The Why, How-to, & Cost of Programmed A.I.-Breeding of Dairy Cows

By Jeffrey S. Stevenson, Ph.D.
Professor, Reproductive Physiology
Kansas State University
Manhattan, KS 66502-0201

Western Dairy Management Conference

The Why, How-to, & Cost of Programmed A.I.-Breeding of Dairy Cows

Management of the estrous cycle is now more practical than it was a decade ago because of our understanding of ovarian follicular waves. With availability of three gonadotropin-releasing hormone (GnRH) products and two prostaglandin products, the cycle can be controlled for fixed-time inseminations with little loss in conception rate compared to inseminations after detected estrus.

Various systems are effective for programming first inseminations with or without some heat detection. With the incorporation of transrectal ultrasonography for early pregnancy diagnosis 28 to 30 days after insemination, routine heat detection programs could be eliminated by reprogramming each cow after an open diagnosis.

The most limiting factor in the control of the cycle is the proportion of missed heats in estrus-synchronization programs that rely partly or solely on heat detection. Pregnancy rate (the proportion of cows that become pregnant of all cows programmed for insemination) is the best measure of an estrus-synchronization program because it measures total number of pregnancies achieved per unit of time rather than simple conception success at any given insemination.

Introduction

Improving dairy herd reproductive management requires an understanding of the basic principles of getting cows pregnant. It is critical to understand each component of the estrous cycle as well as the annual reproductive cycle (calving interval) and determine where limited time and resources might be best concentrated to reach A.I.-breeding goals. A calving interval consists of four major components:

The first component is the rest period or elective waiting period (EWP). The duration of this period is partly a management decision. This period varies from 40 to 70 days on most farms. Part of its duration is based on the physiological need of the cow in which the reproductive tract must undergo an involution process (return to its nonpregnant size and function). Research indicates that when cows calve without complication, this healing process requires no more than 40 days. This process includes macro- and microscopic processes that prepare the uterus for another pregnancy.

The second component is the period of time between the end of the EWP and when the first estrus is detected for the first A.I.-breeding. The duration of this period is a function of the heat detection rate as well as whether or not some hormonal regimen is used to bring cows into estrus after the end of the EWP (e.g., PGF2a). Whether or not PGF2a is used to bring cows into estrus for first services, the percentage of cows detected in estrus depends on the rate of heat detection or the efficiency of detecting estrus in all cows.

The third component of a calving interval is the active A.I.-breeding period for each cow and represents the number of days required for the cow to conceive after the first A.I. service. If a cow conceives at first service, then the third component is nonexistent. Otherwise, it is a function of the heat detection rate and the level of herd fertility. The level of herd fertility depends upon a number factors, including sire and cow fertility, correct thawing and handling of semen, A.I.-breeding technique, and timing of insemination. Fertility and heat detection rates are very important to establishing pregnancy in a timely fashion.

The fourth component of a calving interval is gestation. The duration of gestation is fairly constant. It can’t be shortened significantly without adversely affecting the health or viability of the newborn calf.

Based on these component parts of a calving interval, an EWP of 40-50 days is probably sufficient for essentially all cows. With a rate of heat detection of 65% and a conception rate of 65%, the average period from the end of the EWP until pregnancy is established in 95% of the cows should be 35 days. This means that some cows conceive immediately following the end of the EWP and others remain open for 100 or more days. With an EWP of 50 days, estrus and conception rates of 65%, and a gestation period of 280 days, an average calving interval of 365 days (50+35+280 =365) is attainable, when it is desired that 95% of the cows conceive.

Follicular Growth During The Estrous Cycle

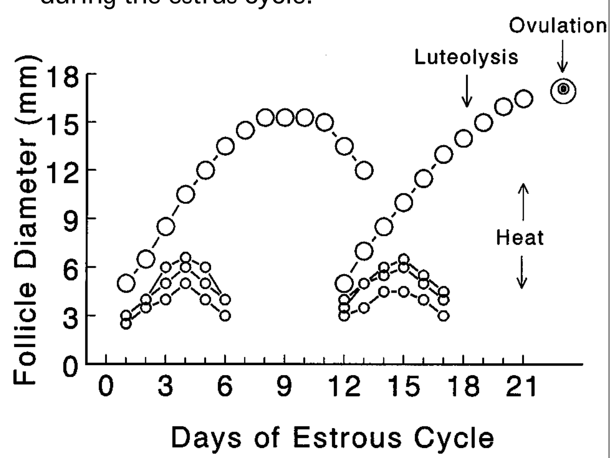
To better comprehend how estrus and ovulation can be synchronized. Let's examine what causes heat in cows and how the follicle containing the egg develops. A follicle is similar to a fluid-filled water blister and contains the egg. The follicle is composed of an outer layer of cells (theca cells), which are exposed to blood capillaries. Blood delivers gonadotropic hormones (FSH and LH) from the anterior pituitary to the follicle, which stimulate its growth, production of gonadal steroid hormones, and growth and maturation of the egg. Inside the follicle, another group of cells (granulosa cells) surround a fluid-filled cavity that forms the antrum of the follicle. These cells take the androgen precursors (stimulated by LH) produced by the thecal cells and synthesize estrogen (stimulated by FSH). Deep in the follicle's antrum, surrounded by specialized granulosa cells, is found the microscopic egg cell. Hundreds of thousands of these follicles are found in the ovaries of the heifer at birth. Once she reaches puberty, these follicles grow in a cyclic fashion from diameters of <1 mm to ovulatory sizes of 16-18 mm in diameter.

For many years, it has been known that as follicles grow, some eventually ovulate whereas others become atretic (die). Earlier, it was thought that follicular growth was either bimodal or continuous. More recently, it was assumed that whatever follicle had reached ovulatory size at the right time during the cycle would be the one that would eventually ovulate. Although this concept is probably correct, it was based on the fact that at least one large follicle can be palpated in the ovaries on almost every day of the estrous cycle.

With the use of the real-time, B-mode ultrasonography, the same type of equipment used in hospitals by physicians to monitor development of human babies within the uterus of their mothers, we can examine the growth of follicles in cattle. This same technology is used to measure backfat and loin-eye areas in finishing cattle and pigs. The probe is inserted into the rectum with the gloved hand just above the reproductive tract as if the cow were palpated. Placement of the probe in this position allows visualization of the ovaries, uterine horns, and cervix. The probe emits ultrasound waves that are absorbed by fluid-filled cavities and appear on the viewing screen as images in various shades of grey or black. Follicles appear as round black circles and the corpus luteum (CL) looks like a peppery elliptical structure.

Using this technology on a daily basis, several patterns of follicular growth have been described, along with new terminology to describe the dynamics of follicular growth. These terms were borrowed from similar studies performed in monkeys. Figure 1 shows the diameters of several follicles during the estrous cycle of a cow. Two groups or "waves" of follicles developed during the cycle. On days 1 and 2, four follicles were visualized, but only one continued to grow (dominant) from this group (cohort) and "dominated" the other (subordinate) smaller follicles. The subordinate follicles underwent atresia (death) and were no longer useful. The first dominant follicle underwent a growth phase (d 1-6), a static phase (d 7-9), and a regressing phase (d 11-12 or longer). The second wave of follicles visualized appeared around days 9-11, one of which dominated the other follicles and became the second dominant follicle that eventually ovu-

Figure 1: Follicular wave of a 'two-wave' cow during the estrus cycle.



lated after luteolysis (death of the CL) and the next heat period.

Although any number of follicles can make up a wave of follicles, usually only one to six develop in a wave. The first wave and its dominant follicle always appear at the same time during the cycle in all cows. A "two-wave" cow has an estrous cycle of 21 days. Two-, three-, and four-wave cycles have been observed in cattle, with the appearance during the cycle of the second, third, or fourth wave being more variable than the first. Estrous cycles become longer with increasing number of follicular waves. Two-wave cycles are 19-20 days and four-wave cycles tend to be 23-25 days in duration.

The growth of a group of follicles that make up a wave is initiated by a transient increase in blood FSH, which is observed 1 or 2 days before the beginning of each follicular wave. Estrogen in the blood also rises and falls with the growth and regression of a dominant follicle. The dominant follicle apparently dominates its subordinate peers by producing substances that inhibit their further growth.

Variation In Interval To Estrus After PGF2a

When PGF_{2a} was being tested as an estrus-synchronization hormone in cattle, a common endpoint to measure its success was the proportion of cows observed in heat during a 2-5-day period after injection. That period reflected the proportion of cows that had a functional CL secreting high blood concentrations of progesterone at injection time. Any cow coming into estrus much before 48 h most likely had natural or spontaneous luteal regression (CL death) before the PGF_{2a} injection. These cows showing estrus before 48 h were likely on days 19-21 of their cycles when PGF_{2a} was injected. Approximately 2-5 days after the injection, cows would come into estrus because blood progesterone would return to baseline concentrations within 12-24 hf and the CL would no longer be functional. Interestingly, regardless of how soon a cow came into estrus, concentrations of progesterone would return to baseline at nearly the same time.

We have learned that the variable part of this interval is the period of time during which the follicle matures and induces estrus by secreting high concentrations of estrogen. So it seems that interval to estrus after PGF_{2a} was not related to concentrations of progesterone during the estrous cycle but rather to the relative maturity of a developing, dominant follicle at the time of PGF_{2a} injection or luteal regression.

What would happen if PGF_{2a} were injected at various stages of the cycle? Intervals to estrus are dependent on the relative diameter (maturity) of the dominant follicle at the time of PGF_{2a} injection. Short, medium, and long intervals to estrus after PGF_{2a} are based on when PGF_{2a} is injected in the cycle. So if PGF_{2a} were given when either a first or second dominant follicle is quite mature (large in diameter), the interval to estrus would be much shorter than if PGF_{2a} were given at mid cycle between follicular waves or later in the cycle when the second dominant follicle is relatively larger in diameter.

Evidence exists for these different intervals based on studies conducted in dairy heifers when PGF_{2a} was given at various stages of the cycle. Assuming that most heifers have two follicular-wave cycles, then injections of PGF_{2a} at various phases of follicular maturity, whether given while the first or second dominant follicle was present, would produce the various intervals to follicular maturation, estrogen secretion, and the onset of estrus (Table 1).

Table 1: Hours To Estrus After PGF_{2a} Injections At Various Stages of the Cycle.

study	short days 5-8	long days 8-11	medium days 12-15
A	48	--	60
B	49	--	61
C	44	71	53
D	54	70	--
unweighted avg.	*47*	*70*	*58*

Is conception rate affected when PGF_{2a} is given at different times? Apparently, it is not, as long as inseminations were based on detected estrus. For example, if a PGF_{2a} injection is given on day 6 or 7, when the first dominant follicle is growing (Figure 1), the CL would regress and the first dominant follicle would ovulate and be normally fertile when

Similar results occur for any dominant follicle that is in its growing phase at the time of PGF_{2a} injection.

Programmed Breeding

Most dairy producers appreciate the benefits and advantages of using an estrus-synchronization program. Synchronizing estrus in cattle simply makes occurrence of estrus more predictable and A.I.-breeding more convenient. Dairy producers have benefitted from the superior genetics of proven bulls, which have increased pride of ownership in better-bred cattle, as well as providing a payoff in greater milk production. Although most are sold on the idea of using heat synchronization, one question most frequently asked by dairy producers and dairy veterinarians is: What is the best way to synchronize estrus in dairy cows and heifers for A.I.-breeding?

The program used successfully on dairy farms is probably the one that is the most simple to execute. Although heat synchronization of large numbers of cows and heifers at one time is not typical on most dairy farms, except in large herds or where seasonal calving is practiced, one needs to develop a system for identifying cows (based on days after calving) and heifers (based on age) that should go into each breeding group cluster.

The breeding cluster is one method that can be used. For example, if the EWP is 50 days before A.I.-breeding, then a breeding cluster of cows can be organized that falls within a certain range of days in milk to fit the targeted first breeding date. These cows can be identified easily from a breeding wheel, computer records, or by simply keeping a chronological list of calving dates.

In our herd of 200 cows, we cluster cows that calve during a 3-wk period so that the freshest cow in the cluster meets the minimum acceptable EWP. When the EWP is 50 days, then a cluster would consist of cows that are 50-70 days in milk during the targeted breeding week. Therefore, the average interval to first insemination is 60 days for the herd. Cows that fail to conceive should return to estrus during the breeding week of the next cluster of cows, which would be estrus-synchronized for A.I.-breeding 3 wk after the first cluster of cows.

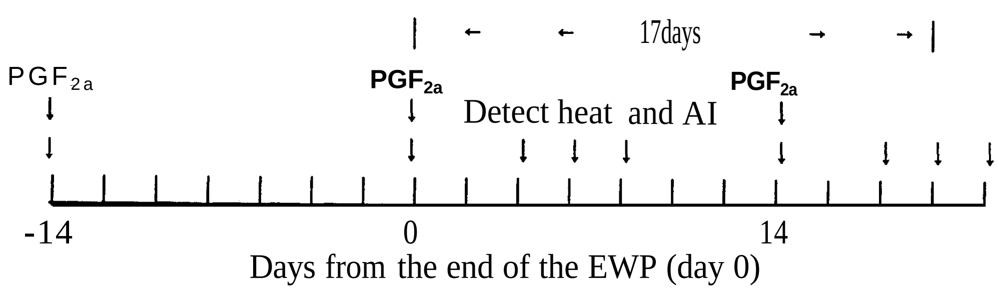
This clustering method allows first services and repeat inseminations occur during the same week, thus concentrating most inseminations to occur during 1 wk out of every 3 wk. This same system can be employed for A.I.-breeding of replacement heifers when they reach an acceptable age and weight to enter a breeding cluster.

In larger herds, grouping cows into 1- or 2-wk clusters is necessary. These clusters simplify A.I.-breeding of cows that meet the breeding criteria on a weekly or biweekly basis. Therefore, during the period before the cows reach their targeted breeding date (based on days in milk and the EWP), estrus is synchronized to occur during each breeding week. Usually, the synchronization period is set so estrus or fixed-time insemination will occur in the Monday-to-Friday work week.

Choosing A Breeding System

Once a system is in place to identify cows and heifers that fit those criteria for inclusion in an A.I.-breeding cluster, then the specific programmed breeding system is fit into a weekly management

Figure 2: "Targeted Breeding" Program



*In the absence of detected estrus, A.I. at 80 h after PGF_{2a}

sequence. What successful programs are available? There are two general categories of programs from which to choose: 1) PGF_{2a} or 2) gonadotropin-releasing hormone (GnRH) + PGF_{2a}.

The first involves using either of two prostaglandin products that are available in the U.S. market (Lutalyse and Estrumate). The second category uses either of three GnRH products (Cystorelin, Fertagyl, or Factrel) plus a prostaglandin product in combination with heat detection or a fixed-time insemination.

Targeted® Breeding Program

The Targeted Breeding program has been promoted by one of the PGF_{2a} manufacturers (Pharmacia & Upjohn) for synchronizing the A.I.-breeding of lactating cows in a herd (Figure 2). Injections of PGF_{2a} are administered 14 days apart. This interval is simply based on the fact that sufficient time must pass after the first injection so those females responding to the first injection (their CL regresses and they come into estrus) have a new CL that is mature enough to respond to a second injection (at least on day 6 of the estrous cycle). In addition, those females that were not in a stage of the estrous cycle with a CL that could regress after the first PGF_{2a} injection should be responsive 14 days later.

Targeted Breeding calls for the first injection (so-called set-up injection) to be given 14 days before the EWP ends. No cows are inseminated after the first injection, although about 50% show estrus in response to the first injection. The second injection (first breeding injection) then is given just prior to the end of the EWP, so first services can occur when cows are eligible for A.I.-breeding. The Targeted Breeding program then suggests that if no estrus is detected after the second injection, a third injection (second breeding injection) is given in another 14 days. If no standing estrus is detected after this third injection, then one fixed-time insemination can be given at 80 hr after this third injection of PGF_{2a}.

Ovsynch

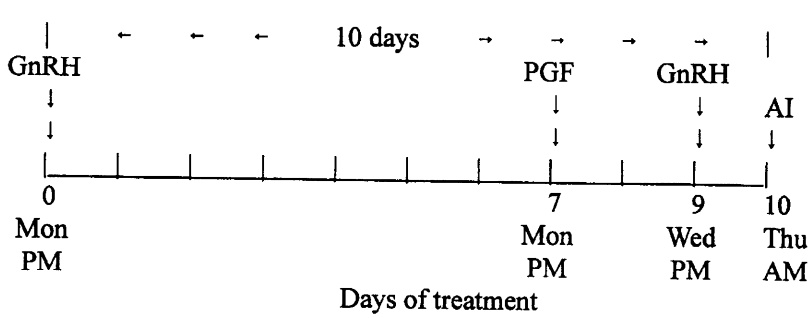
The second method (named Ovsynch) is similar to the previous program, except it requires no heat detection (Figure 3). In fact, it is described more accurately as an ovulation synchronization program; hence the name, Ovsynch.

A 100-mg injection of GnRH is given 7 days before a PGF_{2a} injection, and then a second 100-mg injection of GnRH is administered 36-48 hr after PGF_{2a} with one fixed-time insemination given 8-20 hr later. (A recent study found that 1 mL or 50 mg of Cystorelin is sufficient.) The first GnRH injection alters follicular growth by inducing ovulation of the largest follicle (dominant follicle) in the ovaries after the GnRH injection to form a new or additional CL. Thus, estrus usually does not occur until after a PGF_{2a} injection regresses the natural CL and the secondary CL (formed from the follicle induced to ovulate by the first GnRH injection). Therefore, a new group of follicles appears in the ovaries (based on transrectal ultrasonographic evidence) within 1 to 2 days after the first injection of GnRH.

From that new group of follicles, a newly developed dominant follicle emerges, matures, and can ovulate after estrus is induced by PGF_{2a} or it can be induced to ovulate after a second injection of GnRH. The GnRH injections release pituitary luteinizing hormone (LH), the natural ovulation-inducing hormone of the estrous cycle. Few cows will show heat in this program. About 8-16% may show heat around the time of the PGF_{2a} injection. If so, those cows should be AI-bred according to the AM-PM rule and the second GnRH injection eliminated.

This program works in replacement heifers, but because

Figure 3: Ovsynch Program



of lower pregnancy rates than can be achieved with other programs, it is not recommended. For some unexplained reason, the first GnRH injection fails to ovulate a follicle about 50% of the time in heifers compared to about 17% failure in lactating cows.

We have found that the fixed-time insemination (Ovsynch) produces slightly lower conception rates than are achieved when A.I.-breeding is done after detecting a cow in standing estrus (GnRH + PGF_{2a} + heat detection). However, looking at the number of pregnancies achieved per unit of time, we find that the second program is often superior.

When fixed-time inseminations are performed in cows that you are attempting to A.I.-breed, then by definition conception rate (CR) is the same as pregnancy rate (PR), because the heat detection rate (HDR or A.I. submission rate) is 100%. Therefore, PR = HDR x CR becomes PR = 1 x CR or PR = CR. Examples of various pregnancy rate possibilities are illustrated in Table 2.

For example, let's compare a traditional A.I. program that uses heat detection to Ovsynch in which no heat detection is necessary prior to first service (Table 3). If 70% of the cows in the traditional program are submitted for insemination (70% heat detection rate), with a 50% conception rate, 35% of the cows become pregnant in a 21 -day period. With an Ovsynch program, 100% of the cows are inseminated, and with a similar conception rate, 50% of the cows become pregnant in a 10-day period. Therefore, 15 more pregnancies are achieved at a similar conception rate because all cows eligible for insemination are A.I.-bred; or in other words, 30 eligible cows in the traditional program were not inseminated because they were not detected in heat. Therefore, more pregnancies can be established per unit of time.

Costs Of Heat Detection

Programmed breeding systems not only provide an organized approach to administering first A.I.-breedings to dairy cows or dairy heifers, but should be cost-effective in most herds. Can one determine whether or not the program-breeding system is cost-effective?

The biggest problem in estimating the cost of a programmed-breeding system is estimating the real dollar value of heat detection and the convenience factor of using a programmed-breeding system for first services. If cows were A.I.-bred during one season of the year (seasonal calving and breeding), the value of heat detection could be determined more easily as a component of the total number of pregnant cows at the end of the breeding season.

Perhaps a similar value could be determined by calculating the number of pregnant cows at 100 or 150 days in milk, or the number pregnant after one round of a programmed breeding system. In this way the value of heat detection, as a component of the pregnancy rate equation, might be estimated.

Because programmed breeding systems are designed basically to synchronize estrus before the first A.I.-breeding, cows must be watched to observe the repeat estrus that occurs when they fail to conceive to first service. One way to eliminate heat detection almost completely would be to determine an early pregnancy status (for example,

Table 2: Examples of 21 -Day Pregnancy Rates.

heat detection HDR	x	conception rate CR	=	pregnancy rate PR
60	x	30	=	18
60	x	40	=	24
60	x	50	=	30
60	x	60	=	36
40	x	50	=	20
50	x	50	=	25
60	x	50	=	30
70	x	50	=	35

Table 3: Pregnancy Rates Achieved With Traditional Heat Detection[1] & Ovsynch[2] Programs.

item	traditional	Ovsynch
# cows attempted for A.I. in 21 days	100	100
# cows submitted for A.I. (heat detection rate, %)	70	100
conception rate, %	50	50
pregnancy rate[3], %	35	50

1: Observation for estrus and no hormone use or estrus-synchronization program.
2: See figure 3
3: Pregnancy rate = HDR x CR

by day 15, which is not possible now) before an open cow repeats to estrus and then synchronize the repeat estrus so no heat detection is necessary. Another way would be to use ultrasound and diagnose pregnancy at 28 to 30 days and then reprogram the next estrus in the nonpregnant cows. Even with that approach, some cows will be repeating to estrus at 21 to 23 days after their first A.I.-breeding that should have been detected in estrus and reinseminated before the pregnancy test.

Another successful method is to start all cows found open at pregnancy checks on the Ovsynch protocol so that they will be reared within 10 days (Figure 3). Therefore, our current programmed breeding systems require daily heat detection to pick up the repeat estrus. That being the case, the cost of heat detection should be viewed as a fixed cost just as milking labor.

Costs of Programmed A.I.-Breeding

Assessing the costs of using programmed A.I.-breeding is not easy. Further, most producers assume that it is more costly because of the extra labor, semen, and hormones. Table 4 summarizes how programmed breeding pays for itself. Let's assume that you are using Ovsynch and want to compare that to A.I.-breeding cows based on heat detection, perhaps coupled with tail chalk, tail paint, or even Kamar or Bovine Beacon heat-mount patches.

The total cost of Ovsynch is about $38 ($13 for the three injections, $5 for labor to administer injections, $15 for semen, and $5 for A.I.-breeding). That compares to $20 (semen + A.I.-breeding) for the traditional approach. If we assume that conception rate is 40% in both cases, then at a 70% heat detection rate, the traditional program would produce 28 pregnancies (70 x 40) and Ovsynch would produce 12 more pregnancies or 40 in total.

What is the additional value of those 12 pregnancies? To determine this, we need to estimate the value of one pregnancy after the cow has already failed to conceive once. It takes about 63 days to get a cow pregnant after the first unsuccessful service, so at only $1 per day, the pregnant cow has a $63 greater value compared to the nonpregnant cow. On average 2.5 more doses of semen + A.I. labor will be needed or $50 more per pregnancy. If we assume that 20% of the cows will fail to conceive, the cost of a replacement heifer is $1200, and the value of a cull cow is $500, then we must add $140 ($700 x 20% culls).

So, one additional pregnancy is worth $253 ($63+$50+$140). Because those 12 additional pregnancies cost us $200 each, we have a positive return on our investment of $53 per additional pregnancy.

Now if heat detection is closer to 50% as in most herds, then only 20 pregnancies are achieved in 21 days and that is 20 less that what is achieved with Ovsynch. Each of those pregnancies would cost only $140 ($3,800 Ovsynch costs -$1,000 traditional cost/20). Because of poorer heat detection, it will take one more estrous cycle or 84 days to get 80% of the remaining cows pregnant, so the value of a pregnant cow is $84 more than that of the open cow. The costs of semen, A.I.-breeding, and culling are the same, so the value of one additional pregnancy at a 50%-heat detection rate is $274 ($84+$50+$140).

That means the cost of $140 per each additional pregnancy gained by Ovsynch gives a positive return of $134 per additional pregnancy. Clearly, Ovsynch or other programmed A.I.-breeding systems can pay for themselves because more cows become pregnant per unit of time, so even though more costs are associated with their use, the return on investment is greater. Based on these cost estimates, as heat detection, conception rates, or both decline, the programmed A.I.-breeding, in this case, Ovsynch, pays for itself.

These differences between the two programs might be even greater, if the costs of heat detection and tail chalk, tail paint, or heat-mount detectors in the traditional program were included. We know that heat detection cannot be eliminated completely, so it leaves us wondering how to estimate the real costs of administering a programmed breeding system.

Of course, many variables determine the cost-benefit ratio of a given system on each farm. For example, the number of cows, type of housing, cost and availability of skilled labor. The selection of the best programed-breeding system for an individual herd also depends on that herd's rate of heat detection. Those herds with excellent heat expression and(or) heat detection may be served best by programs with less hormonal intervention.

Table 4, Comparison of A.I.-Breeding Costs of Ovsynch and a Traditional Heat Detection Program without Hormonal Intervention

Per Cow			Traditional	Ovsynch
Hormones[1], $			0	13
Labor, $			0	5
Semen + A.I[2], $			20	20
Total costs, $			20	38
Per 100 Cows	**Heat detection rate, %**			
No. of cows inseminated	50	70	100	100
No. of Pregnancies[3]	20	28	40	40
Cost for 100 cows[4], $	1000	1400	3800	3800
Cost per Pregnancy[5], $	50	50	95	95
Increased no. of pregnancies by Ovsynch[6]			+20	+12
Total cost of additional pregnancies[7], $			2800	2400
Per cow cost of additional pregnancies[8], $			140	200
Value of additional pregnancy[9], $			274	253
Semen + A.I. labor, $			50	50
Additional days open at $1 per day			84	63
Replacement cost, $			140	140
Net return per additional pregnancy, $			+134	+53

Source: Adapted from Hoard's Dairyman, September 10, 1998, p. 662.

1 Cost of PGF_{2a} = $3 and two doses of GnRH = $5.
2 Cost of semen = $15 and insemination = $5.
3 No. of pregnancies or pregnancy rate = heat detection rate x conception rate (40%).
4 No. inseminated (50, 70, or 100) x cost per cow.
5 Cost per 100 cows divided by the number of pregnancies.
6 Compared to 50% and 70% heat detection rates, respectively.
7 Difference in cost for the traditional and Ovsynch programs at each heat detection level.
8 Cost of additional pregnancies divided by the number of pregnancies.
9 Cost of 2.5 more services (40% conception rate) + average of 63 or 84 days open to impregnate successfully 80% of the 12 or 20 remaining open cows (not pregnant after first service in the traditional program) respectively, + the cost of replacing 20% of open cows with replacements valued at $1200 each and cull cows worth $500.

Notes