



Evaluation of estrous synchronization management systems using prostaglandin F2a
by Vickie Lee Adkins

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Animal Science

Montana State University

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Abstract:

A simulation model was developed to evaluate various estrous synchronization systems which considered whether or not to palpate; whether to use one injection, five-day prebreeding or two injection system; and whether to breed by detection, 80 hour appointment or a combination of the two. Total cost (palpation, prostaglandin, semen and breeding supplies), total pregnancy rate and cost per pregnancy were calculated for each of seven systems for 11 different cycling rates (0 to 100 percent) and eight different conception rates (10 to 80 percent). For most cycling rates, five-day prebreeding systems resulted in one of the highest pregnancy rates and the lowest cost per pregnant cow. Single injection systems were usually favored over double injection systems in terms of lower total cost and lower cost per pregnancy. Palpation was desirable in the majority of systems except when 90 percent or more of the herd was cycling. Breeding by detection resulted in a lower cost per pregnancy than other breeding methods except when cows were palpated prior to injection and breeding.

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SYSTEMS USING PROSTAGLANDIN F_{2α}

by

VICKIE LEE ADKINS

A thesis submitted in partial fulfillment
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TABLE OF CONTENTS

Chapter		Page
	VITA	ii
	ACKNOWLEDGEMENTS	iii
	TABLE OF CONTENTS.	iv
	LIST OF TABLES	v
	LIST OF FIGURES.	vi
	ABSTRACT	vii
1	INTRODUCTION	1
2	LITERATURE REVIEW.	3
	Response to PGF _{2α}	3
	Estrous Synchronizing Systems	4
	Single Injection System.	6
	Five-day Prebreeding	8
	Double Injection--Single Insemination.	10
	Double Injection--Split Insemination	12
	Pregnancy Rates for Breeding Systems.	14
3	MATERIALS AND METHODS.	18
	Identifying Systems	18
	Estimating Reproductive Performance	21
	Estimating Costs.	26
	Evaluating Alternatives	28
4	RESULTS AND DISCUSSION	31
	Cost Per Pregnant Cow	31
	Number of Pregnant Cows	43
	Total Cost.	45
	General Considerations.	47
	Cost Factors.	50
	Conclusions	52
	APPENDIX 1 - COMPUTER PROGRAM.	55
	APPENDIX 2 - OUTPUT FROM SIMULATION PROGRAM.	62
	LITERATURE CITED	77

LIST OF TABLES

Table Number		Page
1	Synchronization Systems	19
2	Ranking of Synchronization Alternatives Based on Cost Per Pregnant Cow when Bred by Detection, Appointment or a Combination of the Two.	32
3	Ranking of Synchronization Alternatives Based on Cost Per Pregnant Cow when Bred by Detection	33
4	Ranking of Synchronization Alternatives Based on Cost Per Pregnant Cow when Bred by Appointment or a Combination of Detection and Appointment	34
5	Effect of Conception Rate on Total Pregnancy Rate.	42
6	Ranking of Synchronization Alternatives Based on Number of Pregnant Cows.	44
7	Ranking of Synchronization Alternatives Based on the Total Cost of the System	46

LIST OF FIGURES

Figure Number		Page
1	Estrous Cycle of the Cow.	5
2	Cost Per Pregnant Cow Values for Synchronization Alternatives when Bred by Detection Assuming an 80% Conception Rate	35
3	Cost Per Pregnant Cow Values for Synchronization Alternatives when Bred by Appointment or a Combination of Detection and Appointment Assuming an 80% Conception Rate	36
4	Palpation Versus No Palpation Alternatives for Five-day Prebreeding Systems based on Cost Per Pregnant Cow Assuming an 80% Conception Rate. . .	38
5	Palpation Versus No Palpation Alternatives for Single Injection Systems based on Cost Per Pregnant Cow Assuming an 80% Conception Rate. . .	39
6	Palpation Versus No Palpation Alternatives for Double Injection Systems based on Cost Per Pregnant Cow Assuming an 80% Conception Rate. . .	41

ABSTRACT

A simulation model was developed to evaluate various estrous synchronization systems which considered whether or not to palpate; whether to use one injection, five-day prebreeding or two injection system; and whether to breed by detection, 80 hour appointment or a combination of the two. Total cost (palpation, prostaglandin, semen and breeding supplies), total pregnancy rate and cost per pregnancy were calculated for each of seven systems for 11 different cycling rates (0 to 100 percent) and eight different conception rates (10 to 80 percent). For most cycling rates, five-day prebreeding systems resulted in one of the highest pregnancy rates and the lowest cost per pregnant cow. Single injection systems were usually favored over double injection systems in terms of lower total cost and lower cost per pregnancy. Palpation was desirable in the majority of systems except when 90 percent or more of the herd was cycling. Breeding by detection resulted in a lower cost per pregnancy than other breeding methods except when cows were palpated prior to injection and breeding.

Chapter 1

INTRODUCTION

Cow-calf producers often look to artificial insemination (AI) as one means of increasing pounds of calf weaned per cow bred. AI provides access to superior sires, facilitates crossbreeding programs and helps protect against venereal disease. Despite these advantages, many producers are reluctant to use AI because of the difficulty in detecting estrus under range conditions and the lack of adequate feed and facilities for confining cows during the normal breeding season.

Estrous synchronization would facilitate the use of AI for many producers by minimizing the need for heat detection and allowing cows to be bred during a shorter breeding period. A shorter breeding period reduces the length of the calving season and results in more uniformity in age and size of calves at weaning. More calves are born in the early part of the calving season and are older and heavier at weaning. Cows that calve early also tend to remain early calvers and produce more pounds of calf in their lifetime.

Although many estrous synchronizing agents are currently under study, only Prostaglandin F_{2α} (PGF_{2α}) has been cleared by the Food and Drug Administration for use in the United States. In developing a herd estrous synchronization program with PGF_{2α}, a producer is faced with several decisions. The first decision is whether or not to palpate in order to determine the proportion of cows cycling. Once

the decision is made to synchronize, a producer must then decide whether to use a one or two injection system. Finally, a producer must choose whether to breed by detection, appointment, or a combination of both. When all possible options are considered, several synchronization systems are feasible. In order to choose the most suitable system, a producer must be able to predict the effect of each breeding alternative on the overall pregnancy rate and total breeding cost. The best alternative for a particular producer will depend on the AI pregnancy rate desired, length of the breeding period, availability of labor and facilities, and the cost of prostaglandin and semen.

The purpose of this study was to evaluate various estrous synchronization systems in terms of expected breeding performance and related costs.

Chapter 2

LITERATURE REVIEW

Response to $\text{PGF}_{2\alpha}$

Prostaglandins were discovered in the 1930's by Goldblatt (1933) and Von Euler (1934) and have been identified as playing an integral role in the reproductive process of the beef female (Rowson et al., 1972). Prostaglandin $\text{F}_{2\alpha}$ ($\text{PGF}_{2\alpha}$), which is formed by the endometrium and secreted by the uterus (Wilson et al., 1972; Hansel et al., 1975), has been shown to cause regression of the corpus luteum (CL) and to consequently control the onset of estrus and ovulation (Lauderdale, 1972; Stellflug et al., 1973; La Voie et al., 1975). The specific method of action of $\text{PGF}_{2\alpha}$ on the estrous cycle is complex and has been the subject of several review papers (Inskeep, 1973; Henricks et al., 1974; Louis et al., 1974; Thatcher et al., 1976).

One of the first attempts to use $\text{PGF}_{2\alpha}$ to control estrus in cattle indicated $\text{PGF}_{2\alpha}$ would shorten the lifespan of the corpus luteum by causing it to regress when administered to cows five or more days after estrus (Louis et al., 1973). Regression of the corpus luteum caused return to estrus and ovulation, usually within two to four days after $\text{PGF}_{2\alpha}$ was administered (Rowson, et al., 1972). Therefore Lauderdale (1972) concluded that a cow must have a functional corpus luteum between days five and 16 of the estrous cycle in order for

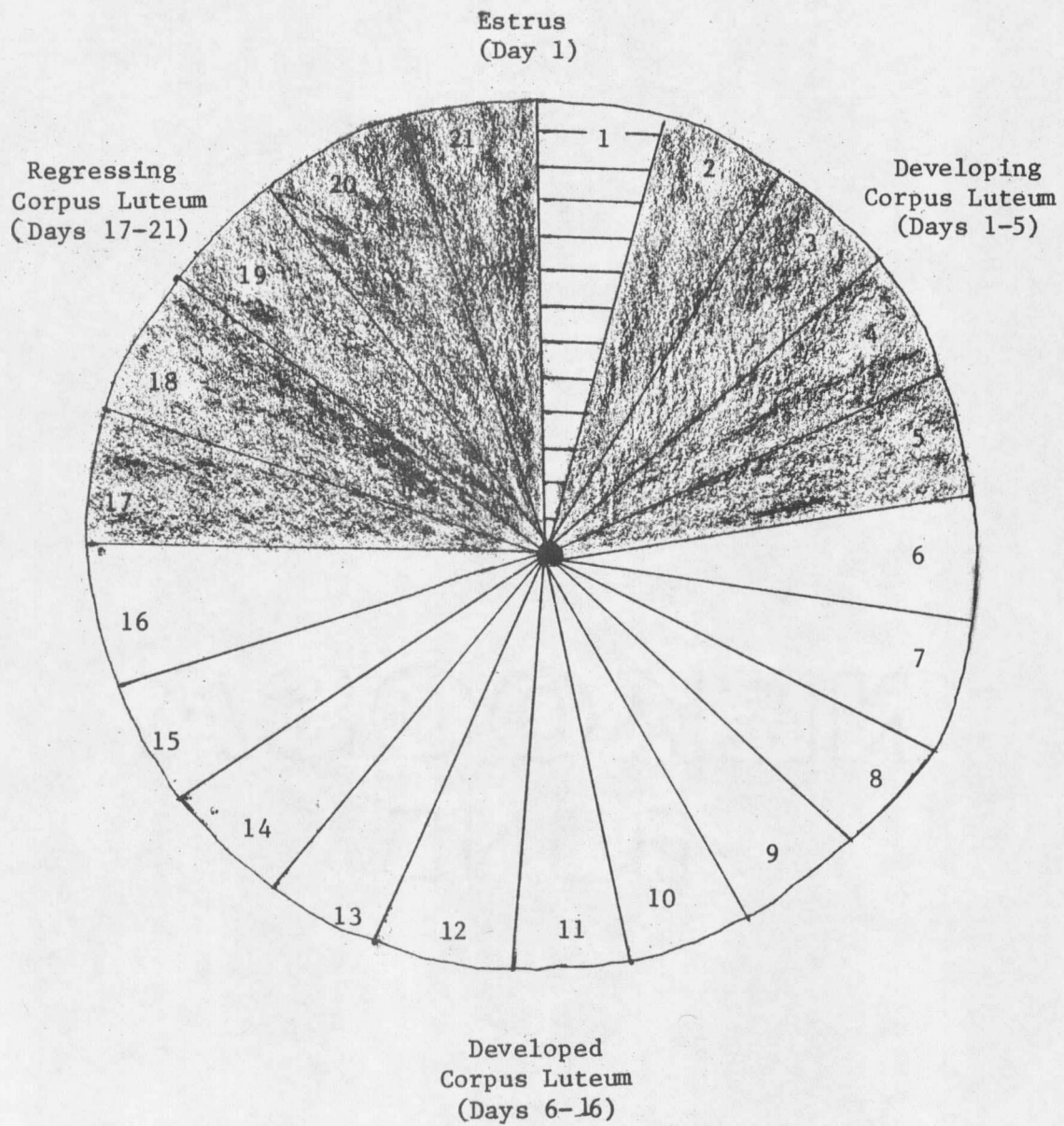
prostaglandins to regress the CL and allow the cow to advance to a new estrus.

Fertility of the synchronized estrus has been comparable to control cows when bred in a similar fashion. Rodriguez et al. (1974) used 188 heifers and 25 cycling cows between day seven and 21 of their estrous cycles to compare control and treated groups bred by detection. Treated animals were injected intramuscularly with 30 mg PGF_{2α} and both groups were inseminated at detected estrus. Pregnancy rates of 38 and 32 percent for control and treated groups were not different ($P > .05$). Lauderdale et al. (1974) also compared control and treated cycling cows bred by detection. Treated cows were given a 30 mg injection. Pregnancy rates of 53.3 and 52.2 percent for the control and treated cows were not significantly different. Moody et al. (1978) performed a similar experiment to compare fertility of control and treated groups bred for 30 days by detection of estrus. Treated cows received a single 25 mg injection. Pregnancy rates at the end of the 30 day breeding season were 72 and 61 percent for treated and control groups, respectively.

Estrous Synchronizing Systems

The objective of synchronization is to manipulate the cow's reproductive cycle so that all cycling cows in a herd show estrus during a short period of time (Figure 1). Prostaglandins are only

Figure 1: Estrous Cycle Of The Cow



effective on cows with functional corpora lutea (day six to 16 of the estrous cycle). Cows between day 17 and 21 of the cycle do not respond to prostaglandin because the corpus luteum is regressing. However, cows in this stage of the cycle exhibit estrus within the next one to five days due to normal CL regression (Louis et al., 1973) and are consequently fairly well synchronized with the cattle responding to PGF_{2α} (Rowson et al., 1972). Cows between day one and five of the cycle do not respond to PGF_{2α} because the corpus luteum is immature (Rowson et al., 1972). Since these cows do not show estrus until 15 to 20 days later, most synchronization systems are designed to manipulate cattle in day one to five of the cycle in order to include them in the synchronized breeding.

Single Injection System

One of the simplest synchronization systems involves a single injection of PGF_{2α}. This system requires cattle to be handled only twice (injection and breeding) and results in a short AI season. However, only 75 percent of the cycling cows are synchronized with a single injection: those cows between days six and 16 of their estrous cycle and those cows between days 17 and 21 of their cycle. Approximately 25 percent of the herd, those cows from day zero to five in their estrous cycle, will not respond to the prostaglandin injection.

Several studies have indicated the single injection system is an effective method of synchronizing estrus in beef cows (Lauderdale, 1973; Hafs et al., 1974; Turman et al., 1975). Roche (1974) compared pregnancy rates of control and treated heifers between day five and 20 of their estrous cycle when all heifers were bred at detected estrus. Treated heifers were injected with 30 mg of $\text{PGF}_{2\alpha}$. The 75 percent pregnancy rate at the synchronized heat in heifers treated with $\text{PGF}_{2\alpha}$ did not differ significantly from the 73 percent pregnancy rate obtained in the untreated control heifers.

La Voie and Self (1979) also compared pregnancy rates of treated and untreated cows when bred by detection. Control cows were bred 12 hours after the detection of estrus while treated cows were given a 25 mg $\text{PGF}_{2\alpha}$ injection and bred them in a like manner. First service pregnancy rates and total pregnancy rates were 38 and 60; 23 and 59 percent for control and treated groups of young cows. First service pregnancy rates and total pregnancy rates for control and treated groups of old cows were 51 and 53; 60 and 65 percent and were not significantly different. Daily et al. (1979) performed a similar experiment with 483 dairy heifers to compare pregnancy rates of control and treated groups bred by detection of estrus. Treated heifers received a 25 mg injection of $\text{PGF}_{2\alpha}$. Total pregnancy rates for the control (47.5) and treated heifers (52) were not significantly different.

Lauderdale et al. (1974) compared pregnancy rates of control animals to those of treated cattle bred by detection or appointment. Control cows were observed for estrus and inseminated accordingly. Treated cattle were given a 30 mg injection of $\text{PGF}_{2\alpha}$ and either inseminated at detected estrus for seven days after $\text{PGF}_{2\alpha}$ or inseminated at 70 and 92 hours after $\text{PGF}_{2\alpha}$ treatment without regard to estrus. Percent cows pregnant at 35 to 60 days after AI was 53.3, 52.2 and 55.8 respectively for control cows, treated cows bred by detection of estrus and treated cows bred by appointment. There was no significant difference in fertility among control and treated animals bred by detection or appointment.

These studies indicate that a single injection of $\text{PGF}_{2\alpha}$ is an effective method of synchronizing estrus in beef cows and that $\text{PGF}_{2\alpha}$ does not effect the pregnancy rate at breeding when compared to a conventional system.

Five-day Prebreeding

Another method to manipulate cows in days one to five of their estrous cycle is to inseminate those cows detected in estrus for five days and then give a single injection of $\text{PGF}_{2\alpha}$ to all cattle not previously inseminated. The remaining unbred cattle must be inseminated according to detection of estrus for four additional days or bred by appointment. Breeding those cows in heat for five days

before injection eliminates those animals that would not have responded to the $\text{PGF}_{2\alpha}$ treatment so that on the fifth day all cycling cows should respond. In addition, it provides an opportunity to determine what percent of the herd is cycling and to evaluate the feasibility of synchronization. Although cattle are handled three times in this system, fewer cows have to be injected and all cycling cows are included in the system.

Doornbos and Anderson (1979) compared this system of five-day prebreeding to a conventional AI system using lactating Hereford cows. Treated cows were inseminated to observed estrus until the fifth day of the breeding season at which time all cattle not previously inseminated were injected with 33.5 mg of $\text{PGF}_{2\alpha}$. Control and treated cattle were bred 12 hours after detected estrus. First service pregnancy rates and total pregnancy rates after 45 days were 76 and 90; 75 and 100 percent for the control and treated groups. Results show no difference in first service pregnancy rates, but that total pregnancy rate of the treated cows was higher than for the untreated control cows.

Lambert et al. (1975) used $\text{PGF}_{2\alpha}$ to compare a conventional AI system to treated cows bred by a combination of detection and appointment. Cattle assigned to the conventional system were inseminated at observed estrus. Animals in the $\text{PGF}_{2\alpha}$ system were inseminated for five days prior to the breeding season. On the fifth day, cows which

hadn't been previously inseminated were injected with 33.5 mg $\text{PGF}_{2\alpha}$. Cattle were bred at detected estrus until 75 hours post-injection at which time all remaining cattle were inseminated. AI first service pregnancy rates were not significantly different between the control (45) and $\text{PGF}_{2\alpha}$ (43) systems. However, the total AI pregnancy for the $\text{PGF}_{2\alpha}$ system (54 percent) was higher ($P < .05$) than for the conventional system (42 percent).

Lambert et al. (1976) did a similar experiment with 240 virgin heifers and 669 postpartum cows. Total pregnancy rates (83 and 77 percent; $P < .018$), total AI pregnancy rates (52 and 41 percent; $P < .01$), and AI first service pregnancy rates (47 and 38 percent; $P < .009$) were higher for the $\text{PGF}_{2\alpha}$ system than the conventional system.

Results of these experiments demonstrate that this single injection $\text{PGF}_{2\alpha}$ system does not decrease pregnancy rates of cattle when compared to a conventional system under range beef cattle management conditions.

Double Injection--Single Insemination

The only system of estrus synchronization approved by the Food and Drug Administration for use in the United States is a two injection system which involves injecting all animals with $\text{PGF}_{2\alpha}$ regardless of the stage of their cycle and then reinjecting eleven days later. Cows in days zero to five of their estrous cycle will not return to estrus

in response to the first injection but should be at about day 11 to 16 at the time of the second injection. The first injection will regress the CL of cows in days six to 16 of their cycle causing them to return to estrus two to five days later and they should be at approximately day seven of their next cycle at the time of the second injection. Cows in days 17 to 21 of the cycle will come into heat at about the same time as the cows responding to the first injection and should be at about day seven to ten of their next cycle at the time of the second injection.

This double injection system is a means to maximize the percentage of a herd responding to treatment and it facilitates breeding by appointment since all cycling cows are synchronized at the time of the second injection. However, cows require two injections with Prostaglandin $F_{2\alpha}$ and must be handled three times.

This system of two injections of $PGF_{2\alpha}$ 10 to 12 days apart has been shown to synchronize estrus in randomly cycling cows and heifers (Cooper, 1974; Roche, 1974; Hafs et al., 1975). A two injection system was first tried by King and Robertson (1974). Thirty randomly cycling Holstein heifers were injected twice with 30 mg $PGF_{2\alpha}$ ten days apart. Fifty-four percent of the 15 control heifers were pregnant at 60 days post insemination compared to 40 percent pregnant for the treated group. Pregnancy rates in the treated and control groups were not significantly different. Ellicott et al., (1975) used a similar

experimental design with a two injection management scheme and also found that the pregnancy rates of the $\text{PGF}_{2\alpha}$ system were comparable to that of a conventional system.

In 1976, Manns, Wenkoff and Adams assigned Hereford heifers to either a control group which was bred at estrus in a 30 day AI program or a treated group which received two 25 mg injection of $\text{PGF}_{2\alpha}$ 12 days apart. Treated heifers were then bred at 80 hours after the second injection. The pregnancy rate of the treated cows were comparable to those in the control group with 46.8 and 46.2 percent respectively.

Manns et al. (1977) assigned two year old heifers to either a control group (n = 33) or a treated group (n = 33) which received two 25 mg injections of $\text{PGF}_{2\alpha}$ 11 days apart and were bred at 80 hours after estrus. Pregnancy rates for the control and Prostaglandin $\text{F}_{2\alpha}$ groups were 48 and 53 percent respectively. First service conception rates were 42 and 52 percent for control and $\text{PGF}_{2\alpha}$ heifers.

On the basis of these experiments, it was concluded that the two injection system may have practical application for synchronization of estrus in the bovine, particularly under range conditions.

Double Injection--Split Insemination

A variation of the two injection method is to breed cows two times, following the first and second injection. In this system all animals are injected with $\text{PGF}_{2\alpha}$ and then inseminated for four days

according to detection of estrus. Eleven days after the first injection, those animals which were not inseminated are reinjected with $\text{PGF}_{2\alpha}$ and then bred when estrus is detected or at a predetermined time. Although this system requires that some animals be handled three times (twice for injection and once for breeding), fewer cows have to be injected a second time and the system facilitates timed insemination following the second injection, thereby allowing the producer to omit detection of estrus after the second injection.

Burfening et al. (1976) performed an experiment with 143 lactating Hereford cows in which he only reinjected those animals not bred after the first injection. Forty-six cows served as a control group and 97 cows were treated with 33.5 mg $\text{PGF}_{2\alpha}$ and bred at estrus (T1). Treated cows not exhibiting estrus ($n = 49$) were reinjected with $\text{PGF}_{2\alpha}$ on day 11 and bred at 84 hours post $\text{PGF}_{2\alpha}$ (T2). There was no significant difference in first service conception rates for controls (72 percent), T1 (67 percent) and T2 (67 percent). Total pregnancy rates were 87, 90 and 85 percent.

Burfening et al., (1978) did a similar experiment with 193 lactating Hereford cows and 59 Hereford heifers which were managed in the same manner as before. First service conception rates and conception rates at the end of the AI season were 61 and 88; 53 and 86; and 28 and 69 percent for the control, T1 and T2 groups. Burfening concluded that $\text{PGF}_{2\alpha}$ applied to cycling cattle will synchronize estrus

with pregnancy rates at the synchronized estrus being comparable to non-synchronized controls.

Doornbos and Anderson (1979) conducted a trial using 76 yearling heifers to evaluate differences in pregnancy rates between an untreated control group ($n = 37$) and a treated group ($n = 39$). Treated heifers were injected intramuscularly with $\text{PGF}_{2\alpha}$ on the first day of the AI season (A) and were bred 12 hours after estrus. All heifers not yet bred on day eight were treated again with $\text{PGF}_{2\alpha}$ (B) and again bred at detected estrus. Percent pregnant to first service and after 45 days AI for control, A and B heifers were 73 and 92; 78 and 93; and 75 and 83, respectively. Both treatments resulted in pregnancy rates comparable to contemporaries in control groups.

Studies using the split insemination system indicate that it is an effective method of synchronizing estrus in beef cows and results in pregnancy rates that are comparable to cows bred in the conventional AI manner.

Pregnancy Rates for Breeding Systems

Three methods of breeding synchronized cows are commonly used. Cows may be bred by detection of estrus; by appointment at a specific interval after $\text{PGF}_{2\alpha}$; or by detection of estrus until a predetermined time and then bred by appointment.

Pregnancy rates of cattle inseminated at estrus following $\text{PGF}_{2\alpha}$

and of cattle inseminated at timed intervals after $\text{PGF}_{2\alpha}$ has been shown to be similar (Han et al., 1977; Burfening et al., 1976). Many experiments have been done varying appointment breeding intervals from as low as 60 or 63 hours (Ellicott et al., 1975; Rodriguez et al., 1974) to 75 or 80 (Manns et al., 1976; Manns et al., 1977) and as high as 90 to 96 hours (Lauderdale et al., 1974; Burfening et al., 1978).

One of the early studies using $\text{PGF}_{2\alpha}$ for estrus synchronization was done by Lauderdale et al. (1973). Non-treated controls were inseminated 12 hours after the onset of estrus. Treated cattle were injected intramuscularly with 30 mg $\text{PGF}_{2\alpha}$ and either inseminated at estrus detected during the seven days after $\text{PGF}_{2\alpha}$ or inseminated at 72 and 90 hours after $\text{PGF}_{2\alpha}$. Percent cows pregnant was 58, 57 and 58 respectively for controls, treated cows bred by detection and treated cows bred by appointment at 72 and 90 hours. Hafs et al. (1974) did a similar study using the same treatment groups. Percent pregnant cows was 58, 57 and 58 respectively for controls, treated cows bred by detection and treated cows bred by appointment at 72 and 90 hours. These two studies demonstrate that the pregnancy rates of cattle inseminated during the estrus after treatment with $\text{PGF}_{2\alpha}$ and those of cattle inseminated by appointment at 72 and 90 hours after injection was equivalent to that of the controls.

Turman et al. (1975) tested different appointment breeding intervals, 64 and 88 hours after estrus using 39 mature, cycling, non-lactating Hereford cows. Treated cows were injected with 30 mg $\text{PGF}_{2\alpha}$ and either inseminated 12 hours after estrus was detected or bred at 64 and 88 hours following estrus. Conception rates for control, treated cows bred by detection and treated cows bred by appointment at 64 and 88 hours were 84.6, 76.9 and 92.3 percent, respectively. Differences between cows bred by detection and cows bred by appointment were not significant.

In recent years, breeding by appointment 80 hours after injection has become the most popular method (Green et al., 1977; Manns et al., 1977; Burfening et al., 1978). Moody and Lauderdale (1977) used 1442 lactating cows, 270 non-lactating cows and 935 beef heifers to compare breeding by detection to breeding at 80 hours after $\text{PGF}_{2\alpha}$ treatment. All animals were given two injections of $\text{PGF}_{2\alpha}$ eleven days apart. Pregnancy rates were 53, 49 and 53 percent for control, cows bred by appointment and cows bred by detection. Pregnancy rates were similar following AI at either 80 hours or at estrus on days two through five after the second injection when compared to AI in non-treated cattle.

Han and Moody (1979), also demonstrated that breeding by appointment at 80 hours was not significantly different than breeding by detection of estrus when using mature, lactating beef cows. Group 1

served as a control group. Group 2 was given a 25 mg $\text{PGF}_{2\alpha}$ injection on day zero of the breeding season and bred at observed estrus. Group 3 was bred at observed estrus until day five when they were injected with 25 mg $\text{PGF}_{2\alpha}$. Treated cows were then detected for estrus until 80 hours at which time all remaining unbred cows were inseminated. First service pregnancy rates, AI pregnancy rates and total pregnancy rates were 58.8, 22.3 and 88.3; 69.1, 42.1 and 90.5; and 51.1, 53.4 and 94.3 percent for groups 1, 2 and 3, respectively.

Results of these experiments indicate that similar pregnancy rates are achieved regardless of the breeding system used.

Chapter 3

MATERIALS AND METHODS

Identifying Systems

In identifying herd estrous synchronization systems, a number of options were considered. The first option was whether or not to palpate ovaries to estimate the number of cycling cows and identify those cows with a corpus luteum that would respond to $\text{PGF}_{2\alpha}$. The second option was to use either one or two injections of $\text{PGF}_{2\alpha}$. The third option was to select a breeding method: breeding by detection of estrus, breeding by appointment or breeding by a combination of detection and appointment. After considering all possible combinations of palpation options, injection schemes and breeding methods, seven systems were selected for evaluation in the simulation model (Table 1).

System 1a was a single injection system. Under this system all cows were injected and then bred by detection or by a combination of detection and appointment.

System 1b was similar to system 1a except for the addition of ovary palpation. Cows were palpated on the day of injection and only those cows identified as having a CL were injected and bred by detection or a combination of detection and appointment.

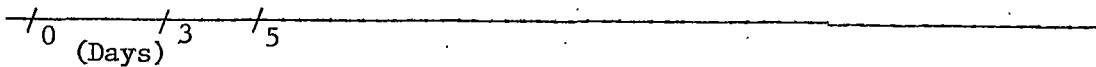
In system 1c, cows were bred by detection for five days prior to injection. On the fifth day all cows not previously bred were

Table 1

Synchronization Systems

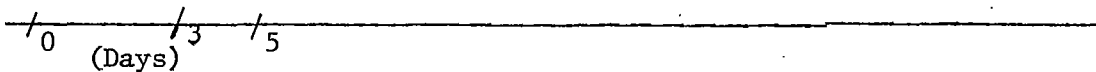
1a Single Injection

Inject	Breed by detection until day 5
all	or
cows	Breed by detection and appointment at 80 hrs



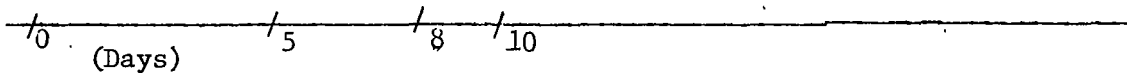
1b Palpate; Single Injection

Palpate	Breed by detection until day 5
and	or
inject	Breed by detection and appointment at 80 hrs



1c Five-day Prebreeding

Detect	Inject	Breed by detection until day 10
heat	remaining	or
and AI	cows	Breed by detection and appointment at 80 hrs



1d Five-day Prebreeding; Palpate

Detect	Palpate and	Breed by detection until day 10
heat	inject re-	or
and AI	maining cows	Breed by detection and appointment at 80 hrs

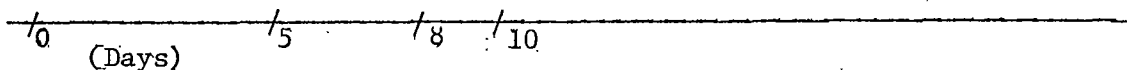


Table 1 Continued

2a Double Injection

Inject all cows	Inject all cows	Breed by detection until day 16 Breed by appointment at 80 hrs or Breed by detection and appointment
/0 (Days)	/11	/14 /16

2b Palpate; Double Injection

Palpate and inject	Inject cows second time	Breed by detection until day 16 Breed by appointment at 80 hrs or Breed by detection and appointment
/0 (Days)	/11	/14 /16

2c Double Injection--Split Insemination

Inject all cows	Breed at standing estrus for five days	Inject remaining cows	Breed by detection until day 16 Breed by appointment at 80 hrs or Breed by detection and appointment
/0 (Days)	/5	/11	/14 /16

injected with PFG_{2α} and were then bred by detection or a combination of the two.

System 1d was similar to system 1c except that following the five days of breeding, cows not detected in estrus were palpated and only those cows with a functional CL were injected and bred by detection or a combination of detection and appointment.

In system 2a all cows were given two injections, eleven days apart, and then bred after the second injection either by detection, appointment or a combination of the two.

System 2b differed from system 2a in that cows were palpated prior to the first injection and only those cows with a palpable CL were considered for both injections. Cows were bred by detection, appointment or a combination of detection and appointment.

System 2c involved two injections with breeding after each injection. All cows were given the first injection and those cows detected in estrus were bred. Cows not detected in estrus after the first injection were given a second injection and bred either by detection, appointment or a combination of the two.

Estimating Reproductive Performance

Proportion of cows cycling during the breeding season depends mainly on days since calving and nutrition before and after calving, but is also affected by suckling and lactation, disease and dystocia.

To simulate these factors, percent cows cycling was allowed to vary from zero to 100 percent by increments of ten percent. Percent cows cycling was assigned to each 100 cow herd on day one of each system and was assumed to remain constant for the duration of the breeding season.

If the palpation option was used, cows were palpated on the day of injection. Only those cows with a CL, as determined by rectal palpation, were injected with $\text{PGF}_{2\alpha}$. It was assumed that a trained technician was capable of palpating the CL between days five and 21 of the estrous cycle. While it was recognized that the CL is regressing between days 17-21, it was assumed that the technician could still identify the structure. The palpater would therefore identify three-fourths of the cycling cows.

If cows were palpated prior to injection, the number of cows injected was calculated by multiplying the number of cycling cows by the number of cows in days five through 21 (75 percent) of the cycle (i.e. 60 percent cycling cows $\times$.75 CL = 45 cows to be injected). If cows were not palpated, it was assumed that all cows would be injected.

It was assumed that $\text{PGF}_{2\alpha}$ would regress the CL in 100 percent of the cycling cows with a viable CL. Cows between days 17 and 21 of their estrous cycle would not respond to $\text{PGF}_{2\alpha}$ because their CL would be regressing. However, these cows would come into heat in the

next five days since their estrous cycle would be almost completed.

Three AI breeding methods were considered. One method was to breed cows for five days after injection with $\text{PGF}_{2\alpha}$ as they were detected in estrus. A second method was to breed all cows by appointment 80 hours after treatment with $\text{PGF}_{2\alpha}$. The third method was to inseminate cows as they were detected in estrus until 80 hours after injection and then breed all remaining cows at that time. Breeding by appointment was used only with the double inject systems (2a, 2b, 2c) because these were the only systems that effectively synchronized cows in days 5 to 21 of the estrous cycle resulting in an appropriate grouping of estrus for appointment breeding. Breeding by appointment was not used with the single injection systems (1a, 1b, 1c, 1d) because these systems do not effectively synchronize cows in days 17 to 21 of the estrous cycle. Although cows in this stage of the cycle would come into heat within the next five days, they do not respond to $\text{PGF}_{2\alpha}$ and therefore are not suitable for appointment breeding since not all of them will be in estrus within twelve hours of appointment breeding.

The conception rate achieved for a specific breeding is primarily dependent on the days since calving, but is also affected by semen fertility and technician proficiency. Conception rates for a given service were varied from 10 to 80 percent by increments of 10 percent to simulate several different conditions. It was assumed that the

same first service pregnancy rate was achieved regardless of whether the cows had been treated with PGF_{2α} or not the number of injections the cows received or the breeding method used.

Pregnancy rates for each of the seven systems were calculated as follows:

System 1a: (Percent cycling X .75) X Pregnancy Rate

The number of pregnant cows was calculated by multiplying three-fourths of the proportion cycling (those showing heat in the synchronized period) by the pregnancy rate.

System 1b: (Percent cycling X .75) X Pregnancy Rate

The number of pregnant cows was calculated in the same manner as system 1a.

System 1c: $\left[\frac{\text{Percent cycling}}{21} \times 5 \right] \times \text{P.R.} + (\text{Percent cycling} \times .75 \times \text{P.R.})$

The number of pregnant cows in the five days prior to injection was calculated by dividing the percent cycling by 21 to get the proportion of cows showing heat each day and then multiplying by five. The number of cows showing heat in the five days before injection is then multiplied by the pregnancy rate. The number of pregnant cows in the synchronized

breeding period (after the injection) was calculated in the same manner as in system 1a. The total number of pregnant cows for this system was calculated by adding the sum of pregnant cows from the five days of breeding prior to injection to the breeding period following injection.

System 1d: $\left[\frac{\text{Percent cycling}}{21} \times 5 \right] \times \text{P.R.} + (\text{percent cycling} - \text{Number bred}) \times \text{P.R.}$

The number of pregnant cows was calculated in the same manner as system 1c.

System 2a: Percent cycling X Pregnancy Rate

The number of pregnant cows was calculated by multiplying the percent cycling by the pregnancy rate since all the cycling cows are synchronized by this system.

System 2b: (Percent cycling X .75) X Pregnancy Rate

The number of pregnant cows was calculated by multiplying three-fourths of the proportion cycling (those identified by palpation as having a CL) by the pregnancy rate.

System 2c: (Percent cycling X .75) X P.R. + (100 - Number bred) X P.R.

The number of pregnant cows was calculated by adding

the number of cows that conceived following the first injection to the number that conceived following the second injection. The number pregnant following the first injection is calculated by multiplying three-fourths of the proportion cycling by the pregnancy rate. The number of cows that conceived at the second injection was calculated by subtracting the number of cows bred at the first injection from the number of cows cycling and multiplying by the pregnancy rate.

Estimating Costs

Costs used in this program were based on published data and conditions believed to be representative of this area at this time. Costs were not meant to be absolute, but rather were intended to provide a means of ranking the alternatives. The following costs were used in evaluating alternatives:

Palpation: \$1.00 per cow.

A local survey of veterinarians showed this to be a reasonable cost. If the palpation option was chosen, then it was assumed that all cows in the herd were palpated and the cost of palpation was the number of cows times \$1.00. The only exception, system 1c, was where the number of cows

inseminated in the five days before injection was subtracted
(i.e. [number of cows - number of cows bred] X \$1.00).

Injection: \$4.50 per injection

This was the recommended retail price for Lutalyse ($\text{PGF}_{2\alpha}$) as advertised by the Upjohn Company. All cows were injected unless the palpation option was used. In this case, the cost of injection was: (Percent cows cycling X .75 which is the percent cows with a palpable CL) X \$4.50.

Breeding: \$7.50 per service which included \$7.00 for semen and
\$.50 for equipment.

An average semen cost of \$7.00 per service was taken from breeding semen catalogues. Approximate prices of breeding supplies, including insemination pipettes, nitrogen tank and gloves, were taken from the catalogue of a supplier of artificial insemination equipment. If cows were bred by detection, the cost of breeding was the number of cows cycling times .75 (the proportion of cows in days five through 21 of the cycle) times the breeding cost of \$7.50. If cows were bred by appointment or a combination of detection and appointment, the cost of breeding was the number of cows injected times the breeding cost of \$7.50.

Evaluating Alternatives

A simulation model was developed to assist in evaluating the system alternatives (Appendix 1). Systems were analyzed on the basis of predicted reproductive performance and estimated costs associated with each alternative. Outcome for 1232 alternatives was estimated (Appendix 2). In the double injection systems where cows were bred by a combination of detection and appointment, the outcome was identical under our assumptions and the results were printed (Appendix 2) for only two breeding alternatives. A separate cost, pregnancy rate and cost per pregnant cow was calculated for each of the 11 cycling percentages, eight conception rates and two breeding methods under each of the seven systems.

Criteria used to evaluate alternatives were total cost, total number of pregnant cows and cost per pregnant cow. The total cost of each alternative was estimated by adding the costs of palpation, injections and breeding. The total number of pregnant cows for each alternative was estimated by adding the number of cows which conceived at each breeding period. Cost per pregnant cow was estimated by dividing total cost by total number of pregnant cows.

An example will clarify the use of the results listed in Appendix 2. Suppose that 90 percent of 100 cows are cycling and the double injection system of synchronization (System 2a) is chosen. All cows would be injected at a cost of \$4.50 per cow (\$450.00).

Eleven days later the cows are injected a second time with $\text{PGF}_{2\alpha}$ and the cost of injection is again \$450.00. A decision is made to breed by detection for five days after $\text{PGF}_{2\alpha}$ treatment. The cost for breeding 90 cows is \$675.00 at \$7.50 per cow bred. The total cost of \$1575.00 for this system is calculated by adding the cost of the first injection (\$450.00), second injection (\$450.00), and breeding (\$675.00). If an 80 percent conception rate is assumed, the conception rate of 80 percent is multiplied by the 90 cows bred for a total of 72 pregnant cows. The cost per pregnant cow of \$21.88 is calculated by dividing the total cost of \$1575.00 by the total number of pregnant cows, 72.

If the palpation option had been used (System 2b), the technician would have indicated that 67 of the cows were cycling (based on the assumption that the technician can identify 75 percent of the 90 cycling cows). The cost of palpation is \$100.00 at a price of \$1.00 per cow for 100 cows. All 67 cows, those identified as having a CL, are injected at a cost of \$303.75 based on a charge of \$4.50 per cow injected. Eleven days later the cows are given a second injection and the cost is again \$303.75. A decision is made to breed by appointment at 80 hours after $\text{PGF}_{2\alpha}$ treatment. The cost for breeding 67 cows is \$506.25 at \$7.50 per cow bred. The total cost of \$1213.75 for this system is calculated by adding the cost of palpation (\$100.00), first injection (\$303.75), second injection (\$303.75) and breeding

(\$506.25). If an 80 percent conception rate is assumed, the conception rate of 80 percent is multiplied by the 68 cows for a total of 54 pregnant cows. The cost per pregnant cow is \$22.48 and is calculated by dividing the total cost of \$1213.25 by the total number of pregnant cows, 54.

Chapter 4

RESULTS AND DISCUSSION

Outcome for the 1232 alternatives is presented in Appendix 2. Evaluation of each synchronization alternative focused on three areas: total cost, total AI pregnancy rate and cost per pregnant cow.

Cost Per Pregnant Cow

Cost per pregnant cow estimates were used to determine optimal breeding policy for each cycling and conception (Table 2). Table 3 lists the ranking of alternatives based on cost per pregnant cow when bred by detection and Table 4 lists the ranking of alternatives for cows bred by appointment or a combination of detection and appointment. Values for cost per pregnant cow were plotted for each alternative in Figure 2 (cows bred by detection) and 3 (cows bred by appointment or a combination of detection and appointment). For all systems, cost per pregnancy varied greatly as percent of cycling cows varied. As percent cycling decreased total AI pregnancy rate decreased and cost per system increased and consequently cost per pregnant cow increased. Differences among alternatives narrowed as percent cycling increased. For example, for cows bred by detection, the spread between least and greatest cost per pregnant cow was \$91.48 when 10 percent of the cows were cycling but only \$8.70 when all cows were cycling (Figure 2). For cows bred by appointment or a combination of

Table 2

Ranking of Synchronization Alternatives
Based on Cost Per Pregnant Cow when Bred by Detection,
Appointment or a Combination of the Two

Rankings*	Percent Cycling									
	100	90	80	70	60	50	40	30	20	10
1	{ 1c-D	1c-D	1c-D	{ 1d-D	{ 1d-D	{ 1d-D	{ 1d-D	{ 1d-D	{ 1d-D	{ 1d-D
2	{ 1c-A	{ 1d-D	{ 1d-D	{ 1d-A	{ 1d-A	{ 1d-A	{ 1d-A	{ 1d-A	{ 1d-A	{ 1d-A
3	{ 1d-D	{ 1d-A	{ 1d-A	1c-D	1c-D	1c-D	{ 1b-D	{ 1b-D	{ 1b-D	{ 1b-D
4	{ 1d-A	1c-A	{ 1b-D	{ 1b-D	{ 1b-D	{ 1b-D	{ 1b-A	{ 1b-A	{ 1b-A	{ 1b-A
5	{ 2c-D	{ 1b-D	{ 1b-A	{ 1b-A	{ 1b-A	{ 1b-A	1c-D	{ 2b-D	{ 2b-D	{ 2b-D
6	{ 2c-A	{ 1b-A	1c-A	1c-A	1a-D	{ 2b-D	{ 2b-D	{ 2b-A	{ 2b-A	{ 2b-A
7	{ 1b-D	2c-D	1a-D	1a-D	{ 2b-D	{ 2b-A	{ 2b-A	1c-D	1c-D	1a-D
8	{ 1b-A	1a-D	2c-D	2c-D	{ 2b-A	1a-D	1a-D	1a-D	1a-D	2a-D
9	1a-D	2c-A	2c-A	{ 2b-D	1c-A	1c-A	1c-A	2c-D	2c-D	1c-D
10	1a-A	2a-D	{ 2b-D	{ 2b-A	2c-D	2c-D	2c-D	2a-D	2a-D	1c-A
11	{ 2a-D	1a-A	{ 2b-A	2c-A	2a-D	2a-D	2a-D	1c-A	1c-A	2c-D
12	{ 2a-A	{ 2b-D	2a-D	2a-D	2c-A	2c-A	2c-A	2c-A	2c-A	2c-A
13	{ 2b-D	{ 2b-A	1a-A	1a-A	1a-A	1a-A	1a-A	1a-A	1a-A	1a-A
14	{ 2b-A	2a-A	2a-A	2a-A	2a-A	2a-A	2a-A	2a-A	2a-A	2a-A

* Ranking is from the least to the most expensive system

D = a system involving breeding by detection

A = a system involving breeding by appointment or a combination of
detection and appointment

{ indicates that the costs of the two systems were the same

Table 3

Ranking of Synchronization Alternatives
Based on Cost Per Pregnant Cow when Bred by Detection

Rankings*	Percent Cycling									
	100	90	80	70	60	50	40	30	20	10
1	1c	1c	1d	1d	1d	1d	1d	1d	1d	1d
2	1d	1d	1c	1c	1c	1b	1b	1b	1b	1b
3	2c	1b	1b	1b	1b	1c	1c	1c	1c	2b
4	1b	2c	1a	1a	1a	2b	2b	2b	2b	1c
5	1a	1a	2c	2c	2b	2b	1a	1a	1a	1a
6	2a	2a	2b	2b	2c	2c	2c	2c	2c	2c
7	2b	2b	2a	2a	2a	2a	2a	2a	2a	2a

* Ranking is from the least to the most expensive system

Table 4

Ranking of Synchronization Alternatives Based
on Cost Per Pregnant Cow when Bred by Appointment or
a Combination of Detection and Appointment

Rankings*	Percent Cycling									
	100	90	80	70	60	50	40	30	20	10
1	1c	1d	1d	1d	1d	1d	1d	1d	1d	1d
2	1d	1c	1b	1b	1b	1b	1b	1b	1b	1b
3	2c	1b	1c	1c	2b	2b	2b	2b	2b	2b
4	1b	2c	2c	2b	1c	1c	1c	1c	1c	1c
5	1a	1a	2b	2c	2c	2c	2c	2c	2c	2c
6	2a	2b	1a	1a	1a	1a	1a	1a	1a	1a
7	2b	2a	2a	2a	2a	2a	2a	2a	2a	2a

*Ranking is from the least to most expensive system

Figure 2

Cost Per Pregnant Cow Values for Synchronization Alternatives
when Bred by Detection Assuming an 80 percent Conception Rate

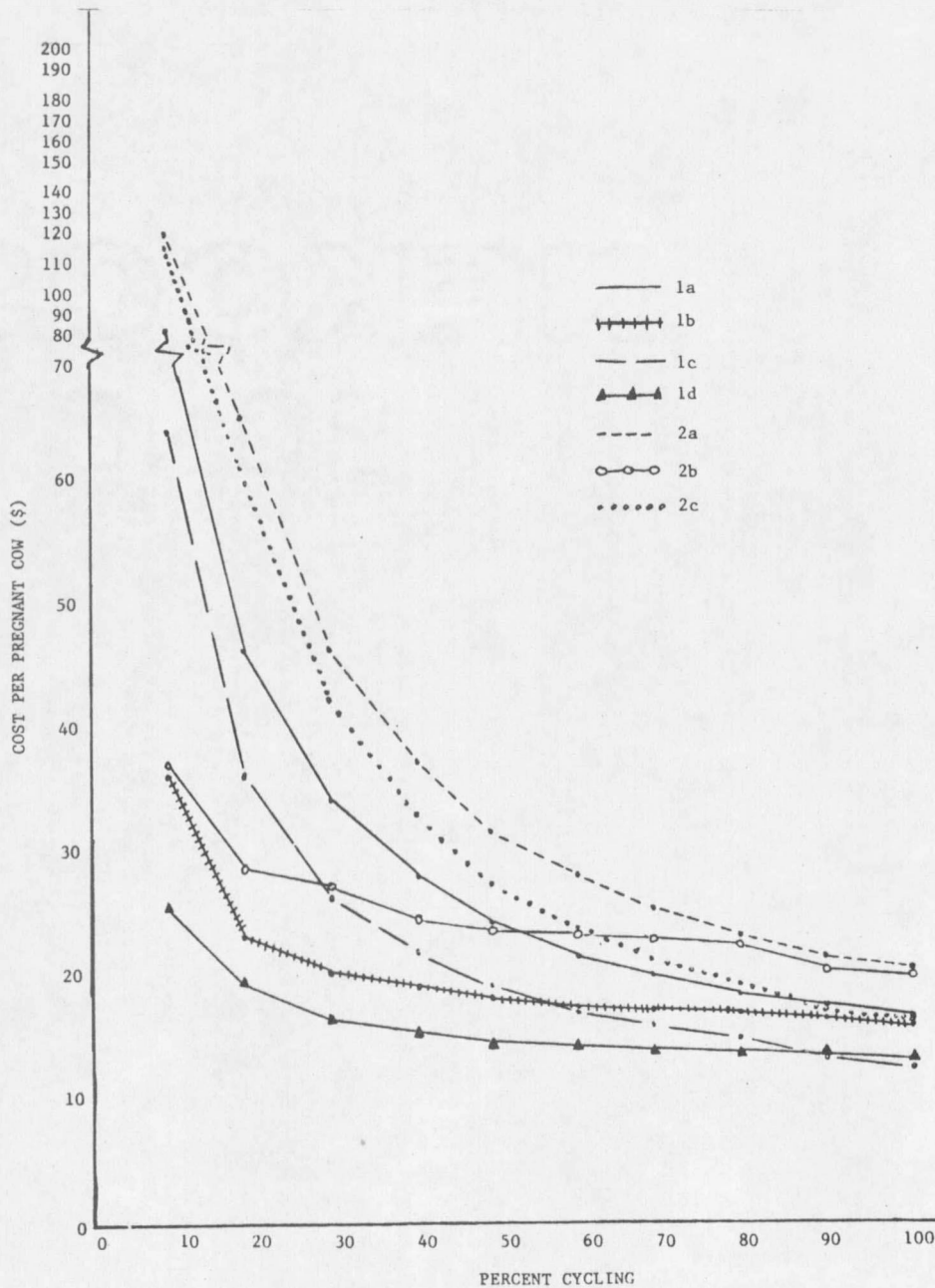
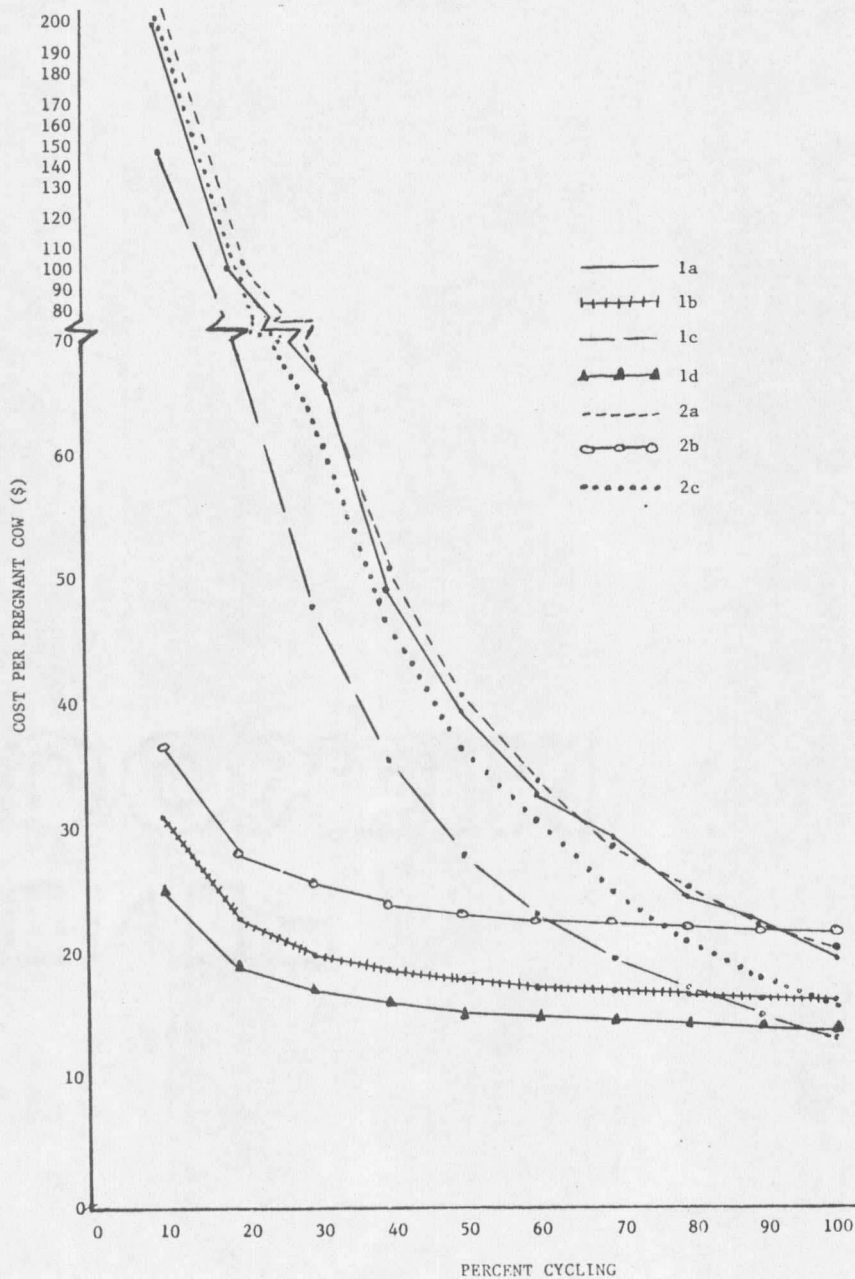


Figure 3

Cost Per Pregnant Cow Values for Synchronization Alternatives
when Bred by Appointment or a Combination of Detection and
Appointment Assuming an 80 percent Conception Rate



detection and appointment, the difference between the lowest and highest cost per pregnant cow was \$173.75 when 10 percent of the cows were cycling but only \$8.70 when 100 percent of the cows were cycling (Figure 3). Regardless of the system used, the greatest potential for minimizing cost per pregnant cow was to have a high percentage of cows cycling.

For a given percent cycling, number of injections, palpation and method of breeding affected cost per pregnancy. For all cycling rates, the five-day prebreeding systems (1c and 1d) had the lowest cost per pregnancy of all systems. When 80 percent or less of the cows were cycling, the palpation option (1d) was preferred. In general, one injection systems (1a and 1b) resulted in a lower cost per pregnancy than the two injection systems (2a, 2b and 2c) due primarily to differences in total drug cost.

In the majority of cases, palpation was desirable in order to avoid injecting and breeding cows that were not cycling. Within the five-day prebreeding systems (1c and 1d) the palpation option (1d) resulted in a lower cost per pregnancy when 80 percent or less of the cows were cycling (Figure 4). Within the second ranked single injection systems (1a and 1b) palpation was advisable regardless of the proportion of cows cycling (Figure 5). Among the third ranked double injection systems (2a, 2b, and 2c) palpation resulted in a lower cost per pregnancy when less than 90 percent of the cows were

Figure 4

Palpation Versus No Palpation Alternatives for
Five-day Prebreeding Systems based on Cost Per
Pregnant Cow Assuming an 80 Percent Conception Rate

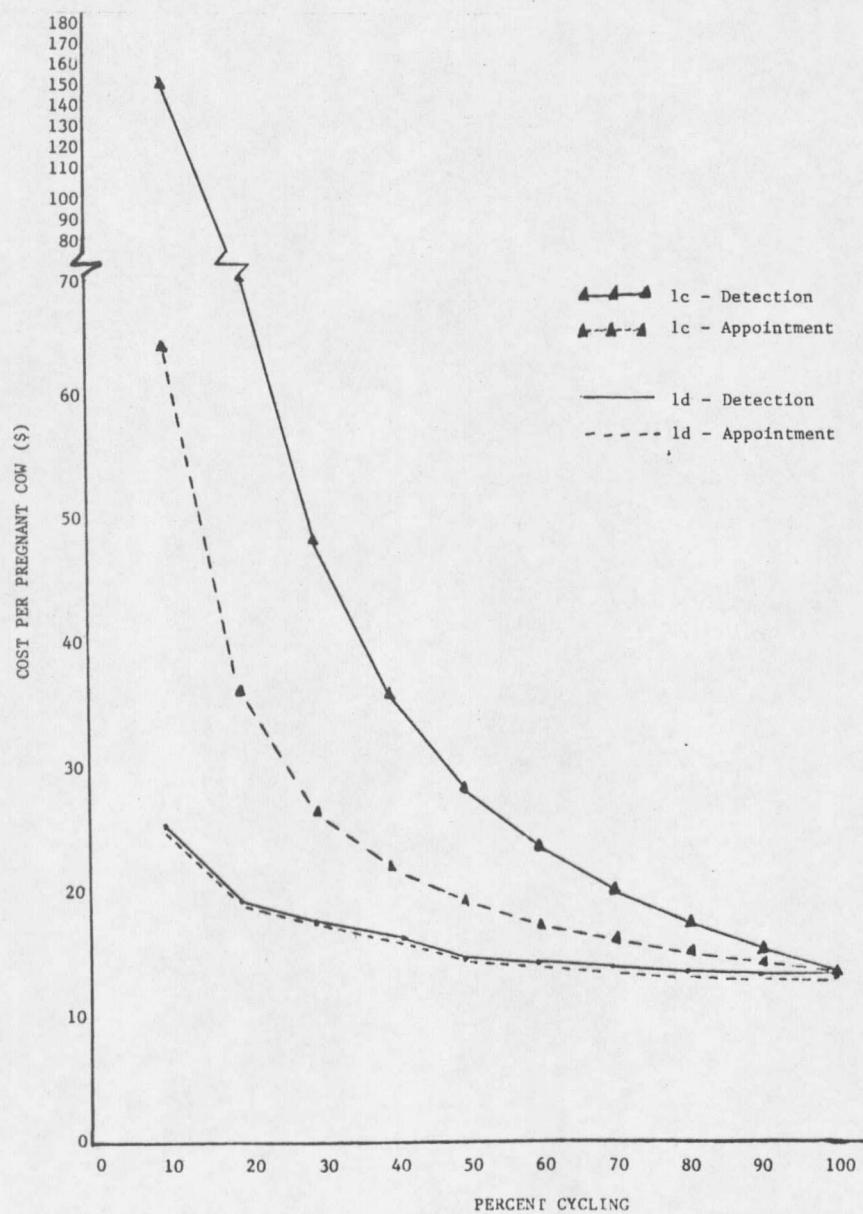
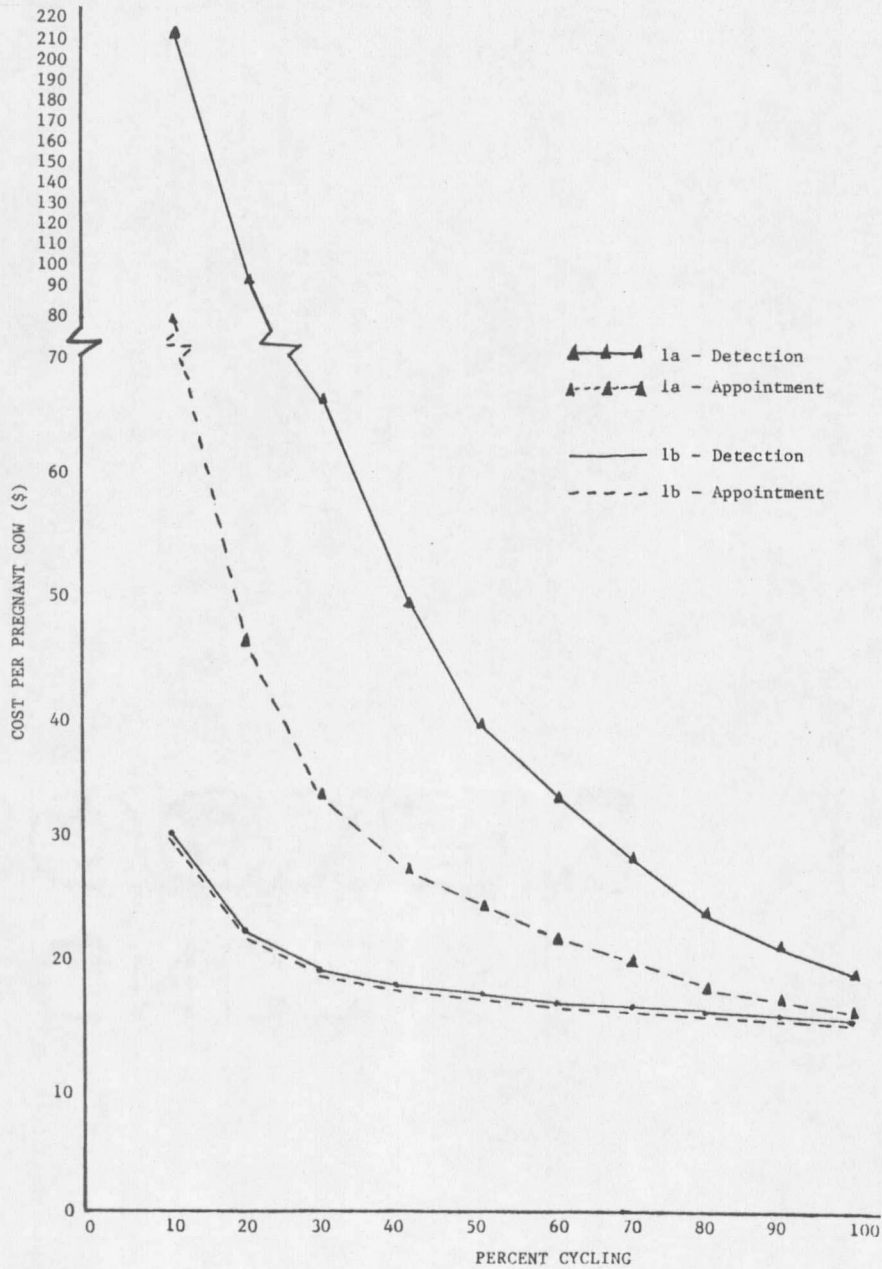


Figure 5

Palpation Versus No Palpation Alternatives for
Single Injection Systems Based on Cost Per
Pregnant Cow Assuming an 80 Percent Conception Rate



cycling (Figure 6).

If cows were palpated before the breeding season, then the method of breeding (i.e. detection, appointment or a combination of the two) did not affect the cost of the system, pregnancy rate of the cows or cost per pregnant cow. However, if cows were not palpated prior to the start of breeding, then the systems in which cows were bred by detection were less expensive than systems in which cows were bred by appointment or a combination of detection and appointment. Only if all cows were cycling (100 percent) was the appointment and combination of detection and appointment breeding method as inexpensive as breeding by detection (Table 2). Due to the assumption of equal conception rates for all breeding methods, conception rate did not alter the ranking of alternatives (Table 5). Given a percent cycling, the total pregnancy rate varied directly with the conception rate. For example, if 70 percent of the cows were cycling and the conception rate was 60 percent, the total number of pregnant cows was 42. If 70 percent of the cows were cycling and the conception rate used was 50 percent, the total number of pregnant animals was 35. Thus the total number of pregnant animals differed only by the cycling rate and differences in conception rate (i.e. $(60 - 50 \text{ percent conception rate} \times 70 \text{ percent cycling} = 7)$).

Figure 6

Palpation Versus No Palpation Alternatives for
Double Injection Systems based on Cost Per
Pregnant Cow Assuming an 80 Percent Conception Rate

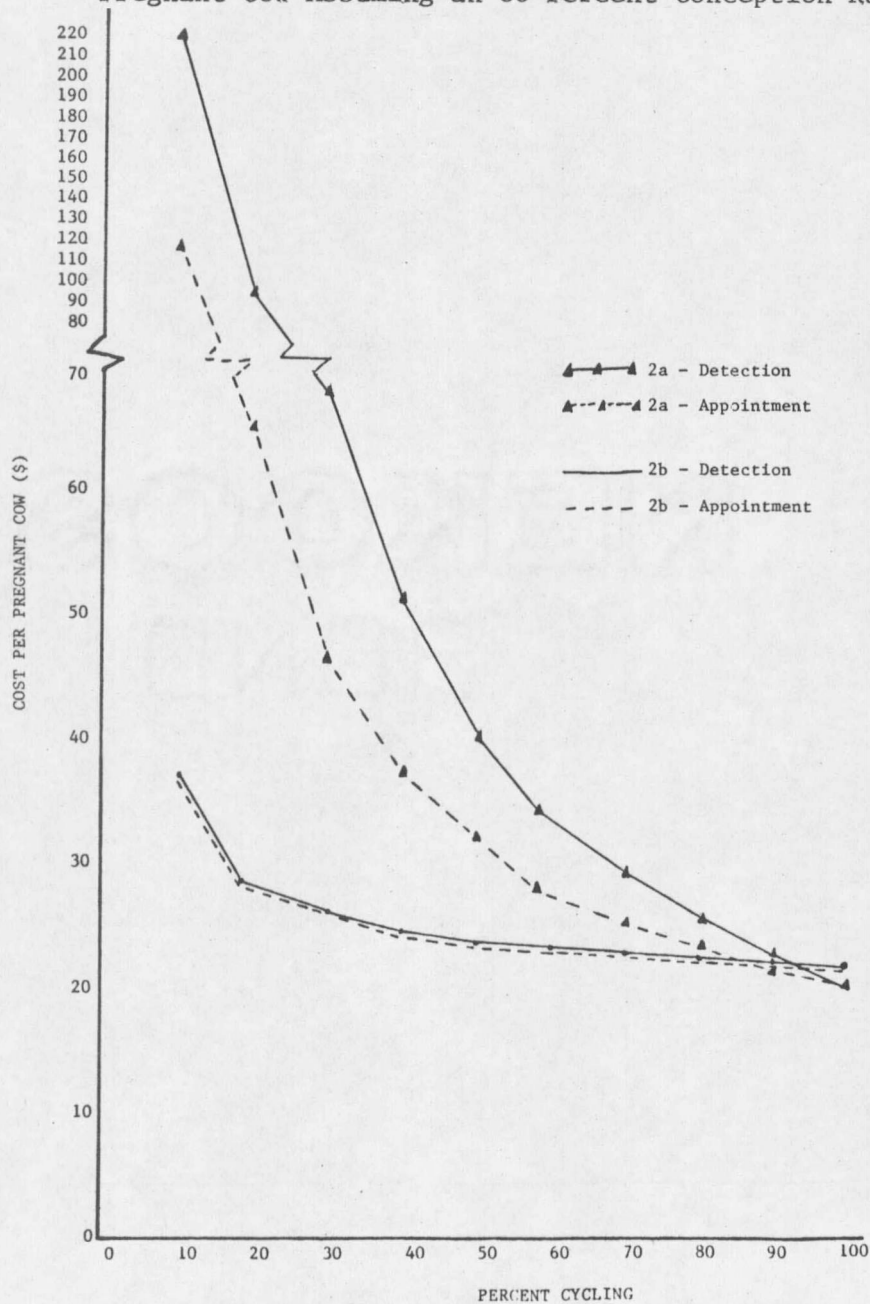


Table 5

Effect of Conception Rate on Total Pregnancy Rate

System	Conception Rate							
	80	70	60	50	40	30	20	10
1a	54	47	40	34	27	20	13	7
1b	54	47	40	34	27	20	13	7
1c	72	63	54	45	36	27	18	9
1d	72	63	54	45	36	27	18	9
2a	72	63	54	45	36	27	18	9
2b	54	47	40	34	27	20	13	7
2c	72	63	54	45	36	27	18	9

Total pregnancy rates are for cows bred by detection assuming a 90 percent cycling rate.

Number of Pregnant Cows

Some producers may want to maximize total AI pregnancy rate, ignoring the costs involved. Table 6 shows the ranking of alternatives and their associated pregnancy rates at 10 different cycling rates (10 to 100 percent).

Total pregnancy rates for the various systems varied directly as percent cycling varied. Within a given cycling rate, systems 1c, 1d, 2a and 2c all resulted in an equal number of pregnant cows as these systems include all cycling cows in the breeding program. On the other hand, systems 1a, 1b and 2b include only 75 percent of the cycling cows in the breeding program and therefore resulted in a similar number of pregnant cows. Thus differences in total pregnancy rate between the two groups varied by approximately 25 percent of the cycling rate.

Palpation did not influence total pregnancy rate achieved for a particular system except within the double injection systems (2a and 2b). If a double injection system was utilized without palpation, all cycling cows were synchronized and bred (2a). However, if cows were palpated prior to the first injection (2b), only three-fourths of the cycling cows were injected. In all other systems the pregnancy rate achieved for a system was the same regardless of whether or not cows were palpated prior to injection.

Table 6

Ranking of Synchronization Alternatives
Based on Total Number of Pregnant Cows

System	Percent Cycling									
	100	90	80	70	60	50	40	30	20	10
1c	80	72	64	56	48	40	32	24	16	8
1d	80	72	64	56	48	40	32	24	16	8
2a	80	72	64	56	48	40	32	24	16	8
2c	80	72	64	56	48	40	32	24	16	8
1a	60	54	48	42	36	30	24	18	12	6
1b	60	54	48	42	36	30	24	18	12	6
2b	60	54	48	42	36	30	24	18	12	6

* Pregnancy rates listed were estimated on the basis of an 80 percent conception rate.

Method of breeding within a given system did not alter total pregnancy rate. It is important to note, however, that equal conception rates were contingent upon appropriate breeding methods being used. For example, appointment breeding was considered only in two injection systems where all cycling cows were effectively synchronized. If cows had been bred only by appointment under a single injection system, the pregnancy rate would be expected to be lower.

Total Cost

If a producer wanted to minimize total cost of a breeding system, regardless of the pregnancy rate achieved, the ranking of alternatives would again change. Table 6 lists the ranking of alternatives from the least to most expensive system.

The percent cows cycling did not affect the total cost of a system unless cows were palpated prior to injection. In a system involving palpation, noncycling cows were not injected or bred. Therefore the drug and breeding costs were less than for a system not involving palpation where all cows were injected and bred.

For the majority of cycling rates single injection systems were ranked above five-day prebreeding systems and double injection systems. Single injection systems were least expensive because only one injection of $\text{PGF}_{2\alpha}$ was administered and fewer cows were bred. The five-day prebreeding systems ranked next because although only one injection

Table 7

Ranking of Synchronization Alternatives
Based on the Total Cost of the System

Rankings*	Percent Cycling									
	100	90	80	70	60	50	40	30	20	10
1	{1d-D	{1b-D	{1b-D	{1b-D	{1b-D	{1b-D	{1b-D	{1d-D	{1d-D	{1b-D
2	{1d-A	{1b-A	{1b-A	{1b-A	{1b-A	{1b-A	{1b-A	{1d-A	{1d-A	{1b-A
3	{1c-D	1a-D	1a-D	{1a-D	{1d-D	{1d-D	{1d-D	{1d-D	{2b-D	{1d-D
4	{1c-A	{1d-D	1c-D	{1d-D	{1d-A	{1d-A	{1d-A	{1b-A	{2b-A	{1d-A
5	{2c-D	{1d-A	{1d-D	{1d-A	1a-D	{2b-D	{2b-D	{2b-D	{1b-D	{2b-D
6	{2c-A	1c-A	{1d-A	1c-D	1c-D	{2b-A	{2b-A	{2b-A	{1b-A	{1d-A
7	{1b-D	1c-A	1c-A	{2b-D	{2b-D	1a-D	1a-D	1a-D	1a-D	1a-D
8	{1b-A	1a-A	1a-A	{2b-A	{2b-A	1c-D	1c-D	1c-D	1c-D	1c-D
9	1a-D	{2b-D	{2b-D	1c-A	1c-A	2c-D	1c-A	2c-D	2c-D	2c-D
10	1a-A	{2b-A	{2b-A	1a-A	1a-A	1c-A	1a-A	2a-D	2a-D	2a-D
11	{2a-D	2c-D	2c-D	2c-D	2c-D	1a-A	2c-D	1c-A	1c-A	1c-A
12	{2a-A	2c-A	2c-A	2c-A	2c-A	2a-D	2a-D	1a-A	1a-A	1a-A
13	{2b-D	2a-D	2a-D	2a-D	2c-A	2c-A	2c-A	2c-A	2c-A	2c-A
14	{2a-A	2a-A	1a-A	2a-A	2a-A	2a-A	2a-A	2a-A	2a-A	2a-A

*Rankings are from the least to most expensive system

D = a system involving breeding by detection

A = a system involving breeding by appointment or a combination of detection and appointment

{ indicates that the costs of the systems were the same

was used, more cows incurred a breeding cost. Double injection systems ranked third because of the higher cost of two injections.

For a given percent cycling, in almost all cases palpation options ranked above no palpation options. One exception was in the five-day prebreeding system when cows were cycling at a rate of 80 percent or more. In this case enough of the cows were bred in the five days before injection to make palpation unwarranted.

The effect of breeding method on total system cost also depended on the palpation option. In systems where cows were palpated, method of breeding did not affect total cost of the system. However, if cows were not palpated prior to injection, breeding by detection was less expensive than breeding by appointment or a combination of detection and appointment since breeding expenses were only incurred for cycling cows. This is especially evident for one injection systems where only 75 percent of the cycling cows are synchronized.

General Considerations

Management systems are highly variable and no one estrous synchronization system is going to provide optimum results for all producers. Consequently, in addition to cost factors already mentioned, producers should consider the number of times cattle must be handled, length of the breeding period and requirements for labor and facilities.

Single injection systems have the lowest total cost but also have the lowest total number of pregnant cows for the synchronized breeding. Cows are handled only twice, injection and breeding, and may be bred within a five-day period following injection. However, since only 75 percent of the cycling cows are synchronized with a single injection, breeding by detection or a combination of detection and appointment is required for satisfactory results.

Five-day prebreeding systems have one of the highest number of pregnant cows and the lowest cost per pregnancy for the total AI period. However, a longer AI breeding period is required (nine versus four days) and heat detection is required for at least five of those days. Cows detected in estrus the first five days are handled only once (breeding) while the remaining cows are handled twice (injection and breeding). Five-day prebreeding systems not only account for those cows in days one to five of the estrous cycle but also provide a means of estimating cycling rate in the herd prior to the decision to synchronize. The five day breeding period may also allow technicians and heat detectors to prepare for the more intensive activities of the synchronized breeding.

Double injection systems had one of the highest total pregnancy rates for the synchronized breeding but also resulted in the highest cost per pregnancy. Double injection systems effectively synchronize all cycling cows and therefore facilitate appointment breeding when a

high proportion of cows are cycling. Although labor requirements for heat detection are eliminated with appointment breeding, there is an increased requirement for chute help, trained AI technicians and good facilities for the appointment breeding and cattle must be handled three times (two injections and breeding). In the system in which cows are bred after the first injection (2c) fewer cows must be injected a second time and one also has the opportunity to abandon the synchronized program if response to the first injection is not satisfactory. However, breeding is extended four to five days and heat detection is required. If cows are to be bred by detection under system 2b (palpation option), then it would not be practical to give the second injection because those cycling cows identified by palpation could be bred in the five day period following the first injection, similar to system 1b. However, if cows are to be bred by appointment, the second injection is necessary to effectively synchronize those cows in days 17 to 21 of the estrous cycle. It should also be noted that, unlike other two injection systems (2a and 2c), system 2b does not synchronize all cycling cows as only those cows in days 6 to 21 of the cycle are selected by palpation for the breeding program.

In selecting a breeding method several factors should be considered, including percent cows cycling, semen cost, availability and cost of labor and existing cattle handling facilities. Breeding by

detection is recommended when cycling rates are less than 90 percent, when costs of semen and supplies are high and when labor is available for heat detection. Breeding by appointment is recommended only when a high proportion of cows are cycling, when all cows are effectively synchronized in a double injection system and when labor and facilities are adequate for breeding all synchronized cows within a few hours. Appointment breeding would not be recommended when fewer than 90 percent of the cows are cycling, when a single injection system is used, when there is a shortage of trained AI technicians and chute help or when breeding facilities are not adequate for handling all synchronized cows at one time. When breeding by appointment, it should also be kept in mind that there can be considerable variability in the time between injection and subsequent estrus. Consequently, the time selected for appointment breeding may differ from the 80-hour interval used in this study.

Cost Factors

The total costs that were estimated in this study were not intended to indicate absolute costs of each synchronization system but rather to provide a means of ranking the alternatives. Prices used in this study were those existing during the Spring and Summer of 1980. If these prices change, it is likely that the ranking of the alternatives will be different. The relative impact of a change

in the cost of a specific variable will depend on how large a portion of the total cost it accounted for. For example, cost of $PGF_{2\alpha}$ was a major factor in the total cost of double injection systems so a change in the price of $PGF_{2\alpha}$ would have a greater impact on double injection systems than single injection systems.

Costs other than palpation, $PGF_{2\alpha}$ injections and breeding are important and may affect optimal synchronization policy. For example, in order to place a more precise value on the outcome of the breeding alternatives it would be necessary to estimate labor costs. Labor costs were not included in the simulation model due to the difficulty in assigning specific dollar values. Considerable variation exists among management systems in the method of heat detection and breeding. The most common heat detection method is to visually observe the cow herd twice daily. The amount of labor required depends on pasture size, number of water sources or if detection aids such as gomer bulls, androgenized cows or KaMar heat mount devices are used. Labor requirements will also depend on which breeding method is used. Requirements are more intensive for appointment breeding but breeding is short-term. Conversely, breeding by detection spreads breeding over a longer period of time but labor requirements per day are less. Finally, availability of labor will affect the cost assigned to it. Some operations may use family members or their regular employees to do heat detecting and breeding while other operations would have to

hire extra help. If the rancher or his family do all of the work, an opportunity cost must be assigned to their labor but this may differ substantially from the cost and availability of outside labor. Because the differences in labor costs may have a large effect on the ranking of alternatives, these costs should be considered when selecting a breeding system.

Conclusions

Management must insure a high percentage of cows are cycling prior to the start of the breeding season if any estrous synchronization program is to be successful. The higher the proportion of cows cycling, the higher the number of pregnant cows and the lower the cost per pregnancy.

To minimize costs, ineligible cows should be identified before the start of the breeding season and removed from the synchronization program. Accurate ovarian palpation is one method to separate cycling from noncycling animals. Observing the cycling activity of the herd for five days before breeding is another method of estimating the percent cycling cows. Approximately five percent of the cycling cows should be observed in heat every day. In cases where less than 80 percent of the cows are cycling, it is feasible to use both the breeding period of five days before injection and palpation. Even though the pre-injection breeding period gives an indication of the

number of cycling cows, palpation identifies which cows are cycling and are candidates for synchronization. Regardless of the method used to estimate percent cows cycling, a decision should be made as to the feasibility of a synchronization program based upon the number of cows cycling.

Results indicate that Montana ranchers could minimize the cost per pregnant cow by using the five-day prebreeding system with palpation (1d) for the majority of cycling rates. In general, one injection systems ranked over two injection systems on the basis of cost per pregnant cow and total cost of the system. Two injection and five-day prebreeding systems ranked over one injection systems in terms of total number of pregnant cows for the synchronized breeding period.

Based on the costs included in this study, breeding by detection was always preferred to breeding by appointment or a combination of detection and appointment. The only exceptions were when 100 percent of the cows were cycling prior to the breeding season or when cows were palpated before injections of $\text{PGF}_{2\alpha}$ were administered. However, breeding by appointment may be preferred by producers who can't or don't want to detect estrus.

Since Prostaglandin $\text{F}_{2\alpha}$ can be used in a variety of management situations, systems are very flexible and can be altered to meet individual requirements. Determining the best system is ultimately

up to the producer. Each individual must weight the advantages and disadvantages of each system as it applies to their particular operation. The correct management system for an individual operation will depend on the goals of the producer, AI pregnancy rate desired, cost of prostaglandin and semen and the available facilities and labor.

APPENDIX 1

COMPUTER PROGRAM

C PROGRAM TO CALCULATE COSTS AND PREGNANCY RATES FOR FARIOUS
C SYNCHRONIZING PROGRAMS. VICKIE ADKINGS APRIL 22 1980

```

      REAL INJECT, INJ2
      WRITE (10,7)
      DO 10 I=0,100,10
      DO 10 J=10,80,10
      INJECT = 100*4.5
      BRDDET = I*.75*7.5
      PR2=I*.75*(J/100)
      TOTALC=INJECT + BRDDET
      PERCOW = TOTALC/PR2
      PR2=PR2+.5
      WRITE (10,17) I,J, INJECT, BRDDET, PR2, TOTALC, PR2, PERCOW
      INJECT=100*4.5
      BRDAPT=100*7.5
      PR2=I*.75*(J/100)
      TOTALC=INJECT + BRDAPT
      PERCOW=TOTALC/PR2
      PR2=PR2+.5
10    WRITE(10,27) I,J, INJECT, BRDAPT, PR2, TOTALC, PR2,
      *PERCOW
C 1B  PALPATE INJECT BREED
      WRITE(10,7)
      DO 20 I=0,100,10
      DO 20 J=10,80,10
      PALPAT = 100 * 1
      INJECT = I*.75*4.5
      BRDDET = I*.75*7.5
      PR2=I*.75*(J/100)
      TOTALC=INJECT + BRDDET + PALPAT
      PERCOW = TOTALC/PR2
      PR2=PR2+.5
      WRITE (10,37) I,J, PALPAT, INJECT, BRDDET, PR2, TOTALC, PR2, PERCOW
      BRDAPT=I*.75*7.5
      PR2=I*.75*(J/100)
      TOTALC=INJECT + BRDAPT + PALPAT
      PERCOW=TOTALC/PR2
      PR2=PR2+.5
20    WRITE(10,47) I,J, PALPAT, INJECT, BRDAPT, PR2, TOTALC, PR2,
      *PERCOW
C 1C  BREED 5 DAYS, INJECT, BREED
      WRITE(10,7)
      DO 30 I=0,100,10
      DO 30 J=10,80,10
      BD5DAY=I*.25*7.5
      PR1=I*.25*(J/100)
      INJECT=(100-I*.25)*4.5
      BRDDET=(.75*I)*7.5
      PR2=(.75*I)*(J/100)
      TOTALC=BD5DAY + INJECT + BRDDET
      TOTALP=PR1 + PR2
      PERCOW=TOTALC/TOTALP
      TOTALP=TOTALP+.5
      WRITE(10,57) I,J, BD5DAY, PR1, INJECT, BRDDET, PR2, TOTALC,
      *TOTALP, PERCOW
      BRDAPT=(100-I*.25)*7.5
      PR2=(.75*I)*(J/100)
      TOTALC=BD5DAY + INJECT + BRDAPT
      TOTALP=PR1+PR2

```

```

PERCOW=TOTALC/TOTALP
TOTALP=TOTALP+.5
30  WRITE(10,67)I,J,BD5DAY,PR1,INJECT,BRDAPT,PR2,TOTALC,
    *TOTALP,PERCOW
10  BREED 5 DAYS, PALPATE, BREED, INJECT
    WRITE (10,7)
    DO 40 I=0,100,10
    DO 40 J=10,80,10
    BD5DAY=I*.25*7.5
    PR1=I*.25*(J/100)
    PALPAT=(100-I*.25)*1
    INJECT=(.75*I)*4.5
    BRDDET=(.75*I)*7.5
    PR2=(.75*I)*(J/100)
    TOTALC=BD5DAY + PALPAT + INJECT + BRDDET
    TOTALP=PR1+PR2
    PERCOW=TOTALC/TOTALP
    TOTALP=TOTALP+.5
    WRITE(10,77)I,J,BD5DAY,PR1,PALPAT,INJECT,BRDDET,PR2,
    *TOTALC,TOTALP,PERCOW
    BRDAPT=(.75*I)*7.5
    TOTALC=BR5DAY + PALPAT + INJECT + BRDAPT
    TOTALP=PR1+PR2
    PERCOW=TOTALC/TOTALP
    TOTALP=TOTALP+.5
0   WRITE(10,87)I,J,BD5DAY,PR1,PALPAT,INJECT,BRDAPT,PR2,
    *TOTALC,TOTALP,PERCOW
: 2A INJECT TWICE AND BREED
    WRITE(10,7)
    DO 50 I=0,100,10
    DO 50 J=10,80,10
    INJECT = 100 * 4.5
    INJ2=100*4.5
    BRDDET = I*7.5
    PR3=I*1.0*(J/100)
    TOTALC=INJECT + INJ2 + BRDDET
    PERCOW = TOTALC/PR3
    PR3=PR3+.5
    WRITE(10,97)I,J,INJECT,INJ2,BRDDET,PR3,TOTALC,PR3,
    *PERCOW
    BRDAPT=100*7.5
    TOTALC=INJECT + INJ2 + BRDAPT
    PR3=PR3-.5
    PERCOW = TOTALC/PR3
    PR3=PR3+.5
50  WRITE(10,107)I,J,INJECT,INJ2,BRDAPT,PR3,TOTALC,PR3,
    *PERCOW
C 2B PALPATE, INJECT TWICE, BREED
    WRITE (10,7)
    DO 60 I=0,100,10
    DO 60 J=10,80,10
    PALPAT = 100 * 1
    INJECT=PALPAT * ( I/100) * .75 * 4.5
    INJ2 = INJECT
    BRDDET = I * .75 * 7.5
    PR3=I*.75*(J/100)
    TOTALC = PALPAT + INJECT + INJ2 + BRDDET
    PERCOW = TOTALC/PR3
    PR3=PR3 + .5

```

```

WRITE(10,117) I,J,PALPAT,INJECT,INJ2,BRDDDET,PR3,TOTALC,
*PR3,PERCOW
BRDAPT = I * .75 * 7.5
TOTALC = PALPAT + INJECT + INJ2 + BRDAPT
PR3=PR3 - .5
PERCOW=TOTALC/PR3
PR3=PR3 + .5
60 WRITE(10,127) I,J,PALPAT,INJECT,INJ2,BRDAPT,PR3,TOTALC,
*PR3,PERCOW
C 2C INJECT, BREED, INJECT, BREED
WRITE(10,7)
DO 70 I=0,100,10
DO 70 J=10,80,10
INJECT= 100 * 4.5
BRDDDET = I * .75 * 7.5
PR2=I * .75 * (J/100)
INJ2=(100 - (I * .75)) * 4.5
BRDDDET2= (.25 * I) * 7.5
PR3=(I - (I * .75)) * (J/100)
TOTALC=INJECT + BRDDDET + INJ2 + BRDDDET2
TOTALP=PR2 + PR3
PERCOW=TOTALC/ TOTALP
TOTALP= TOTALP + .5
WRITE(10,137) I,J,INJECT,BRDDDET,PR2,INJ2,BRDDDET2,PR3,
*TOTALC,TOTALP,PERCOW
BRDAPT=(100 - (I * .75)) * 7.5
TOTALC=INJECT + BRDDDET + INJ2 + BRDAPT
TOTALP=TOTALP - .5
PERCOW= TOTALC/TOTALP
TOTALP=TOTALP + .5
70 WRITE(10,147) I,J,INJECT,BRDDDET,PR2,INJ2,BRDAPT,PR3,
*TOTALC,TOTALP,PERCOW
7 FORMAT('1SYSTEM',1X,'%CYCLING',2X,'CONCEPTION',3X,
*'BRD5DAY',3X,'PR1',2X,'PALPATE',3X,'INJECT',3X,'BREED',
*3X,'PR2',3X,'INJECT',3X,'BREED',3X,'PR3',2X,'TOTAL COST',
*2X,'TOTAL PREG',2X,'PERCOW')
17 FORMAT(2X,'1A',7X,I3,8X,I2,32X,F6.2,2X,F6.2,3X,I2
*27X,F8.2,7X,I2,5X,F8.2)
27 FORMAT(2X,'1A',7X,I3,8X,I2,32X,F6.2,2X,F6.2,3X,
*12,27X,F8.2,7X,I2,5X,F8.2)
37 FORMAT(2X,'1B',7X,I3,8X,I2,24X,I3,5X,F6.2,2X,
*F6.2,3X,I2,27X,F8.2,7X,I2,5X,F8.2)
47 FORMAT(2X,'1B',7X,I3,8X,I2,24X,I3,5X,F6.2,2X,
*F6.2,3X,I2,27X,F8.2,7X,I2,5X,F8.2)
57 FORMAT(2X,'1C',7X,I3,8X,I2,7X,F7.2,3X,I2,13X,F6.2,
*2X,F6.2,3X,I2,27X,F8.2,7X,I2,5X,F8.2)
67 FORMAT(2X,'1C',7X,I3,8X,I2,7X,F7.2,3X,I2,
*13X,F6.2,2X,F6.2,3X,I2,27X,F8.2,7X,I2,5X,F8.2)
77 FORMAT(2X,'1D',7X,I3,8X,I2,7X,F7.2,3X,I2,5X,I3,
*5X,F6.2,2X,F6.2,3X,I2,27X,F8.2,7X,I2,5X,F8.2)
87 FORMAT(2X,'1D',7X,I3,8X,I2,7X,F7.2,3X,I2,5X,I3,
*5X,F6.2,2X,F6.2,3X,I2,27X,F8.2,7X,I2,5X,F8.2)
107 FORMAT(2X,'2A',7X,I3,8X,I2,32X,F6.2,17X,F6.2,3X,
*F6.2,3X,I2,3X,F8.2,7X,I2,5X,F8.2)
117 FORMAT(2X,'2B',7X,I3,8X,I2,24X,I3,5X,F6.2,17X,F6.2,3X,
*F6.2,3X,I2,3X,F8.2,7X,I2,5X,F8.2)
127 FORMAT(2X,'2B',7X,I3,8X,I2,24X,I3,5X,F6.2,17X,F6.2,3X,
*F6.2,3X,I2,3X,F8.2,7X,I2,5X,F8.2)

```

```
137  FORMAT(2X,'2C',7X,I3,8X,I2,32X,F6.2,2X,F6.2,3X,I2,  
*4X,F6.2,3X,F6.2,3X,I2,3X,F8.2,7X,I2,5X,F8.2)  
97   FORMAT(2X,'2A',7X,I3,8X,I2,32X,F6.2,17X,F6.2,3X,  
*F6.2,3X,I2,3X,F8.2,7X,I2,5X,F8.2)  
147  FORMAT(2X,'2C',7X,I3,8X,I2,32X,F6.2,2X,F6.2,  
*3X,I2,4X,F6.2,3X,F6.2,3X,I2,3X,F8.2,7X,I2,5X,F8.2)  
END
```

Computer Program Variables

<u>I</u>	Percent cycling cows Varies from 0 to 100 percent in increments of 10 percent
<u>J</u>	Conception Rate Varies from 10 to 80 percent in increments of 10 percent
<u>Palpat</u>	Cost of palpating cows Calculated by multiplying the number of cows palpated by the cost of palpation which is \$1.00 per cow.
<u>Inject</u>	Cost of injecting cows Calculated by multiplying the number of cows to be injected by the cost of injection which is \$4.50 per cow.
<u>Bd5day</u>	Cost of breeding cows AI for 5 days prior to injection under systems 1c and 1d Calculated by dividing the number of cycling cows by 21 to get the number of cows showing heat per day and multiplying this figure by 5. The number of cows in estrus in the 5 days of breeding prior to injection is then multiplied by the breeding cost of \$7.50 per cow.
<u>Brddet</u>	Cost of breeding by detection of estrus; can be used in any of the synchronization systems Calculated by multiplying the number of cows expected to show heat (for one injection systems this is the percent cows cycling times .75 and for the two injection systems this is the percent cows cycling) by the breeding cost of \$7.50 per cow.
<u>Brdapt</u>	Cost of breeding by appointment or a combination of detection and appointment Calculated by multiplying the number of cows responding to PGF _{2α} treatment by the breeding cost of \$7.50 per cow. For one injection systems the number of cows responding would be the percent cows cycling times .75. For two injection systems, the number of cows responding could be the number of cycling cows.

- PR1 Number of cows pregnant after breeding for 5 days prior to injection under systems 1c and 1d
Calculated by dividing the number of cycling cows by 21 and then multiplying by 5. This represents the number of cows expected to show estrus and is multiplied by the conception rate.
- PR2 Number of cows pregnant after the first injection of any system
Calculated by multiplying the number of cows cycling by the number of cows in days 5 through 21 of their estrous cycle (.75) and then multiplying by the conception rate.
- PR3 Number of cows pregnant when breeding after the second injection under systems 2a, 2b and 2c
Calculated by multiplying the number of cows injected by the conception rate.
- TotalC Total cost of the system
Calculated by adding the cost of palpation (Palpat) to the cost of injection (Inject) and the cost of breeding (Bd5day, Brddet or Brdapt).
- TotalP Total number of pregnant cows
Calculated by adding PR1, PR2 and PR3.
- Percow Cost per pregnant cow
Calculated by dividing the total cost of the system (TotalC) by the total number of pregnant cows (TotalP).

APPENDIX 2

OUTPUT FROM SIMULATION PROGRAM

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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
2	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122	124	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	166	168	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198	200
3	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96	99	102	105	108	111	114	117	120	123	126	129	132	135	138	141	144	147	150	153	156	159	162	165	168	171	174	177	180	183	186	189	192	195	198	201	204	207	210	213	216	219	222	225	228	231	234	237	240	243	246	249	252	255	258	261	264	267	270	273	276	279	282	285	288	291	294	297	300
4	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108	112	116	120	124	128	132	136	140	144	148	152	156	160	164	168	172	176	180	184	188	192	196	200	204	208	212	216	220	224	228	232	236	240	244	248	252	256	260	264	268	272	276	280	284	288	292	296	300	304	308	312	316	320	324	328	332	336	340	344	348	352	356	360	364	368	372	376	380	384	388	392	396	400
5	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230																																																						

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Journal of Interpersonal Violence 36(1)

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LITERATURE CITED

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