can yield acceptable fertility in dairy heifers if AI to estrus is conducted between the two GnRH treatments and AI efficiency is optimized. Such a protocol may be useful for dairy producers who wish to breed a group of heifers within an 8 d period and reduce the need for extended periods of estrus detection. Furthermore, use of this protocol will concentrate return services for heifers failing to conceive to first AI and may allow for development of systematic resynchronization protocols for second AI. Expression of estrus during the protocol greatly reduces the synchronization response to the GPG protocol. Therefore, we conducted a second study focused on increasing the proportion of heifers receiving TAI and reducing the necessity for estrus detection was conducted.

Experiment 2 (Rivera et al., 2003).

The objectives of this study were 1) to evaluate the effect of a Controlled Internal Drug Releasing (CIDR) device as a tool to increase the proportion of heifers submitted to TAI after receiving a hormonal protocol for synchronization of ovulation, and 2) to determine the effect of CIDR devices to resynchronize dairy heifers for a second AI service. We hypothesized that inclusion of CIDR between the first 2 injections of the GPG protocol will eliminate the necessity of estrus detection before $PGF_{2\alpha}$, and that resynchronization using CIDR devices would result in a tighter synchrony of estrus for heifers failing to conceive to TAI.

Holstein dairy heifers (n = 189) were subjected to a 42 d AI breeding period in which they received AI after once daily evaluation of removed tail chalk. At AI breeding period onset (d 0), heifers were randomly assigned to receive synchronization of ovulation (100 µg GnRH, d 0; 25 mg $PGF_{2\alpha}$, d 6; 100 µg GnRH d 8) and timed artificial insemination (TAI) at the time of the second GnRH injection either without (GPG; n=95), or with inclusion of a CIDR device (CIDR; n = 94) from d 0 to d 6.

No CIDR heifers received AI before d 8 compared to 24 % of GPG heifers, and pregnancy rate per artificial insemination (PR/AI) at 30 d after TAI did not differ between treatments (32 vs. 29% for CIDR vs GPG heifers, respectively; Table 5). To synchronize estrus for second AI service, heifers (n = 166) receiving TAI to first service were randomly assigned to receive no further treatment (Control; n = 85) or insertion of a new CIDR device from d 14 to d 20 after TAI (Resynch; n = 81). No Resynch heifers received AI during CIDR treatment compared to 33 % of Control heifers, and the proportion of heifers receiving AI within 72 h after the d of CIDR removal was 78 vs. 50 % for Resynch vs. Control heifers, respectively. Resynch heifers had a greater PR/AI at second or greater insemination than Control heifers (47 vs. 26 %). No treatment by inseminator interaction was detected for first or second AI; however, overall PR/AI was low for heifers throughout the experiment due to poor performance of two of the three herd inseminators (14, 6, and 58 %). Inclusion of a CIDR device suppressed estrus during the TAI protocol with no detrimental effect on PR/AI, and resynchronization of estrus using a CIDR device resulted in tighter synchrony of return to estrus among heifers for second AI.

Inclusion of a CIDR device in a protocol for synchronization of ovulation suppressed estrus during the protocol thereby allowing a 100% submission rate for TAI without affecting fertility. Due to the strong inseminator effect detected in this study, PR/AI do not represent the expected results for dairy heifers managed under excellent conditions. In contrast, the high synchronization response in this study shows that inclusion of CIDR for a TAI protocol can be successfully implemented when estrus detection is a limiting factor for AI programs in dairy heifers. The inclusion of CIDR alone for resynchronization of a second AI service in dairy heifers is a useful practice to obtain a tight synchrony of estrus in heifers that failed to conceive to TAI and to avoid mistakes due to erroneous estrus detection.

Table 5. Effect of treatment on pregnancy rate per artificial insemination (PR/AI) and pregnancy loss for Holstein dairy heifers after first timed artificial insemination (TAI).

Item	Treatment		p-value
	CIDR	**GPG**	
PR/AI to 1st AI at 30 d after insemination			
Overall, %	32	29	0.75
After TAI, %	32	31	0.19
After removed tail chalk, %	-	26	-
PR/AI to first AI at 65 d after insemination			
Overall, %	30	27	0.74
Pregnancy loss, 30 to 65 d after insemination			
Overall, %	7	7	0.97

Effect of Inseminator on PR/AI.

A key finding from both of these experiments was the profound effect of inseminator on PR/AI. Most herd-level variation in conception rate among heifers is due to variation among inseminators (Ron et al., 1984). Barth (1993) reported that timing of AI, semen quality, semen handling, and inseminator expertise influenced fertility to AI in cattle. Improper semen placement in the reproductive tract also affects fertility to AI with over half of inseminators evaluated depositing semen into the cervix rather than correctly depositing it into the uterine body (Peters et al., 1984; López-Gatius, 1999). A common mistake was for inseminators to deposit semen in the cervix while withdrawing the pipette during AI (Zavy and Geisert, 1994). The unanticipated low PR/AI due to inseminator in these field trials conducted on a commercial custom heifer grower serves as a teachable moment for dairy farmers and the consultants in the dairy industry who advise them.

Conclusion

The most effective method to accelerate genetic progress and maximize profitability on a dairy operation is to breed dairy heifers using AI. We have made some progress in developing protocols that allow for fixed-time AI in heifers by modifying the Ovsynch protocol and using CIDR devices. Research is ongoing to develop methods for successful timed AI in dairy heifers.

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