A Comparison of Three Estrous Detection Management Schemes for Dairy Heifers

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A COMPARISON OF THREE ESTROUS DETECTION MANAGEMENT
SCHEMES FOR DAIRY HEIFERS

by
Ann Lagerstedt

A thesis submitted in partial fulfillment
of the requirements for the degree
of
MASTER OF SCIENCE
in
Dairy Science
(Management)

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Logan, Utah
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Ann Lagerstedt
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ABSTRACT

A Comparison of Three Estrous Detection Management Schemes for Dairy Heifers

by

Ann Lagerstedt, Master of Science
Utah State University, 1990

Major Professor: Dr. Robert C. Lamb
Department: Animal, Dairy and Veterinary Science

Heifers should represent the greatest genetic potential within a dairy herd. To maximize this potential, heifers must be inseminated to proven sires, a practice requiring management changes on many dairies. Holstein heifers (n=115) were allotted to one of three groups to compare alternatives to daily estrous detection that may facilitate the management of a program of artificial insemination for heifers. Group 1 heifers (Controls) received no treatment but were observed twice daily for signs of estrus. Group 2 heifers (2X-PGF) were synchronized with two injections of prostaglandin F2 alpha given 11 days apart and observed for estrus. Group 3 heifers (MGA+PGF) were synchronized with 9 days of melengestrol acetate feeding and an injection of prostaglandin F2 alpha 14 days after the last feeding and observed for estrus. Comparisons were made on the
effectiveness of each treatment in estrous response and pregnancy rates and on the management requirements and economics associated with each program. Estrous response was significantly higher for the 2X-PGF group, while synchronized pregnancy and first-service conception rates did not differ. On an annual basis, the MGA+PGF group was calculated to require three-quarters of the labor input as compared to the 2X-PGF group and less than a fifth of the labor required for the Control group. A program of daily estrous detection was calculated to have an economic advantage over estrous synchronization programs when synchronization was scheduled four times per year. When the frequency was increased to six times per year, synchronization had a slight economic advantage over daily estrous detection when animal numbers were low and labor costs were high. The economic advantage of daily estrous detection is reduced when synchronization is performed more frequently throughout the year.

(93 pages)
STATEMENT OF THE PROBLEM

Introduction

This study addresses a common management problem on many dairy farms today: dairymen have not yet taken advantage of the genetic progress that can be made by adopting the practice of artificial insemination (A.I.) of breeding-age heifers. Approximately one-third of the nation's dairy heifers are currently bred to proven A.I. sires (23). The majority are still bred naturally to unproven dairy or beef sires.

Research compiled for the USDA Sire Summary, as reported by Senger (68), has shown that the average A.I. sire has a Predicted Transmitting Ability (PTA) for milk of +1,158 pounds compared with the average non-A.I. sire with a PTA for milk of -18 pounds. Heifers that are bred to high-plus proven A.I. sires should contribute earlier to the genetic future of the herd by producing daughters that will generate more milk income per year. Additionally, these daughters will be more likely to remain in the herd as replacements than will daughters of heifers bred to non-A.I. sires. Despite the genetic progress that can be made through the practice of A.I., approximately two-thirds of the nation's dairy heifers are still bred naturally.

One major reason for the failure to adopt A.I. for heifers lies in the fact that natural service is more
convenient than A.I. for many dairymen. A program of A.I. requires a commitment to a daily schedule of estrous detection. With many demands on a dairyman's time and attention, daily estrous detection for heifers often becomes a problem of labor and management. An effective, simple and economical method of synchronizing the occurrence of estrus in heifers would help to make estrous detection and A.I. more feasible for more dairymen.

Statement of Objectives

The objective of this study is to compare two methods of estrous synchronization to each other and to a program of intense estrous detection by daily observations on the basis of:

1) the effectiveness of each method as measured by estrous response and conception and pregnancy rates,
2) the management requirements of each method as measured in time and labor, and
3) the cost of each treatment as measured in labor, treatment, A.I. and animal-carrying costs.

Hypotheses

1) Pregnancy rates of animals in either synchronization group are equivalent to pregnancy rates of untreated control animals on a program of
daily estrous detection.

2) The two synchronization treatments are equally effective in synchronizing estrus.

3) Equivalent pregnancy rates are achieved with the two synchronizing treatments.

4) The melengestrol acetate (MGA+PGF) synchronization treatment requires approximately half the labor input as the double prostaglandin (2X-PGF) treatment.

5) The MGA+PGF synchronization treatment is more economical than the 2X-PGF synchronization treatment.
Introduction

To remain abreast of today's rapid tide of genetic progress in dairy cattle, continual genetic improvement within individual herds is necessary. The majority of dairymen has grasped the importance of practicing artificial insemination (A.I.) with their milking cows, using quality semen from proven sires. But while genetic progress is being made in matings with older cows, one major source of genetic improvement has gone largely unused in most dairy herds. That is the dairy heifer. Heifers have much to offer in a program of genetic improvement through A.I. However, this potential is not being maximized on many dairies largely due to the inconvenience of the estrous detection necessary for successful A.I. Estrous synchronization could put heifer A.I. within the grasp of more dairymen so that the important genetic resource of breeding-age heifers will be more fully utilized.

Heifers in a Program of Artificial Insemination

Heifers have a number of advantages in a breeding-improvement program compared to older cows. Ideally, heifers should represent the best genetic potential within a herd (12, 23, 77). When older cows are bred to A.I. sires
which are chosen to help improve the desirable and correct the undesirable characteristics of each cow, the resulting offspring should be genetically superior to their dams. In this manner, progress is made with every generation, so that the very best genetics in the herd should always be found in its youngest members. Herd improvements will be optimized when these genetically superior youngsters are themselves bred to superior A.I. sires.

Heifers bred to A.I. sires contribute to the progress of the dairy herd in several ways. First, they increase the number of genetically superior animals that will be available as future herd replacements (77). Bennet Cassell (14), a firm advocate of heifer A.I., reported from a 19-year study of over 500,000 calvings that 31.9 percent of calves born annually were to heifers beginning their first lactation. This means that first-calf heifers produce nearly one-third of a dairyman's yearly calf crop, which translates to one-third of potential future herd replacements. Dairymen severely limit herd replacement opportunities by breeding first-calf heifers to unproven dairy or beef bulls. Daughters of heifers bred to average A.I. sires are superior to daughters of heifers bred to average non-A.I. sires in both milk and fat production and will, therefore, generate higher annual production income (45, 46, 68, 70). Using top A.I. sires will increase this
production difference to an even greater degree. Additionally, since heifers should be genetically superior to older cows, a heifer's offspring should be genetically superior to the offspring of the older cow, making an A.I.-bred heifer the best candidate for producing future herd replacements (23).

Having more than enough quality replacement animals available gives dairymen greater flexibility in herd-culling and -selling decisions (77). They may choose to cull a greater number of older or problem cows and replace them with these superior young animals. Or, they may choose to keep just the very best young animals as replacements and sell the others with the potential of bringing top prices due to their genetic quality. In contrast, breeding heifers to unproven dairy or beef bulls reduces the number of good replacements available, thereby limiting dairymen's culling options. They may be forced to delay the culling of problem cows due to a lack of appropriate replacements or may find it necessary to purchase replacements from outside sources.

A second advantage of breeding-age heifers over older cows is their higher conception rate. R. W. Everett (23) showed that conception rates decreased as a cow's lactation number increased. The greatest decrease, a 10 percent drop, was reported between animals in their first and second lactations. Conception rate dropped at a decreasing rate
for each higher lactation number. Everett noted that higher conception rates translated to lower semen costs per pregnancy for heifers, making it more efficient to produce a replacement animal from a heifer than from a milking cow. Artificially inseminating heifers can give dairymen the greatest return on their investment dollars in a breeding program.

Given heifers' superior genetic make-up, their potential to produce top-quality herd replacements, and their higher fertility, they are prime candidates for a program of artificial insemination. Despite these advantages, approximately one-third of the nation's dairy heifers are bred by A.I. (23).

One reason for this failure to adopt a widespread program of heifer A.I. is that heifers are frequently a low priority on many farms (14, 24, 77). The economic impact of management decisions (particularly mating choices) which affect heifers may not be felt for nearly three years, when the heifer's offspring enters the herd. But because cows being milked are the dairyman's current money makers, the economic impact of management decisions affecting them is often felt immediately. This more immediate economic effect generally gives milking cows a higher priority. Realizing a heifer's true value as the greatest asset for improving future herd genetics should provide incentive to improve her
position on a dairyman's list of priorities.

Concern over calving problems associated with large calves sired by A.I. bulls leads some dairymen to breed their heifers to beef bulls or young unproven dairy bulls in an attempt to produce smaller first calves (69, 77). Information is available today on the calving difficulty associated with every A.I. sire. With this information, dairymen should be able to choose mates for their heifers with the characteristic of calving ease while still maintaining the genetic benefits of practicing A.I.

The major reason that heifers are not being bred A.I., however, is inconvenience (24, 69, 77). Practicing A.I. requires that estrous detection be performed on a daily basis. This may be difficult to include in a dairyman's schedule, particularly if the heifers are located on pasture or are housed separately from the main dairy center. Under such circumstances, it is often more convenient for a herd bull to do the work, particularly given his willingness and his built-in ability to detect and breed heifers in estrus.

With a tongue-in-cheek tone, Phil Senger (68) wrote that we ought to "shoot the bull" on all dairy farms. He pointed out that bulls are dangerous, they can transmit disease, and they may have breeding biases favoring certain cows over others. But most importantly, herd bulls are genetically inferior to selected and proven A.I. sires. The
greatest genetic risk that a dairyman can take is to restrict the breeding practices on his dairy to the use of a single, unproven young sire at any one time (70). McDaniel and King (46) stated that "breeding to superior bulls through artificial insemination is the fastest way to improve the genetic quality of the nation's dairy herd" (pg. 112). Including heifers in the practice of A.I. adds to the pace and scale of this improvement. The goal of all dairymen, therefore, should be to adopt the use of 100 percent A.I. for breeding-age heifers.

Estrous Detection in a Program of Heifer A.I.

Accurate detection of estrus is the key to an effective program of heifer A.I. (25, 37). At least two observation periods per day are necessary for accurate detection results. Gwazdauskas et al. (27) found that only 18 percent of estrous animals will still show signs of heat 12 hours after first being observed in estrus, thereby demonstrated that one observation period per day was insufficient for accurate estrous detection. But good results were achieved with two observation periods per day. Donaldson (21) found that 89 percent of the heats detected by 24-hour continuous monitoring were observed with two daily observation periods scheduled for the early morning and the late afternoon. Whitmore (80) reported a 90 percent detection rate possible
To achieve high rates of estrous detection, observations must be made under favorable conditions. Observations should be scheduled at times free from the distraction of other management activities such as feeding or corral scraping. In addition, the physical setting for observations should be conducive to the expression of estrous behavior (27). For example, mounting activity is likely to decrease when heifers are observed on slick, wet, concrete surfaces. Introducing heifers to a new or novel environment during observation periods can help to increase estrous behavior. Moving heifers from one pen to another, for example, or from a concrete lot to a dirt lot for observations tends to boost activity level, making estrus more obvious to detect (27).

Successful estrous detection also requires that the observer be able to recognize multiple signs of estrus. Besides the primary sign of standing to be mounted, heifers in estrus are generally more active, walking the fence, bawling loudly, sniffing other heifers and spending less time at the feed manger (25). They may attempt to mount other heifers which may or may not be in heat (39). Other indications of estrus are a clear mucus discharge, a swollen vulva, or signs of having been mounted, such as roughed-up hair on the tailhead or dirt and mud left on the flanks by
mounting animals (25). Secondary signs are additional clues that aid observers in accurately detecting estrus.

A program of heifer A.I. requires commitment to a successful daily schedule of estrous detection. The inconvenience of such a schedule is the primary reason more heifers are not being bred by A.I. Addressing this problem, Phil Senger (67) states that "...if routine heat checks cannot be used, then induce heat..." (pg. 10) to take advantage of the benefits realized with heifer A.I. Synchronizing the occurrence of estrus in heifers may reduce the labor and time required for estrous detection, thereby making a program of heifer A.I. more convenient for more dairymen.

Estrous Synchronization in a Program of Heifer A.I.

Estrous synchronization is the process of controlling the estrous cycle so that many animals experience estrus within the same time period (66). Synchronizing the estrous cycles of dairy heifers may allow greater use of A.I. by reducing the chore of daily estrous observations. Synchronizing estrus allows dairymen to manage heifer breeding, heat detection and even calving when the resources of time, labor and facilities are most available. In this way, breeding can be planned around the dairyman's schedule to avoid busy times of the year.

Estrous synchronization not only increases the
flexibility of scheduling heat detection and A.I. but also makes estrous activity somewhat simpler to detect. The intensity of estrous behavior is enhanced by increasing the number of heifers experiencing estrus at the same time (24, 31, 37, 39, 41). When compared to just one animal being in heat, heifers will stand to be mounted more frequently when two or more animals are in heat together, giving observers more opportunity to catch estrous behavior. Hurnik et al. (39) reported that cows stood to be mounted an average of 54 times per estrus when three or more cows were in heat together. This compared to only 12 stands per estrus when a single cow was in heat. Additionally, synchronization helps observers anticipate the timing of estrus so they will know when to observe more closely for estrous indications (24). This increases the potential for observing each treated animal in heat and for timing her insemination more accurately. Labor for estrous detection, therefore, is used more efficiently since observations are made only during the time that estrus is anticipated.

When synchronization is used for improving the scheduling and accuracy of estrous detection it becomes a valuable tool for increasing the efficiency of a heifer breeding program. To interest dairymen in estrous synchronization as an aid to a program of heifer A.I., synchronization methods must be highly effective, simple to
administer and economical (12, 53).

Estrus can be successfully synchronized by the administration of the hormones prostaglandin F2 alpha or progesterone. These compounds may be used separately, together, or in combination with several other hormones under a variety of regimes. No one single regime yet seems able to fully accomplish all of the criteria of effectiveness, simplicity and economy.

Prostaglandin F2 Alpha as a Synchronizing Agent

Prostaglandin F2 alpha (PGF) is a biologically active lipid naturally produced by cells in the endometrial lining of the uterus (3). Its role in an estrous synchronization program is to destroy luteal tissue on the ovaries of cycling animals. To understand how PGF functions as a synchronizing agent, it is helpful to first review the physiological events associated with the bovine estrous cycle, then to examine the manner in which PGF affects this cycle.

The estrous cycle averages 21 days in length in heifers (3). Estrus, the period in which the female is receptive to the male, occurs on day 1 of the cycle. Estrus averages 12-18 hours in length, and it is during this time that heifers will stand to be mounted by other animals. Estrous behavior is influenced by the hormone estrogen, a steroid
secreted by follicles on the ovaries which have matured under the influence of follicle stimulating hormone (FSH), secreted by the anterior pituitary. Under the influence of luteinizing hormone (LH), also secreted by the anterior pituitary gland, ovulation, or the rupture of the mature follicle, occurs approximately 12 hours after the end of estrus. This eruption eliminates the source of estrogen. During metestrus (days 2-5), luteal tissue begins to grow and fill the large cavity left by the ruptured follicle, forming the structure known as the corpus luteum (CL). During diestrus (days 6-17) this newly formed structure secretes the steroid progesterone. High progesterone levels inhibit the release of FSH and LH by blocking the release of gonadotropin releasing hormone (GnRH) from the hypothalamus. This effectively prohibits the maturation of a new follicle and prevents estrus and ovulation as long as the progesterone level remains high. During proestrus (days 18-21), the corpus luteum regresses and progesterone levels consequently drop. Declining progesterone levels remove the inhibitory effect on estrus and ovulation by allowing GnRH from the hypothalamus to stimulate the release of FSH and LH from the anterior pituitary. A new follicle now begins to mature and estrogen is again produced, bringing the animal back into estrus to repeat the cycle.

The CL regresses on day 17 or 18 due to the luteolytic
affect of PGF. The CL can be artificially regressed and the heifer induced into heat prematurely by injecting PGF during diestrus when there is a functioning CL on one of the ovaries. In a synchronization program, PGF destroys the CL when administered during the diestrous period, causing heifers to experience estrus approximately two to four days after treatment. Animals injected during estrus, proestrus, or metestrus will not respond to PGF treatment. For estrous synchronization with PGF to be successful, treated animals must be in the diestrous stage of the estrous cycle with a functioning CL. This can be accomplished with synchronizing regimes using either single (15, 17, 18, 22, 43, 66), or double injections of PGF (13, 22, 24, 33, 40, 63, 66).

A single-injection regime begins with four days of estrous detection (days 1-4 of the treatment period). During these four days, any animals that come into heat on their own are inseminated 12 hours after first being observed in estrus. Heifers that come into heat during days 1-4 would have been in estrus (day 1) or proestrus (days 18-21 of the estrous cycle) when the treatment period began. On day 5 of the treatment period, any heifers not observed in estrus during days 1-4 receive an injection of PGF. Estrus is detected for an additional four days following the day of treatment, and heifers are inseminated 12 hours after first observed in estrus. Any animals in metestrus at the
time treatment began would have progressed to the diestrus stage of the cycle by day 5 of the treatment period when PGF is administered. These and any heifers that began treatment while in the diestrus stage of the cycle should have functional corpora lutea that are responsive to PGF and should come into heat within two to four days after PGF treatment. Animals in proestrus at the time of PGF treatment would not have corpora lutea that would be responsive to PGF but should come into heat naturally during the four-day observation period following treatment. All animals, therefore, should be detected in estrus and inseminated within a total of nine days. Conception rates have been found to be equivalent to untreated controls using this method (17, 18, 43).

A synchronizing regime using two injections of PGF can further reduce the days required for estrous detection. Heifers are given two PGF injections spaced 11 days apart and are inseminated following the second injection. On any given day, approximately 50% of a group of cycling heifers would be expected to be in the diestrous stage of the estrous cycle, with 25% in metestrus, and the remaining 25% in proestrus (33). Animals in diestrus at the first PGF injection should respond by coming into heat approximately three days after treatment. These animals will have returned to diestrus with a seven to eight day old CL at the
time of the second injection, and should respond again by coming into heat within three days. Heifers in metestrous will not have a functioning CL responsive to the first PGF injection. By the second injection, however, they should be in diestrus with a 12-15 day old CL that will respond to treatment. Heifers in proestrus at the initial PGF injection will not have a responsive CL but should come into heat naturally within one to four days of treatment. They should be in diestrus with a 7-10 day old CL by the second injection. A double injection regime using PGF puts all cycling animals into the diestrous stage for the second injection, regardless of their cycle stage at the time of the first injection.

Heifers can either be inseminated 12 hours after being observed in estrus or at a fixed time following the second injection without estrous detection being performed. Conception rates are similar to untreated control animals when heifers are inseminated following observed estrus (22, 47, 61) but have been reported to be lower as compared to controls when heifers are bred at a fixed time following PGF treatment (13, 22, 72).

PGF can cause abortion in cattle at any stage of gestation, so it is vital that only non-pregnant animals be treated in an estrous synchronization program. PGF will not induce estrus in animals that are not already cycling (24,
To respond to PGF treatment, it is essential that heifers have a functioning CL. To prevent the waste of labor and treatment costs which occurs when non-cycling animals are presented for PGF treatment, heifers must be well managed and on a high plain of nutrition. Estrous synchronization is not a cure-all for reproductive problems experienced on a dairy farm. If basic management and nutrition practices are inadequate, a program of synchronization may in fact compound existing problems (24, 66).

Progesterone as a Synchronizing Agent

Progesterone is naturally produced by corpora lutea on the ovaries of cycling animals. Progesterone functions to inhibit GnRH release from the hypothalamus, thereby preventing the occurrence of estrus and ovulation. As a synchronizing agent, exogenous progesterone mimics the action of the CL, preventing estrus and ovulation throughout the time it is administered.

Melengestrol acetate (MGA) is an orally active synthetic progesterone (1, 49, 53, 56, 59) that was developed in the early 1960's (56). It is currently federally approved as an additive for feedlot heifers to promote increased weight gains and feed efficiency (1, 49, 53, 56). Fed on a daily basis, MGA inhibits the expression
of estrus while the heifers are in the feedlot, thereby eliminating estrous activity which is associated with poor feedlot performance (4, 38, 51, 52).

Although not yet federally approved for such use, MGA can function as an agent for synchronizing estrus in dairy heifers. It has certain advantages over other synchronizing agents which make it attractive for this purpose. MGA is simple to administer as an additive or supplement to the daily feed ration (56). It requires less labor compared to other synchronization methods since it requires no injections and no extra handling of animals (10, 12). In addition, the cost of MGA compared to other synchronizing agents is minimal (10, 12, 56).

The development of MGA as a synchronizing agent has closely paralleled the development of estrous synchronization methods in four distinct phases, as cited by Patterson et al. (56). Phase I, the initial development period was characterized by exogenous progesterone administration for relatively long periods of time. This established an artificial luteal phase which prevented estrus and ovulation while the already existing corpora lutea regressed naturally (34). Phase II was characterized by long-term progesterone treatment combined with estrogen or other gonadotropins, given to improve fertility at the synchronized estrus. Phase III introduced the use of
prostaglandins as luteolytic agents as discussed previously, and Phase IV, which is ongoing, involves combinations of progesterone and prostaglandin.

As in Phase I, in initial synchronization studies using MGA, researchers administered the compound for long-term periods of 14-18 days (8, 19, 65, 73, 82) and in some cases up to 24 days (26, 50). The minimal dose for daily administration, to prevent both estrus and ovulation during the treatment period, was established during this phase as .4 mg per animal per day (50, 85). Doses of .5 mg, ranging to a high of 1 mg per day, became standard for these early studies (6, 8, 19, 65, 82). Initially, MGA was either administered orally in gelatin capsules (7, 16) or feed supplements (42, 59), or by intravenous injection (84). Potency was found to be equal for either route. Currently, MGA is readily available as an additive in protein pellets designed for feedlot heifers.

Estrous was synchronized within seven days after MGA withdrawal in 75 percent or more of treated heifers in several early studies with long treatment periods (19, 35, 42, 59, 82, 84, 85). The degree of synchrony was approximately equal, but synchrony occurred earlier for heifers fed a low as compared with a high dose of MGA (35, 50, 56, 59, 84). At doses of .5 mg per day, estrus occurred at an average of 3.7 to 4.7 days following the last day of
MGA treatment (35, 59, 84). When the dose was increased to 1 mg per day, synchrony occurred later at an average of 5.3 to 7.3 days after MGA withdrawal (35, 59, 84).

Fertility on the first estrus following MGA treatment was reported to be significantly lower for treated heifers than for untreated controls (7, 8, 32, 35, 56, 59, 84). Randel et al. (59) reported a zero percent conception rate for 20 treated heifers on the first estrus following 14 days of MGA treatment, but other studies reported conception rates that ranged from 14 to 50 percent below untreated controls following 14-18 days of MGA treatment (8, 32, 35, 56). Studies using various other progestational compounds, under similar treatment regimes, support the finding of significantly decreased fertility at the estrus immediately following progesterone treatment (28, 29, 56, 73, 74).

Decreased fertility was reported only for the estrous cycle immediately following progesterone treatment. Subsequent cycles had fertility levels equivalent to or even greater than untreated controls (8, 19, 28, 73, 82, 84). Synchrony was poor, however, at these subsequent cycles.

Altered hormone patterns occurring during and following MGA treatment resulted in several abnormal conditions which were believed to adversely affect fertility. These included a higher incidence of uncleaved ova (2, 35, 42), altered folliculogenesis (2, 55), extended estrous cycles with
overstimulation of follicles and delayed ovulation (2, 56), changes in the amount and physiological nature of cervical mucus (7), changes in the histochemical nature of the endometrium (7), decreased energy stores (glycogen) for developing blastocysts in the uterus (56, 83), and inhibited sperm transport (55, 56, 57, 62).

MGA significantly altered hormone profiles during the time it was fed, and for several days thereafter. Plasma progesterone levels were significantly higher in heifers during MGA treatment than in untreated heifers at an equivalent luteal or metestrus phase of the estrous cycle (7, 42, 60). Britt and Ulberg (7) measured plasma progesterone levels of heifers during pretreatment estrous cycles and reported that levels ranged from a low of .5 ng/ml at estrus, to a high of 4.4 ng/ml at day 15 during the luteal phase of the estrous cycle, then returned to .5 ng/ml on the day preceding estrus. During the treatment cycle, plasma progesterone levels were unusually high, varying between 3.7 and 7.7 ng/ml in the 14 days that MGA was fed. Following MGA withdrawal, plasma progesterone remained significantly elevated through the synchronized estrus. Plasma progesterone during the three days prior to synchronized estrus averaged 4.8 ng/ml compared to 2.2 and 2.3 ng/ml for the same period during pretreatment and post-treatment cycles. Randel et al. (59) suggested that the
source of this elevated plasma progesterone following MGA treatment was abnormal follicles which persisted on the ovaries after MGA withdrawal. During the luteal phase of the cycle following the synchronized estrus and the proestrous stage of the subsequent cycle, progesterone levels in treated animals were equivalent to progesterone levels of control animals in similar stages of the cycle (7, 35). Similar studies supported the finding of elevated progesterone levels during and immediately following MGA treatment (42, 59, 60). Chow et al. (16) however, reported plasma progesterone levels below the level of controls immediately following MGA treatment.

Although increased levels of plasma progesterone normally inhibit the release of LH, levels of plasma LH were significantly higher in treated heifers than in controls following MGA withdrawal and for up to nine days following the first post-treatment ovulation (58, 59, 60). Randel et al. (59) reported that LH surged at 80-88 hours after the last MGA treatment. Although LH levels at this surge did not differ from controls (59, 79), base levels of LH before and after the surge were significantly higher (58, 59, 60). Levels of LH during the period of MGA feeding were equivalent to controls in the luteal phase of the estrous cycle (59, 60). Hill et al. (35), however, reported that LH levels during MGA treatment were somewhat greater, as
compared with controls, for heifers that began treatment while late in the luteal phase of the estrous cycle. Additionally, those heifers fed .5 mg had a slightly higher LH level during MGA treatment than those fed a dose of 1 mg, suggesting that the higher dose has a greater inhibitory effect on LH.

Estrogen levels were similar to controls during MGA treatment but were significantly higher than controls after withdrawal of MGA (16, 60). Estrogen remained abnormally elevated for at least three days following treatment (60), thus prolonging the proestrous period preceding synchronized estrus (35, 60). Randel et al. (60) hypothesized that increased estrogen levels probably originated from new follicular growth that began after MGA withdrawal.

Hormone alterations associated with MGA treatment are believed to be responsible for abnormalities seen in ovarian structures during MGA treatment. Guthrie et al. (26) reported that no corpora lutea were present on the ovaries of treated animals after 21 days of MGA administration. Randel et al. (58) reported that 93 percent of treated heifers had a regressed or absent CL following 14 days of MGA feeding. Britt and Ulberg (7) reported that corpora lutea of treated heifers had regressed to less than 10 mm after just three days of MGA treatment. Lamond et al. (42) reported that no corpora lutea were present on the ovaries
after six days of MGA treatment in heifers slaughtered at 3-day intervals during treatment. These reports led to the assumption that MGA treatment caused the premature regression of the CL. Through additional information gathered after this research trial was initiated, it appears that MGA actually does not affect the lifespan of the CL (19, 35, 56, 60). Maturation and regression of corpora lutea proceed during MGA treatment as they would in a normal cycle.

Follicular development in treated animals was dramatically affected by MGA treatment. After 14 days of MGA feeding, the large majority of treated animals had an abnormally large follicle (1.5-2.0 cm) on one of a pair of ovaries (26, 35, 42, 56, 58, 59, 60, 85) and displayed a marked decrease of medium- (0.6-1.0 cm) and small-sized (0.5 cm) follicles. Untreated control animals had few or no very large follicles with several medium- or small-sized follicles (35, 42, 56). Zimbelman and Smith (85) speculated that abnormally large follicles resulted from LH being inhibited to a degree that prevented ovulation from occurring during progesterone treatment, thereby allowing the follicle to continue growing throughout the treatment period.

Follicular abnormalities such as cystic follicular atresia (26, 42, 56), unusual softness prior to ovulation
(59), a thickened theca interna (26, 35, 42), abnormal luteal infiltration (71) and an expanded volume of follicular fluid (56, 85) were reported following 14-day MGA treatments. These abnormalities were most prevalent for heifers that began MGA treatment while late in the luteal or diestrous stage of the cycle (35). The primary follicle of such heifers would have developed early during the MGA treatment period and would have remained on the ovary without ovulating for the longest time before MGA withdrawal.

In addition to affecting ovarian structures, MGA treatment also abnormally affected the uterus. Zimbelman and Smith (85) reported accumulations of tenacious mucus in the uterine horns and cervix of treated heifers during the first one to three days following MGA withdrawal. This may be associated with elevated estrogen levels and prolonged proestrous periods reported following MGA treatment (35, 60). The mucus was no longer present, however, after the animal had experienced estrus. Wordinger (83) found that glycogen content in the uterus was reduced following MGA treatment, thus decreasing the energy stores necessary for developing blastocysts.

Because satisfactory synchrony with minimal labor and cost inputs could be achieved using long-term treatments of MGA, its use was not abandoned due to poor fertility
experienced with its administration. Researchers experimented using combinations of various hormones with MGA to improve fertility. Human chorionic gonadotropin failed to improve fertility at the synchronized estrus when it was administered 48 hours after the withdrawal of progesterone to facilitate ovulation. It was found, in fact, to further decrease fertility at the synchronized estrus (56, 64, 73). Ovulation was successfully synchronized by combining MGA with gonadotropins (LH, PMSG), but estrous response was inconsistent (56). Estrus and ovulation were both synchronized by combining MGA with estrogen, but poor fertility at the synchronized estrus was not improved with this treatment (56), and the incidence of ovulation without estrus was increased (59).

Combining other hormones with long-term MGA treatment did not help to solve the fertility problem associated with lengthy progesterone administration. The next step in overcoming this hurdle came in shortening the length of the progesterone treatment. Boyd and Corah (5) reported that cutting the treatment period in half resulted in an acceptable conception rate (61.5%). This was done, however, at the expense of synchrony (46.4%). A luteolytic agent administered on the last day of a short-term progesterone treatment was used to improve synchrony results. Good synchrony was achieved when progesterone was administered
for a minimum of seven days with an injection of PGF on the final day of progesterone treatment (1, 2, 15, 20, 30, 48, 49, 54, 55, 72, 81). However, comparing this synchronizing regime (7-day progesterone + PGF) with a regime that administered only a single PGF injection, Chenault et al. (15) and Neibergs and Reeves (49) reported that no advantages existed for the 7-day progesterone + PGF treatment over PGF alone. Fertility, in fact, was depressed with the 7-day progesterone + PGF treatment as compared to untreated controls (2, 55, 62).

As with long-term progesterone treatments, short-term treatments affected fertility only at the synchronized estrus following progesterone withdrawal. Fertility returned to normal by the second and subsequent estrous cycles following treatment (2, 5, 44, 54, 55).

With this in mind, researchers at Colorado State University (10) experimented with a synchronizing regime that reverted to a 14-day MGA feeding period but was followed by a single PGF injection 17 days after MGA withdrawal. MGA was used to initially synchronize estrus so that animals would be in a similar luteal stage of the estrous cycle at the time of PGF administration (10). No heifers were inseminated following MGA treatment when fertility would be expected to be low. All inseminations occurred at the synchronized estrus following PGF injection.
Good synchrony response (75-94%) and pregnancy rates (55-70%) were reported using this regime with beef heifers (10, 12, 44). Mauck et al. (44) compared this regime with the 7-day progesterone + PGF regime and found estrous response to be 20 percent greater (75.4% vs. 56.3%) for heifers treated with the 14-day MGA+PGF regime. Pregnancy rates were also over 20 percent higher (55.2% vs. 32.4%).

This regime appears promising in achieving both good synchrony and high fertility in an estrous synchronization program. Fertility rates were significantly higher as compared to animals treated with MGA alone, and synchrony results were tighter than for animals treated with just a single injection of PGF (12). In addition, labor requirements with this regime were minimal. MGA was simply added to the daily ration, requiring no additional labor. Animals were handled only once for PGF administration and once for insemination. Treatment costs were limited to the price of a single PGF injection and just pennies per day for MGA.

Protocol for the present research project was based on fresh information regarding the above new synchronizing method (11, 12). Brown et al. (11) fed MGA for 14-16 days and injected PGF 16-17 days following withdrawal of MGA. Heifers were inseminated on observed estrus following PGF injection. Brownson (12) fed MGA for 14 days and injected
PGF 18 days after MGA withdrawal. Initially believing the CL to be regressed in the majority of treated animals with nine days of feeding MGA, and desiring to avoid any follicular abnormalities associated with prolonged MGA treatment, the MGA-feeding period for the present research trial was reduced to nine days.

With the objective of this research trial being to evaluate estrous synchronization using an MGA+PGF regime from a management, as opposed to a physiological point of view, feeding MGA for nine days was hypothesized to be enough time to attain satisfactory initial estrous synchrony within a three- to seven-day period after MGA withdrawal. Heifers experiencing synchronized estrus at three to seven days after MGA would have a 7-11 day old CL at the time of PGF administration 14 days following MGA withdrawal. This would put them in approximately the same stage of the estrous cycle at the time of PGF injection as animals facing the second injection of a double PGF regime with injections spaced 11 days apart. Essentially, MGA treatment would substitute for the first PGF injection in a double PGF injection regime.

It was anticipated that this treatment would reduce costs and labor requirements associated with synchronizing estrus in dairy heifers, and would result in synchrony rates equivalent to those achieved with a double PGF injection
regime, and pregnancy rates equivalent to untreated controls.
METHODS AND MATERIALS

Experimental Design

One-hundred fifteen Holstein heifers from the Utah State University dairy herd were randomly allotted to one of three treatment groups in five experimental trials over a 15-month period. Heifers were allotted when they reached a minimum body weight of 340 kg.

Heifers in group 1 (Controls) (n=36) were observed for signs of estrus during two 30-minute observation periods each day throughout the length of the trial. They were artificially inseminated approximately 12 hours after first being observed in standing heat (Figure 1).

Heifers in group 2 (2X-PGF) (n=39) received an intramuscular injection of 5 ml of prostaglandin F2 alpha (PGF) on day 12 of the trial. Heifers that expressed estrus following this injection were inseminated 12 hours after first being observed in standing heat. Any heifers not observed in estrus within six days following the first injection received a second 5 ml PGF injection on day 23, eleven days after the first, and were inseminated 12 hours after first observed in standing heat (Figure 1). Heifers were considered synchronized if observed in heat within the first six days following either PGF injection.
Heifers in group 3 (MGA+PGF) (n=40) were fed .5 mg Melengestrol Acetate (MGA) per day for the first nine days of the trial. Following withdrawal of MGA from the feed, occurrence of estrus was recorded, but no inseminations were performed. Heifers were injected with 5 ml PGF 14 days...
after MGA withdrawal, then observed for estrus and inseminated 12 hours after first being observed in standing heat (Figure 1). They were considered synchronized if observed in heat within six days following PGF administration.

Heifer Management

All five trials were conducted at the University Dairy Farm located in North Logan. Trials covered a 15-month period from February, 1988, through April, 1989, beginning at two to three month intervals and finishing when all heifers in a trial were confirmed either pregnant or open after a maximum of two inseminations. Heifers were included in the next scheduled trial after reaching a minimum required weight of 340 kg. Average weight was 403 kg and ranged from 340 to 515 kg. Heifers in each trial ranged in age from 13.5 to 19.2 months at the beginning of the trial, with the average age being 15.7 months. Trial initiation dates and the number of heifers included in each trial are shown in Table 1.

Heifers in all three groups were managed identically throughout the trial excepting the 9-day period when MGA was fed to the MGA+PGF group. All heifers had free access to a vitamin-mineral premix and were fed a ration twice daily that consisted of corn silage, alfalfa haylage,
Table 1. Trial information.

<table>
<thead>
<tr>
<th>Trial no.</th>
<th>Beginning date</th>
<th>No. heifers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2/24/88</td>
<td>21</td>
</tr>
<tr>
<td>2</td>
<td>5/26/88</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>9/19/88</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>12/7/88</td>
<td>27</td>
</tr>
<tr>
<td>5</td>
<td>2/16/89</td>
<td>17</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>115</strong></td>
</tr>
</tbody>
</table>

alfalfa and grass hays. All groups were housed together and allowed to freely intermingle in a free stall facility with concrete corrals and head-locking mangers.

For the first nine days of each trial, heifers in the MGA+PGF group were separated from the Control and 2X-PGF groups by a gate in the heifer facility. MGA was supplemented to the MGA+PGF group in 1 lb per head per day of a 32% protein pellet containing MGA at the rate of .5 mg/lb. This pellet was hand-fed each afternoon just prior to the heifers receiving the balance of their ration. During this time, Control and 2X-PGF heifers were fed an equivalent amount of a 32% protein pellet that did not contain MGA. Animals in all groups were preconditioned to
their respective pellets by feeding untreated pellets for three days prior to the beginning of each trial. To better control pellet intake, heifers were head-locked at the manger when pellets were fed.

**Estrous Detection and Breeding**

Heifers from all groups were moved together twice daily to an adjacent dirt lot for a 20-30 minute estrous observation period. Daily observations were done before 0730 hours and after 1630 hours to avoid conflicts with other activities (feeding, corral scraping, construction) occurring on the farm between these times. Estrous behavior observed during each detection period was recorded on daily observation sheets (Appendix A), according to the type and frequency of each activity. Each activity was assigned a code number (Table 2).

**Table 2. Coded estrous activities**

<table>
<thead>
<tr>
<th>Code No.</th>
<th>Description of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heifer stood to be mounted</td>
</tr>
<tr>
<td>2</td>
<td>Heifer mounted another heifer</td>
</tr>
<tr>
<td>3</td>
<td>Heifer would not stand to be mounted</td>
</tr>
<tr>
<td>4</td>
<td>Heifer chin rode another heifer</td>
</tr>
<tr>
<td>5</td>
<td>Heifer stood for a chin ride</td>
</tr>
<tr>
<td>6</td>
<td>Heifer had a clear mucus discharge</td>
</tr>
<tr>
<td>7</td>
<td>Heifer had a bloody mucus discharge</td>
</tr>
<tr>
<td>8</td>
<td>Heifer displayed unusual behavior</td>
</tr>
</tbody>
</table>
Estrous observations throughout all five trials were scheduled between four individuals, trained prior to the onset of Trial 1 to recognize the coded activities.

During the days of each trial that the MGA+PGF group was separated for MGA feeding, it was not possible to move heifers to the dirt lot for estrous detection. Observations, therefore, were made within the divided heifer pen for 30 minutes twice daily, and activity codes were still recorded during this time.

Inseminations were performed by two trained technicians. Technician 1 inseminated all animals in Trials 1 and 4, and Technician 2 inseminated all animals in Trials 2 and 3. Inseminations in Trial 5 were evenly alternated between the two technicians. Pregnancy was initially determined by means of rectal palpation performed by one of two university veterinarians at 45 days post-insemination and confirmed again by palpation by the veterinarians at 65-75 days post-insemination.

Immediately following insemination, a 10 ml blood sample was taken from the coccygeal vein of all heifers from all groups. These samples were immediately centrifuged and serum was collected and stored at -20 C until radioimmunoassayed to determine serum progesterone concentrations. Progesterone assays were performed by trained technicians at the USU Animal Physiology Lab.
Statistical Analysis

The data were analyzed by least-squares analysis of variance. Mean differences were tested for significance based on F ratios.
RESULTS AND DISCUSSION

One objective of this research project was to compare two methods of estrous synchronization for effectiveness in synchronizing the occurrence of estrus, and to compare both programs with a program of daily estrous observations for effectiveness in achieving conception and pregnancy.

Due to the relatively small number of animals in each trial, data from the five trials were pooled for analyses. Table 3 shows the number of heifers in each of the treatment groups in each trial.

Table 3. Animal numbers by group and by trial.

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>2X-PGF</th>
<th>MGA+PGF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Trial 2</td>
<td>9</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Trial 3</td>
<td>7</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Trial 4</td>
<td>8</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Trial 5</td>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>39</td>
<td>40</td>
</tr>
</tbody>
</table>

One heifer was never observed in standing heat and consequently was the only animal on this project that was
not inseminated. She was from the Control group in the fifth trial. Metestrus bleeding was recorded for this heifer during the trial, indicating that she was cycling. However, because she was not inseminated, data for this heifer was not included in any of the analyses, resulting in data from 114 heifers being analyzed.

Estrous Response

Estrous response (percentage of heifers showing estrus within six days after treatment) following treatment is given in Table 4 for the 2X-PGF and MGA+PGF groups following prostaglandin treatment, and for the MGA+PGF group following MGA treatment.

Table 4. Estrous response in five trials comparing 2X-PGF and MGA+PGF for estrous synchronization in Holstein heifers.

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Estrous response after PGF</th>
<th>Estrous response after MGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2X-PGF</td>
<td>88.9%c</td>
<td>-</td>
</tr>
<tr>
<td>MGA+PGF</td>
<td>63.3%d</td>
<td>48.1%</td>
</tr>
</tbody>
</table>

Percentages shown represent least-squares means.

Estrous response after both PGF injections for 2X-PGF group, or after single PGF injection for MGA+PGF group.

Figures in same column with different superscripts differ (P<.01).
Estrous response for the 2X-PGF group (88.9%) was similar to response rates reported in other synchronization studies using two injections of PGF (9, 24, 76, 78). Estrous response for the 2X-PGF group includes heifers that were synchronized following either PGF injection. Estrous response following the first injection was 64.1 percent. Heifers were inseminated if detected in estrus following the first injection, and only those heifers that were not observed in estrus were injected a second time. This protocol follows practical experience which indicates that producers often will inseminate animals that are observed in estrus following the first injection rather than wait to inject these animals a second time. A mistake was made in the 2X-PGF group by inseminating four heifers that came into estrus on days 7-10 after the synchronized period following the first injection. Presumably these four animals would not have been in the luteal stage and therefore would not have been responsive to the second PGF injection given on day 11. They were considered in the analyses, therefore, as not being synchronized.

It was anticipated that estrous response for the MGA+PGF group following PGF treatment would be similar to the estrous response rate of the 2X-PGF group, but these results show it to be significantly lower (63.3% vs 88.9%; P<.01). This low rate appears to be due to poor initial
synchrony following MGA treatment. Only 20/40 of MGA-treated heifers were synchronized within the first six days following MGA treatment. All of these were in heat between days 3-6, with no heats occurring before day 3. These synchronized heifers should have had 8-11 day old corpora lutea that should have been responsive to the PGF injection given on day 14. Another 14/40 (35%) of MGA+PGF heifers were in estrus on days 7-14 following MGA treatment. Half of these, which experienced estrus on days 7-8, may have had corpora lutea responsive to the PGF injection on day 14. It is unlikely, however, that the other half, in heat between days 9-14, would have responded to PGF given on day 14. The remaining 6/40 (15%) of MGA+PGF heifers were not observed in estrus following MGA treatment. Of these, two were in synchronized estrus following the PGF injection given on day 14, and the remaining four were observed in estrus on day 11, 20, 21, or 46 following PGF treatment.

The estrous response rate to nine days of MGA treatment in this research project is much lower than estrous response rates of 70-100 percent reported for longer (14-day) MGA treatment periods (19, 35, 42, 59, 82, 84). MGA treatment for nine days appears to be an insufficient length of time to obtain acceptable estrous synchrony results following treatment. If MGA feeding had caused corpora lutea to regress within nine days of treatment as believed at the
onset of this research project, nine days should have been a sufficient treatment period for synchronizing the majority of heifers. But poor estrous response following nine days of MGA treatment, as seen in this study, may support previous reports that the lifespan of the CL is not affected by MGA treatment (19, 56, 58, 60).

MGA treatment suspends the estrous cycle in a false luteal stage but does not prevent normal maturation and regression of corpora lutea. As existing corpora lutea regress naturally during the treatment period, new follicles begin to mature. These follicles are held in a proestrous-like state without ovulating until after MGA withdrawal. Heifers that begin MGA treatment while in the proestrous stage of the estrous cycle, with a regressed CL and a maturing follicle, are held in that stage with the follicle continuing to mature, but not ovulating, until after MGA is withdrawn. Heifers in the diestrous or luteal stage of the estrous cycle when MGA treatment begins should experience normal maturation and regression of the CL during treatment. If in late diestrus when MGA treatment begins, the CL will completely regress and a new follicle will mature which should then ovulate when MGA is withdrawn. If in early diestrus at the initiation of MGA treatment, the CL may just be reaching the point after nine days of MGA treatment where it regresses naturally. Since the CL is at the point of
natural regression when MGA is withdrawn, these heifers should come into heat on their own within four to six days after treatment and would appear to be synchronized along with heifers that began treatment in late diestrus or proestrus.

Part of the synchrony problem with a 9-day MGA feeding period appears to lie with those animals that began MGA treatment while in the metestrous stage of the estrous cycle. With normal maturation and regression of the CL continuing during MGA treatment, these animals would have advanced only to a point in mid-diestrus after nine days of MGA treatment. These presumably would have a mature CL but no significant follicular growth at MGA withdrawal. They would not be expected to be in estrus, then, until approximately 7-11 days following MGA treatment and would therefore not be synchronized with the other treated animals. Illustrating this point, Roche (62) found from a study with heifers given a nine-day progesterone dew-lap implant, that estrous response was low for animals that began treatment during periods of CL formation (metestrus). He reported an estrous response rate of only 50 percent for heifers beginning progesterone treatment on day 3 of the estrous cycle. But approximately 25 percent of a group of animals might be expected to be in metestrus at any given time, so this metestrus group would probably not account for
the full synchrony problem experienced in this research project.

Roche's study (62) provides additional information on estrous response rates as a function of the stage of the estrous cycle when animals begin progesterone treatment. He found that the best estrous response came from animals that were in the luteal stages of the estrous cycle when progesterone treatment began. He reported a 100 percent estrous response rate for heifers that began progesterone treatment on days 6-14 of the estrous cycle. But the estrous response rate for heifers beginning treatment during periods of follicular growth (day 17 of the estrous cycle) was only 56 percent. Hill et al. (35) reported a similar estrous response rate of 53 percent for heifers that were fed MGA for 14 days, beginning on day 15 of the estrous cycle. This was compared to an estrous response rate of 80 percent for heifers beginning the same treatment on day 4 of the estrous cycle. A third study by Henricks et al. (32) supports these findings with an estrous response rate of 56 percent for heifers that began 14-day MGA feedings on day 15 of the estrous cycle.

From these studies, there appears to be an additional synchrony problem with animals beginning progesterone treatment while in proestrus or late diestrus. The exact cause of this problem is not fully understood. Roche (62)
reported that heifers which began progesterone treatment on day 17 of the estrous cycle, but were not observed in estrus following treatment, all had palpable corpora lutea five days after treatment. This indicates that the heifers had all ovulated following treatment but did not express estrus. Hill et al. (35) found that animals which began MGA treatment while late in the estrous cycle were more likely to have abnormal follicular populations on their ovaries than animals that began treatment in earlier stages of the estrous cycle. No attempt was made in the present study to determine the cycle stage of heifers at the initiation of treatment, but it can be assumed that approximately 25 percent of a group of animals might be expected to be in proestrus at any given time. It is presumable that animals in proestrus or late diestrus contributed significantly to the MGA synchrony problem experienced in the present study.

Days to estrus following prostaglandin treatment (Table 5) did not differ significantly for the 2X-PGF and the MGA+PGF groups (2.93 and 3.31 days respectively). Days to estrus following MGA treatment for the MGA+PGF group was significantly longer (P<.05) than days to estrus following PGF treatment for the same group (4.15 vs. 3.31 days). This longer interval to estrus following MGA treatment agrees with previous studies which reported estrus occurring at an
average of 3.7–4.7 days after 14-day MGA treatments (35, 59, 84).

Table 5. Days to estrus in five trials comparing 2X-PGF and MGA+PGF for estrous synchronization in Holstein heifers.a

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Days to estrus after PGF</th>
<th>Days to estrus after MGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2X-PGF</td>
<td>2.93+.20</td>
<td>-</td>
</tr>
<tr>
<td>MGA+PGF</td>
<td>3.31+.24b</td>
<td>4.15+.27c</td>
</tr>
</tbody>
</table>

aPercentages shown represent least-squares means. 
b,cFigures in same row with different superscripts differ (P<.05).

Conception Rates

Estrous response, synchronized conception rate (percentage of inseminated animals conceiving within six days of treatment) and synchronized pregnancy rate (percentage of treated animals conceiving within six days of treatment) are shown in Table 6. The synchronized conception rate tended to be higher for the MGA+PGF group than for the 2X-PGF group (81.2% vs. 63.6%), although the difference was not statistically significant (P=.12). This tendency suggests a more fertile estrus following MGA+PGF treatment than seen with the PGF treatment alone.
Table 6. Estrous response and synchronized conception and pregnancy rate in five trials comparing 2X-PGF and MGA+PGF for estrous synchronization in Holstein heifers.

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Estrous response</th>
<th>Synchronized conception rate</th>
<th>Synchronized pregnancy rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2X-PGF</td>
<td>35/39=88.9%</td>
<td>24/35=63.6%</td>
<td>24/39=59.2%</td>
</tr>
<tr>
<td>MGA+PGF</td>
<td>26/40=63.3%</td>
<td>21/26=81.2%</td>
<td>21/40=51.2%</td>
</tr>
</tbody>
</table>

Percentages shown represent least squares means.
Figure in same column with different superscripts differ (P<.01).

Although fertility was high for animals in the MGA+PGF group that were inseminated, synchronized pregnancy rate, which accounts for the total number of animals that were initially treated in a group, was lower (nonsignificantly; P<.5) for the MGA+PGF group than for the 2X-PGF group (51.2% and 59.2% respectively). The low synchronized pregnancy rate seen in the MGA+PGF group is a reflection of the low synchrony resulting after MGA (48.1%) and PGF (63.3%) treatments. From a management point of view, synchronized pregnancy rate is the true determinant of the effectiveness of an estrous synchronization program. It gives the best indication of the percentage of animals that can actually
be expected to calve from inseminations following a particular synchronization treatment.

The first service conception rate (Table 7) did not differ significantly between either treatment groups or controls. Although the differences were not significant (P<.3), first service conception rate for the MGA+PGF group showed a tendency towards increased fertility over the other two groups. While we know that progesterone has an adverse effect on fertility rates when heifers are inseminated at the estrus immediately following progesterone treatment (2, 7, 8, 32, 35, 56, 59, 84), there is some evidence to suggest that progesterone treatment may actually enhance conception during subsequent estrous cycles. If this is so, it may explain the high synchronized conception rate, and the tendency toward increased first service conception rate for the MGA+PGF group shown in this study. Britt et al. (8), Roche and Crowley (64), and De Bois and Bierschwal (19) all reported unusually high conception rates on the second estrus following progesterone treatment. This may be due to progesterone having a priming effect on the estrous cycle. This priming effect is visible in the fact that progesterone treatment is known to induce estrus in animals that are not already cycling when treatment is initiated (1, 53, 54).
Table 7. First service conception rate in five trials comparing Control, 2X-PGF, and MGA+PGF groups.

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>First service conception rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>68.4 %</td>
</tr>
<tr>
<td>2X-PGF</td>
<td>70.2 %</td>
</tr>
<tr>
<td>MGA+PGF</td>
<td>81.7 %</td>
</tr>
</tbody>
</table>

*Percentages shown represent least squares means.

Estrous Behavior

Estrous response and conception and pregnancy rates were measured to determine the effectiveness of each of the control and synchronization programs when used in a program of heifer A.I. In addition to these measures, estrous behavior data provided further information on each program's effectiveness. Estrous behavior for control and treatment groups was recorded throughout the project. Table 8 presents estrous behavior responses for each group as seen during the first 21 days of the breeding period. The breeding period for the control heifers began on the beginning date of each trial. The breeding period for the 2X-PGF group began on the day following the first PGF injection for heifers that responded to the first injection
and on the day following the second injection for heifers to which this second injection was given. For the MGA+PGF group, the breeding period began on the day following PGF treatment.

Table 8. Observed estrous behavior during first 21 days of breeding period in five trials comparing Control, 2X-PGF, and MGA+PGF groups.

<table>
<thead>
<tr>
<th>Code no.</th>
<th>Activity</th>
<th>Group</th>
<th>No. times action performed/heifer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>7.4a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2X-PGF</td>
<td>8.1ab</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MGA+PGF</td>
<td>10.6b</td>
</tr>
<tr>
<td>1</td>
<td>Stand</td>
<td></td>
<td>10.2</td>
</tr>
<tr>
<td>2</td>
<td>Mount</td>
<td></td>
<td>10.2</td>
</tr>
<tr>
<td>3</td>
<td>No-stand</td>
<td></td>
<td>3.0a</td>
</tr>
<tr>
<td>4</td>
<td>Chin-stand</td>
<td></td>
<td>3.2</td>
</tr>
<tr>
<td>5</td>
<td>Chin-mount</td>
<td></td>
<td>3.7</td>
</tr>
<tr>
<td>3</td>
<td>Chin-mount</td>
<td></td>
<td>3.6b</td>
</tr>
<tr>
<td>5</td>
<td>Chin-mount</td>
<td></td>
<td>3.8</td>
</tr>
</tbody>
</table>

Figures in same column with different superscripts differ (P<.05).

Occurrence of estrous activities No. 6 (clear mucus discharge), No. 7 (bloody mucus discharge), and No. 8 (unusual behavior) were limited. These activities, therefore, were not included in the analysis. Heifers in the MGA+PGF group tended to be more actively involved in
standing and mounting activities during the first 21 days of the breeding period than either control or 2X-PGF heifers. An increase in standing behavior could prove beneficial in an estrous synchronization program by increasing the probability that estrus will be detected following treatment.

Odde (53) reported a prolonged period of sexual hyperactivity (up to 36 hours or more) with manifestations of secondary heat signs prior to estrus in 14-day MGA+PGF treated heifers. Similar behavior for the MGA+PGF group was not observed in this study, however, as evidenced by data recorded during twice daily estrous observation periods. Standing activity was confined to one, and in some cases two consecutive observation periods for each heifer that was detected in estrus. Mounting activity was concentrated mainly during the same one to two observation periods in which standing activity was observed, but some additional random mounting activity occurred throughout the 21-day period. There were no detectable activity patterns for refusals to mount and for chin resting activities throughout the 21-day period.

Estrous Detection

Hillers et al. (36) has suggested that poor accuracy of estrous detection is an additional factor which may
discourage the practice of A.I. on some dairies. Blood samples taken at the time of insemination in this study were assayed for plasma progesterone levels to determine the accuracy of estrous detection. Plasma progesterone did not differ between control and treatment groups (Table 9).

Table 9. Plasma progesterone levels at first insemination in five trials comparing Control, 2X-PGF, and MGA+PGF groups.

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Plasma Progesterone ng/ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.193 ± 0.077</td>
</tr>
<tr>
<td>2X-PGF</td>
<td>0.329 ± 0.071</td>
</tr>
<tr>
<td>MGA+PGF</td>
<td>0.201 ± 0.072</td>
</tr>
</tbody>
</table>

Estrous detection accuracy, or the percentage of animals inseminated that were actually in heat, was determined by the percentage of heifers with plasma progesterone levels below 1 ng/ml (75) at the time of insemination. A total of 114 first service blood samples were assayed for plasma progesterone content during the course of this research project. Of these, 113 (99.1%) were below 1 ng/ml. One heifer in the 2X-PGF treatment group had a plasma progesterone level of 4.56 ng/ml at the time of
first insemination, indicating that she was probably not in estrus. This heifer did not conceive to the breeding.

The result of estrous detection accuracy (99.1%) in this research project was considered to be excellent. This was achieved with two 30-minute observation periods each day. In agreement with Gwazdauskas et al. (27) moving heifers on this research project from their usual environment on concrete to a novel dirt lot for observations was believed to enhance the expression of estrous behavior, thereby making estrus easier to detect.

Labor Requirements

A second objective of this research project was to compare the two synchronizing methods with the control program of daily estrous observations on the basis of management requirements as measured by labor inputs. In determining labor requirements for the control and treatment groups, the following assumptions were made:

- untreated control heifers would be observed for estrus 365 days per year
- synchronization treatments would be conducted four times per year
- 100 heifers would be inseminated per year for each treatment or control group

Under these conditions it was possible to calculate daily and yearly labor requirements for each of the control and treatment groups. The control group was calculated to
require an average of 1.14 hours of labor per day for 365 days per year. This includes two 30-minute estrous observation periods per day and 30 minutes per heifer for inseminating and record keeping (Appendix B). On an annual basis, this translates to 416 hours of labor per year for an A.I. program based on twice daily estrous observation periods.

Given the above assumptions, labor requirements for the 2X-PGF synchronizing regime was calculated to be 2.17 hours per day for the twelve days included in each treatment period (six days following each PGF injection). Labor requirements again included two 30-minute estrous detection periods per day. The remaining 1.17 hours is the average amount of time per day estimated as necessary on this project for inseminating, record keeping, and administering PGF injections to heifers in this treatment group (Appendix B). This time estimate would be expected to vary somewhat for each individual dairy situation. A twelve-day treatment period, then, would require a total of 26 hours of labor. With four treatment periods per year, this synchronizing method would require 104 hours of labor annually.

Labor requirements for the MGA+PGF synchronizing regime was calculated to be 3.08 hours per day for six days each treatment period (the first six days following PGF treatment). In addition to two 30-minute estrous
observation periods, an average of 2.08 hours per day was estimated as necessary for inseminating, record keeping, and administering a single PGF injection to heifers on this treatment (Appendix B). Again, this time estimate may vary for individual situations. This regime requires a total of 18.5 hours of labor per six-day treatment period and 74 hours of labor on an annual basis.

Clearly, the MGA+PGF synchronizing regime requires the least annual labor input (74 hours) as compared with the 2X-PGF regime (104 hours), and the control regime, which requires over five times the hours (416 hours). Annual labor for the control group is four times greater than for the 2X-PGF group. Estrous synchronization appears to be a practical alternative to daily estrous detection for dairymen with limited time to invest in a program of heifer A.I. In addition, where labor costs are high, there may be an economic advantage in synchronizing dairy heifers to minimize the labor required for estrous detection.

Economic Results

A third objective of this study was to compare the costs involved in administering a program of heifer A.I. with either daily estrous observations or estrous synchronization. The cost of administering each program was determined by projecting total labor, treatment,
insemination and feed costs from the time animals in a treatment group were started on either a program of daily estrous observations or estrous synchronization, until each animal in a group had calved. This was measured by assuming that all animals in each treatment group began treatment on the same day and that each group began with an equal number of heifers. Costs included were labor costs for heat detection and insemination, semen costs, treatment costs for the synchronization groups, and feed costs to carry each group of animals through the insemination and gestation periods. All heifers in the synchronization groups were treated at the initial synchronization and the percent that were calculated to conceive was the synchronized pregnancy rate (59.2% for the 2X-PGF group, and 51.2% for the MGA+PGF group). Heifers in these two groups were calculated to be synchronized a maximum of three times. If not pregnant following the third synchronization, they were assumed to conceive within two natural cycles after the third synchronization. The percentage of Control heifers calculated to conceive at each 21-day cycle was the first service conception rate (68.4%). A maximum of five inseminations were also allowed for heifers in the Control group.

Labor costs for each group were calculated by multiplying the number of heifers in a treatment group by
the hours required per heifer for restraint, inseminating, and record keeping (Appendix B). The number of hours required per day for heat detection was multiplied by the number of days required for heat detection and added to the total hours required for A.I. The total hours for heat detection and A.I. were then multiplied by the hourly labor charge to obtain a total cost of labor.

Insemination costs were calculated by multiplying the cost per straw of semen by the services per conception rate calculated for each treatment from the results of this study. Services per conception for the Control group were calculated using the first service conception rate: $1+\left(1-\text{first service conception rate}\right)$. Services per conception for the two synchronizing groups were calculated using the synchronized pregnancy rate: $1+\left(1-\text{synchronized pregnancy rate}\right)$.

Treatment costs for the 2X-PGF group were calculated by multiplying the cost of a single PGF injection by the number of injections required per heifer. The number of injections per heifer was calculated using the estrous response rate from this study following the first PGF injection: $1+\left(1-\text{estrous response after first PGF}\right)$. Treatment costs for the MGA+PGF group was calculated by multiplying the cost per pound of MGA pellets by the total number of pounds fed per heifer and adding the cost of a
single PGF injection. There were no treatment costs for the Control group.

Feed costs were calculated by multiplying the daily feed cost per heifer by the total number of heifers in each of three feeding periods: Early feeding period - from beginning of treatment until confirmed pregnancy. Middle feeding period - from confirmed pregnancy until 30 days before calving. Late feed period - from 30 days before calving until calving.

Calculations in the economic analysis use the actual treatment costs experienced in this study as shown below. Services per conception and the number of injections per heifer were calculated from results of this research.

Treatment costs per heifer:

<table>
<thead>
<tr>
<th>Service</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGF injection</td>
<td>$5.50</td>
</tr>
<tr>
<td>9 lbs MGA pellets</td>
<td>$0.99</td>
</tr>
<tr>
<td>Semen/straw</td>
<td>$15.00</td>
</tr>
</tbody>
</table>

Services per conception:

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>1.32</td>
</tr>
<tr>
<td>2X-PGF</td>
<td>1.41</td>
</tr>
<tr>
<td>MGA+PGF</td>
<td>1.49</td>
</tr>
</tbody>
</table>

No. injections per heifer:

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>0</td>
</tr>
<tr>
<td>2X-PGF</td>
<td>1.36</td>
</tr>
<tr>
<td>MGA+PGF</td>
<td>1.00</td>
</tr>
</tbody>
</table>
These figures were used to determine the total costs associated with a heifer A.I. program involving either daily estrous observations (Control) or estrous synchronization (2X-PGF or MGA+PGF). Tables 10, 11, and 12 are examples of the tables used to project total costs. Table 10 shows calculations for the Control group with a group size of 100 heifers. The analysis covers a total of 567 days. This was the time required for all heifers in the MGA+PGF group to calve when synchronization was scheduled four times per year. This time period was divided into 27 periods, 21 days in length (the length of an average estrous cycle). Calculations for all treatment groups, therefore, were made over 27 periods for an equal basis of comparison. The next three columns list by period the number of pregnant heifers in each of the three feed price groups. The next column shows the number of open heifers per period. The following three columns show the feed cost per heifer per day for the three feed price groups. The labor column shows the cost per period with labor calculated at five or 10 dollars per hour. Labor costs were included only in periods when estrous detection, A.I., or synchronization treatments were performed. Estrous detection continued until all heifers were confirmed pregnant, which was two cycles after the last heifer was bred. The next column shows the insemination costs calculated during periods in which A.I. was performed.
Table 10. Calculation of total costs for 100 Control heifers.

<table>
<thead>
<tr>
<th>Control 100 heifers</th>
<th>No. pregnant</th>
<th>No. open</th>
<th>Feed cost per heifer</th>
<th>Labor $5</th>
<th>A.I. $</th>
<th>Total $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>Early Mid Late</td>
<td>Early Early Mid Late</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-21</td>
<td>68</td>
<td>32</td>
<td>$1.00 $1.25 $3.00</td>
<td>$355.00</td>
<td>$1,980.00</td>
<td>$4,435.00</td>
</tr>
<tr>
<td>22-42</td>
<td>90</td>
<td>10</td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td>$633.60</td>
<td>$2,918.60</td>
</tr>
<tr>
<td>43-63</td>
<td>97</td>
<td>3</td>
<td>$1.00 $1.25 $3.00</td>
<td>$130.00</td>
<td>$198.00</td>
<td>$2,428.00</td>
</tr>
<tr>
<td>64-84</td>
<td>99</td>
<td>1</td>
<td>$1.00 $1.25 $3.00</td>
<td>$112.50</td>
<td>$59.40</td>
<td>$2,271.90</td>
</tr>
<tr>
<td>85-105</td>
<td>32 68</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$105.00</td>
<td></td>
<td>$2,562.00</td>
</tr>
<tr>
<td>106-126</td>
<td>10 90</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$105.00</td>
<td></td>
<td>$2,677.50</td>
</tr>
<tr>
<td>127-147</td>
<td>3 97</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,633.60</td>
</tr>
<tr>
<td>148-168</td>
<td>1 99</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,669.25</td>
</tr>
<tr>
<td>169-189</td>
<td>100</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>190-210</td>
<td>100</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>211-231</td>
<td>100</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>232-252</td>
<td>100</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>253-273</td>
<td>100</td>
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<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
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<tr>
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<td>32 68</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>295-315</td>
<td>10 90</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>316-336</td>
<td>3 32</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>337-357</td>
<td>1 10</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>358-378</td>
<td>3</td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>379-399</td>
<td>1</td>
<td></td>
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<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>400-420</td>
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<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
</tr>
<tr>
<td>421-441</td>
<td></td>
<td></td>
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<td>$185.00</td>
<td></td>
<td>$2,625.00</td>
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<tr>
<td>442-462</td>
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<td>$185.00</td>
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<td>$2,625.00</td>
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<tr>
<td>463-483</td>
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<td>$2,625.00</td>
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<tr>
<td>484-504</td>
<td></td>
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<td>$1.00 $1.25 $3.00</td>
<td>$185.00</td>
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<td>$2,625.00</td>
</tr>
<tr>
<td>505-525</td>
<td></td>
<td></td>
<td>$1.00 $1.25 $3.00</td>
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<td>$2,625.00</td>
</tr>
<tr>
<td>526-546</td>
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$49,706.50 Total costs
$48,427.88 Net present value
5 Annual interest rate
27 No. of periods
$484.28 NPV cost per heifer
Table 11. Calculation of total costs for 100 MGA+PGF heifers, with synchronization four times per year.

<table>
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<tr>
<th>MGA+PGF 4X/yr</th>
<th>No. pregnant</th>
<th>No. open</th>
<th>Feed cost per heifer</th>
<th>Labor $5</th>
<th>Treat $</th>
<th>A.I. $</th>
<th>Total $</th>
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<td>100 heifers</td>
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</tr>
<tr>
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<td>Mid</td>
<td>Late</td>
<td>Early</td>
<td>Mid</td>
<td>Late</td>
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<td>$1.25</td>
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<td>$1.25</td>
<td>$3.00</td>
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<td>$3.00</td>
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<td>$1.25</td>
<td>$3.00</td>
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<td>$1.25</td>
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<td>$1.00</td>
<td>$1.25</td>
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<td>$107.91</td>
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<td>$1.25</td>
<td>$3.00</td>
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<td>$1.25</td>
<td>$3.00</td>
<td>$107.91</td>
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<td>$1.25</td>
<td>$3.00</td>
<td>$107.91</td>
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<tr>
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<td>$1.25</td>
<td>$3.00</td>
<td>$107.91</td>
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<td>400-420</td>
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<td>$3.00</td>
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<td>$1.25</td>
<td>$3.00</td>
<td>$107.91</td>
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<td>$1.25</td>
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<td>$107.91</td>
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<td>$1.25</td>
<td>$3.00</td>
<td>$107.91</td>
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<tr>
<td>484-504</td>
<td>25</td>
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<td>$1.25</td>
<td>$3.00</td>
<td>$107.91</td>
</tr>
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<td>505-525</td>
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<td>$3.00</td>
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<td>$1.25</td>
<td>$3.00</td>
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<td>$1.00</td>
<td>$1.25</td>
<td>$3.00</td>
<td>$107.91</td>
</tr>
</tbody>
</table>

| Totals        | $365.07      | $1,122.77 | $2,756.73           | $56,093.57 |

$56,093.57 Total costs
$54,332.20 Net present value
5 Annual interest rate
27 No. of periods
$543.32 NPV cost per heifer
Table 12. Calculation of total costs for 100 2X-PGF heifers, with synchronization six times per year.

<table>
<thead>
<tr>
<th>Day 1-21</th>
<th>59</th>
<th>41</th>
<th>Early</th>
<th>$1.00</th>
<th>$1.25</th>
<th>$3.00</th>
<th>$308.92</th>
<th>$748.00</th>
<th>$1,880.24</th>
<th>$5,037.16</th>
</tr>
</thead>
<tbody>
<tr>
<td>22-42</td>
<td>59</td>
<td>41</td>
<td>Early</td>
<td>$1.00</td>
<td>$1.25</td>
<td>$3.00</td>
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<td>$748.00</td>
<td>$1,880.24</td>
<td>$5,037.16</td>
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<tr>
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<td>$1.25</td>
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<td>$3.00</td>
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<td>$1.25</td>
<td>$3.00</td>
<td>$162.06</td>
<td>$306.68</td>
<td>$770.90</td>
</tr>
<tr>
<td>106-126</td>
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</tr>
<tr>
<td>148-168</td>
<td>10</td>
<td>83</td>
<td>7</td>
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<td>$1.00</td>
<td>$1.25</td>
<td>$3.00</td>
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<tr>
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<td>$2,588.25</td>
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<tr>
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<tr>
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<td>$1.25</td>
<td>$3.00</td>
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<td>$30.00</td>
<td>$2,418.25</td>
<td>$2,588.25</td>
</tr>
<tr>
<td>337-357</td>
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<td>24</td>
<td>Early</td>
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<td>$1.25</td>
<td>$3.00</td>
<td>$138.60</td>
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<td>$2,418.25</td>
<td>$2,588.25</td>
</tr>
<tr>
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<td>$138.60</td>
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<td>$1.25</td>
<td>$3.00</td>
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<td>$2,418.25</td>
<td>$2,588.25</td>
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<tr>
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<td>10</td>
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<td>$1.25</td>
<td>$3.00</td>
<td>$138.60</td>
<td>$30.00</td>
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<td>$2,588.25</td>
</tr>
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<td>$1.25</td>
<td>$3.00</td>
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<td>$2,418.25</td>
<td>$2,588.25</td>
</tr>
<tr>
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<td>$1.25</td>
<td>$3.00</td>
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<td>$30.00</td>
<td>$2,418.25</td>
<td>$2,588.25</td>
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<tr>
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<td>$1.25</td>
<td>$3.00</td>
<td>$138.60</td>
<td>$30.00</td>
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<td>$2,588.25</td>
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<td>$1.25</td>
<td>$3.00</td>
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<td>$30.00</td>
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<td>$2,588.25</td>
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<tr>
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<td>$1.25</td>
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<td>$2,418.25</td>
<td>$2,588.25</td>
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<td>$1.25</td>
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<tr>
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<td>$1.25</td>
<td>$3.00</td>
<td>$138.60</td>
<td>$30.00</td>
<td>$2,418.25</td>
<td>$2,588.25</td>
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</tr>
</tbody>
</table>

$51,409.50 Total costs
$50,047.49 Net present value
5 Annual interest rate
27 No. of periods
$500.47 NPV cost per heifer
The final column calculates the total cost per period for feed, labor, and A.I. Total costs, net present value of total costs, the discount rate, and the net present value cost per heifer are presented at the bottom of the table.

Costs were projected over a 567-day period, as this was the total number of days required for all animals to calve when MGA+PGF synchronization was scheduled four times per year (Table 11). By projecting costs over this total period, costs were measured as they occurred for each treatment group, taking time value into account during the period. The total costs projected for each treatment group during this 567-day period were put on an equal basis of comparison by calculating their net present values. An annual discount rate of 5% was used in these analyses.

Tables 11 and 12 also include treatment costs for synchronization. Treatment costs were calculated only in periods in which they were incurred. Table 11 calculates costs for the MGA+PGF group when synchronization was scheduled four times per year. Table 12 calculates costs for the 2X-PGF group when synchronization was scheduled six times per year. Similar tables were calculated for each treatment group with 50, 100, or 200 heifers per group, with labor at both five and 10 dollars per hour, and with synchronization scheduled for four and six times per year. These calculations are summarized in Tables 13 and 14.
Table 13. Costs of administering a program of heifer A.I. with daily estrous observations or estrous synchronization scheduled four times per year.

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<th>4X per year</th>
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<td></td>
<td>Labor $5/hr</td>
<td>Labor $10/hr</td>
<td></td>
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<tr>
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<td></td>
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<td></td>
</tr>
<tr>
<td><strong>50 Heifers</strong></td>
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<tr>
<td>Control</td>
<td>$24,538.04</td>
<td>$25,443.86</td>
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</tr>
<tr>
<td>2X-PGF</td>
<td>$25,924.57</td>
<td>$26,294.56</td>
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<td>$27,384.27</td>
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<tr>
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<td></td>
</tr>
<tr>
<td><strong>100 Heifers</strong></td>
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</tr>
<tr>
<td>Control</td>
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<td>$54,693.23</td>
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<td>4</td>
<td></td>
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<td><strong>200 Heifers</strong></td>
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<tr>
<td>Control</td>
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<td>$103,745.12</td>
<td>$104,702.58</td>
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</tr>
<tr>
<td>MGA+PGF</td>
<td>$108,575.78</td>
<td>$109,209.20</td>
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</tr>
<tr>
<td></td>
<td>5</td>
<td>6</td>
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</table>
Table 14. Costs of administering a program of heifer A.I. with daily estrous observations or estrous synchronization scheduled six times per year.

<table>
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<th>6X per year</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Labor $5/hr</td>
<td>Labor $10/hr</td>
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</tr>
<tr>
<td>50 Heifers</td>
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</tr>
<tr>
<td>Control</td>
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<tr>
<td>MGA+PGF</td>
<td>$26,236.96</td>
<td>$26,461.28</td>
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<tr>
<td>100 Heifers</td>
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<td>$48,552.75</td>
<td>$49,642.78</td>
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<td>$50,047.49</td>
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<td>MGA+PGF</td>
<td>$52,465.99</td>
<td>$52,827.40</td>
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<td>200 Heifers</td>
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<tr>
<td>Control</td>
<td>$96,378.96</td>
<td>$97,832.46</td>
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<tr>
<td>2X-PGF</td>
<td>$99,917.04</td>
<td>$100,876.07</td>
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<tr>
<td>MGA+PGF</td>
<td>$104,843.18</td>
<td>$105,477.20</td>
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The net present values of total costs when synchronization is scheduled four times per year are compared in Table 13. In all situations, the Control group had an economic advantage over either synchronization group. This advantage increased as heifer numbers increased. The frequency of estrous synchronization was increased to six times per year in Table 14. The economic advantage of the Control group decreased by increasing the frequency of synchronization. Estrous synchronization by the 2X-PGF method had a slight economic advantage, in fact, when heifer numbers were low and labor costs were high.

The totals presented in Tables 13 and 14 represent projected costs using results from this study. These totals would be expected to vary with each individual situation. They are useful, however, in identifying trends that may help dairymen to determine the most economical method for administering a heifer A.I. program on their own dairies.

With a four-times-per-year synchronizing program, synchronization was scheduled once every three months. Heifers were allowed a maximum of three synchronizations followed by two breedings from natural heats, meaning the last of these heifers would calve between 547-567 days after the beginning of the initial treatment period (Table 11). This was compared to heifers in the Control group with the last of these projected to calve between 379-399 days after
the beginning of the breeding period (Table 10). Although overall labor costs for the Control group were higher, they were offset by the cost of feeding a percentage of the synchronized heifers for an additional 168-188 days.

When synchronization is scheduled six times per year, it is performed once every two months, thereby reducing the time between synchronization treatments, and cutting the time until the last heifers calve to approximately 484-504 days (Table 12). This reduces the overall cost of feeding the synchronized heifers, thereby reducing the economic advantage of daily estrous detection over estrous synchronization.

In all cases, estrous synchronization by the 2X-PGF method had an economic advantage over synchronization by the MGA+PGF method. The margin between the two synchronization groups was greatest when labor costs were low.

Feed was the major cost associated with each treatment in this economic analysis. Moderate shifts in feed prices which affected one or more of the three feed price groups tended to slightly increase or decrease the margins between treatment groups but did not significantly alter the overall economic results. A program of daily estrous detection tends to minimize feed costs by reducing the number of days between inseminations when a heifer does not conceive.
Synchronization generally increases feed costs by lengthening the time between inseminations. However, increasing the frequency of synchronization treatments will reduce the time between inseminations, thereby reducing feed costs. This effect was seen in this analysis when total costs were reduced by increasing synchronization from four to six times per year.

These economic results are not meant to be conclusive. Because economics will vary widely for each dairy situation, these results can best be used as guidelines to aid dairymen in determining the most economical method of administering a heifer A.I. program given their individual situations.
CONCLUSIONS

Results of this study showed that the management of a heifer A.I. program involving either daily estrous observations or estrous synchronization with two injections of PGF or with MGA and PGF to be equivalent in overall effectiveness. Synchronized pregnancy rates, which account for the total number of animals treated in a group, did not differ between the two synchronization groups. In addition, first service pregnancy results did not differ between the treatment and control groups.

The overall effectiveness of programs of daily estrous detection and estrous synchronization were found to be equivalent in this study. This equivalency gives the dairyman the opportunity to base management decisions to a greater degree on the labor inputs and economic factors associated with each treatment when considering daily estrous detection or estrous synchronization for managing a program of heifer A.I.

Results of this study show the MGA+PGF synchronization regime (nine days of MGA feeding followed with a single PGF injection 14 days later) to require the least amount of labor input (74 hours per year when synchronization is repeated four times annually). Synchronization with two injections of PGF was calculated in this study to require
104 hours annually. Daily estrous observations required over five times the amount of labor as the MGA+PGF group and four times more than the 2X-PGF group. These results suggest that synchronization would be a practical option when labor for managing a heifer A.I. program is costly or unavailable.

Economic results of this study show that a program of daily estrous detection has an economic advantage over estrous synchronization programs when synchronization is scheduled four times per year. When synchronization is increased to six times per year, the economic advantage of daily estrous observations over estrous synchronization is reduced. Estrous synchronization is slightly favored when animal numbers are low and labor costs are high. Daily estrous detection is favored when animal numbers are high and labor costs are low. Since feed was the major cost of each group, a program of daily estrous observations had an advantage in being able to reduce feed costs by decreasing the number of days that heifers had to be fed between inseminations when they did not conceive. Estrous synchronization, on the other hand, tended to increase the number of days between inseminations, thereby increasing total feed costs. Increasing the frequency of synchronization treatments helped to reduce the days between inseminations, thereby decreasing feed costs.
In addition to the above comparisons between programs of daily estrous detection and estrous synchronization, this project studied the effectiveness of a combination of MGA and PGF for synchronizing estrus in dairy heifers. As reported in the results, a nine-day administration period for MGA was not of sufficient length to achieve satisfactory synchrony following treatment. Low synchrony following MGA withdrawal led to low synchrony following PGF injection. But because fertility tended to be greater for those animals that were synchronized, treatment with MGA and PGF holds great potential as a synchronizing regime if estrous response results can be improved.

Estrous response should be improved by lengthening the MGA administration period so that animals in metestrus at the initiation of treatment will have time to progress to late diestrus or proestrus by the time of MGA withdrawal. MGA treatment would need to be at least 14 days in length to achieve this. Brown, et al. (10) reported good synchrony results with a 14-day MGA-feeding period followed 17 days later with a single injection of PGF. Additional research is needed to compare such a 14-day MGA+PGF treatment with control groups and with other synchronizing methods. Such a treatment could be of significant value, particularly if fertility is indeed enhanced as the tendency showed in this study.
REFERENCES


64. Roche, J. F., and J. P. Crowley. 1973. The fertility of heifers inseminated at predetermined intervals following treatment with MGA and hCG to control ovulation. J. Reprod. Fertil. 35:211.


APPENDIXES
Appendix A. Heifer Heat Report

DATE: ___________  TIME: ________  OBSERVER: ______________________________

1. Stood to be mounted  
2. Mounted another heifer  
3. Would not stand to be mounted  
4. Chin rest stand  
5. Chin rest ride  
6. Clear mucous discharge  
7. Blood mucous discharge  
8. Unusual activity

<table>
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<tr>
<th>Heifer #</th>
<th>Code #</th>
<th>No. X</th>
<th>Other Heifer</th>
<th>Heifer #</th>
<th>Code #</th>
<th>No. X</th>
<th>Other Heifer</th>
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Appendix B. Labor Calculations

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Hrs/day for estrous detection</th>
<th>Hrs/heifer for restraint, A.I., records</th>
<th>Hrs/heifer for PGF injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1</td>
<td>.5</td>
<td></td>
</tr>
<tr>
<td>2X-PGF</td>
<td>1</td>
<td>.33(^a)</td>
<td>.17</td>
</tr>
<tr>
<td>MGA+PGF</td>
<td>1</td>
<td>.33(^a)</td>
<td>.17</td>
</tr>
</tbody>
</table>

\(^a\) Labor for A.I. for both synchronization groups is reduced per heifer, due to the affect of inseminating several animals at the same time.

Labor Equations - calculated for 100 heifers per treatment group, with 365 days per year of estrous detection for the Control group, and synchronization scheduled four times per year for the 2X-PGF and MGA+PGF groups.

**Control:** \((100 \text{ heifers} \times .5 \text{ hrs/heifer})/365 \text{ days})+1 \text{ hr} = 1.14 \text{ hrs labor/day}\)

**2X-PGF:** \((100 \text{ heifers}(.33 \text{ hrs/heifer} + (.17 \text{ hrs/heifer} \times 1.36 \text{ PGF injections/heifer}))/48 \text{ days/year})+1 \text{ hr} = 2.17 \text{ hrs labor/day}\)

**MGA+PGF:** \((100 \text{ heifers}(.33 \text{ hrs/heifer} + .17 \text{ hrs/heifer}))/24 \text{ days/year})+1 \text{ hr} = 3.08 \text{ hrs labor/day}\)