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USE OF PROSTAGLANDINS TO SYNCHRONIZE ESTRUS IN POSTPARTUM BEEF COWS

by

ROYDON GARTH WHITE

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ABSTRACT

Prostaglandins were used to synchronize estrus in suckling pluriparous Angus x Charolais cows in a study conducted over a 2 year period. In Year 1, 15 cows were given two im injections of 20.0 mg $PGF_{2\alpha}$ 12 days apart and bred by natural service at observed estrus. In Year 2, 30 cows received two injections of 2.0 mg ICI-80996. Cows were palpated weekly and were treated when a corpus luteum was detected. Cows were divided randomly in Year 2 into two groups following treatment; Group II was bred by natural service and Group I was artificially inseminated at 72 and 96 hours following the second drug injection. In both years blood samples were taken twice a week and assayed for progesterone (P) by radioimmunoassay. Time to first presumed ovulation was 49.3 $\pm$ 2.1 and 44.4 $\pm$ 3.3 days postpartum (PP) for Year 1 and Year 2, respectively, and time to first injection was 56.9 $\pm$ 1.3 and 66.9 $\pm$ 2.7 days PP, respectively. Interval to first estrus from second injection was 3.62 $\pm$ 0.41 days in Year 1, and 4.20 $\pm$ 1.01 days in Year 2 - Group II. Time to breeding was 73.6 $\pm$ 1.6, 82.9 $\pm$ 4.3 and 85.1 $\pm$ 4.0 days for Year 1, Year 2 - Group II and Year 2 - Group I, respectively. Conception rates at syn-

chronized estrus were 73.3%, 60.0% and 40.0% for Year 1, Year 2 - Group II and Year 2 - Group I, respectively.

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INTRODUCTION

The major limitations to extensive usage of artificial insemination(AI) in beef cattle is the large amount of labour involved in detecting estrus in cycling cows and the improper timing of AI with respect to time of ovulation. These limitations may possibly be alleviated by the technique of estrous control or synchronization.

There are a number of advantages to be gained by the employment of estrous synchronization. The technique can greatly reduce the amount of time, feed and labour required during the total AI program. In the last decade considerable attention has been given to the possible use of a luteolytic agent such as prostaglandin (PG) as a means of estrous synchronization.

From extensive research on the use of PG, a few problems in practical application have become apparent. Firstly, upon administration of a single luteolytic dosage of PG to a group of normally cycling cows, approximately 33% of the animals will not respond. This is a result of the fact that a luteolytic agent can only be effective in cows that are in the luteal phase of their cycle. Secondly, the implementation of the type of AI program that disre-

gards estrous detection after estrous synchronization is dependent upon the accurate timing of one or two inseminations with respect to a hopefully precisely synchronized time of ovulation. Thirdly, as a luteolytic agent, PG cannot be effective on the non-cycling postpartum cow. Therefore, it becomes imperative that the average length of the postpartum anestrous period be determined.

Recently, a number of management regimes have been investigated which could eventually alleviate the problems outlined above. Hearnshaw (1976) suggested that it would be advantageous if a number of field trials, examining subsequent fertility, could be conducted to investigate a number of feasible management regimes in several envionmental and physical situations. In response to the problem of the partially effective single dose of PG, a number of workers have reported good results from the use of a double injection scheme designed to cause all cycling cattle to respond. Research workers are still searching for a reliable scheme whereby AI could be done without regard to detection of estrus following synchronization. Finally, the lengthy duration of postpartum anestrus in beef cows is one of the problems that is commonly encountered. At the time that this study was contemplated, there were no data on the postpartum anestrous interval under Western Canadian conditions.

Thus, in 1975, a study was initiated in collaboration with Dr. J. G. Manns, of the College of Veterinary

Medicine, University of Saskatchewan, with two primary purposes. Firstly, the purpose was to determine the length of postpartum anestrus in beef cattle in this locality. Secondly, the purpose was to assess the effectiveness of two commonly used PG's (Prostaglandin $F_{2\alpha}$ and a synthetic analogue, ICI-80996, or "Estrumate") as possible estrous synchronizing agents.

LITERATURE REVIEW

Postpartum Activity in the Cow

Progesterone and the Corpus Luteum

It is generally acknowledged that progesterone (P) is the single most important hormone in determining the cyclic activity of the cow. It is particularly indicative of the three phases of postpartum (PP) activity in the bovine.

The primary phase of PP activity is that of the waning corpus luteum (CL) of pregnancy. The decreasing P concentration is indicative of this phase. Significant decreases in P concentration are first observed 2 to 3 days before parturition (Erb et al., 1971b; Morrow et al., 1968a; Pope et al., 1969) when the CL of pregnancy begins to regress. Donaldson et al. (1970) observed that P concentration began decreasing in beef cows 2 to 3 weeks before parturition, although there was still a much more rapid decrease during the last 24 hours (h) preceeding calving.

Research during the early part of the century indicated that the CL of pregnancy remained unchanged for

a long period of time after parturition, and prevented normal follicular activity. However, recent research indicates that the CL of pregnancy is maintained in only a very small number of cattle (Trimberger and Fincher, 1956; Hammond 1927). Wagner and Hansel (1969) observed a longer maintenance of size in CL of pregnancy as compared to cyclic CL, which is apparently due to the larger amount of vascular tissue present in pregnancy CL as compared to cyclic CL. However, even at day 7 PP there were few, if any luteal cells present. Other workers have also established that the CL of pregnancy is not palpable at 14 to 20 days PP (Morrow et al., 1968a, 1968b; Pope et al., 1969; Wagner and Oxenreider, 1971; Oxenreider, 1971; Morrow et al., 1966).

The next phase of PP activity is one of ovarian quiesence, where very little P can be detected in the ovary or vascular system, and follicular activity has not resumed (Fig. 1). Erb et al. (1971) indicated that P shows no serious imbalance during the early PP period; some individuals had low plasma P (1-3 ng/ml) during PP anestrus and showed no relation to luteinizing hormone (LH) levels or estrogen levels. Most individuals after 2 weeks PP averaged 7-10 ng/ml progesterone, and the adrenal gland was the suggested likely source. Balfour et al. (1957) and Morrow et al. (1968) suggested that the adrenal gland may serve as an alternate source of P when the ovary is absent or essentially non-functional, as appears to be

the case a few days after calving.

In Fig. 1, the low P levels are indicative of the immediate PP ovarian quiesence, and they remain low until cyclic activity begins. Exactly what begins the cyclic activity is yet unknown. However, there must be a correct ovarian-hypothalmic relationship before ovulation can occur. Erb et al. (1971b) reported that the endocrine balances which are required to support normal estrous cycles and to re-establish fertility, are restored gradually after calving. Callahan et al. (1971) added that cellular debris and the involuting uterus may inhibit both neural and humoral feedback mechanisms regulating the endocrine control of estrous cycles. However, Oxenreider (1968) and Morrow et al. (1966) did observe that follicular growth is initiated during the time of CL regression and uterine involution. Additionally, it was shown that although gonadotrophic activity is low during PP anestrus in suckled beef cows, this did not effect the rate of involution (Oxenreider, 1968).

Marion and Gier (1968) suggested that cytological disturbances in the endometrium during early uterine regression may inhibit ovulation and CL development. When cellular relationships have returned to near normal, which occurs first in the non-gravid uterine horn, ovulation occurs. However, slight distension of the horn and its associated endometrial effects accompany a poorly developed short-lived CL. By 30 days PP the endometrium is again

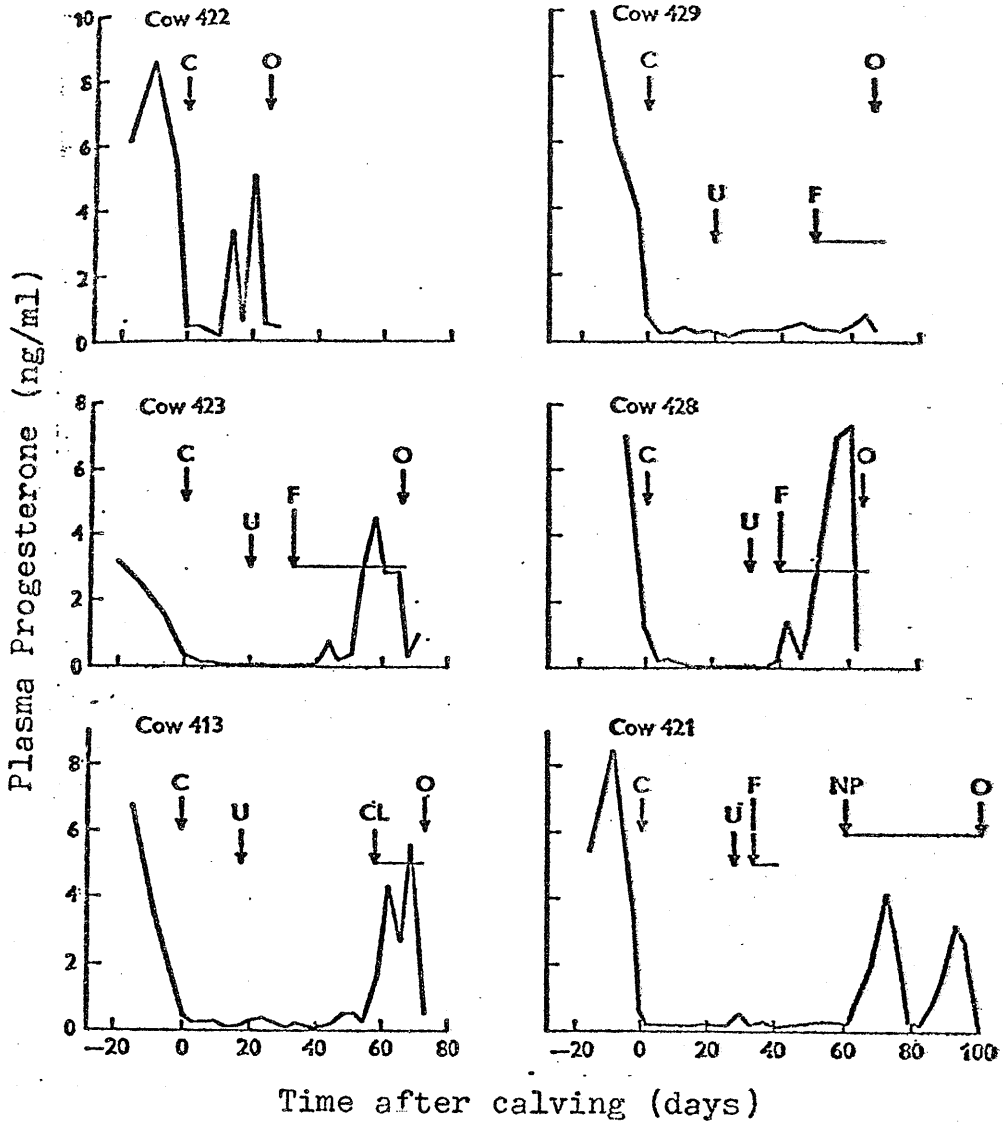

FIG. 1. Changes in plasma P concentration of cows be-between the time of calving (C) and the first observed PP estrus (O). The functional state of the ovaries was assesed by rectal palpation. U, Uterine involution complete; F, follicle present; CL, corpus luteum present; NP, not palpated. The calf of cow 422 died 2 days after birth. The horizontal lines indicate the period during which a follicle or CL was present, (Donaldson et al., 1970).

capable of being involved in normal ovarian activity.

Although pituitary gonadotrophic activity during the estrous cycle can be explained quite conveniently by related ovarian functions, the control of this activity during anestrus is less obvious (Wagner and Oxenreider, 1971). Sawhney (1966) and Wagner and Oxenreider (1971) observed that pituitary LH decreased until calving and then increased until first ovulation. This trend in LH concentration is opposite to that of P during PP anestrus. However, the trends of these two hormones within their respective glands are quite similar during the estrous cycle (Wagner and Oxenreider, 1971).

The third phase is cyclic activity and begins at variable times PP depending upon the endocrine balance. The beginning of cyclic activity is preceeded by increasing follicular development. Donaldson et al. (1970) and Pope et al. (1969) observed small but significant increases in P concentration approximately 3 to 4 days before the start of the first cycle PP. Rectal palpation suggested that this increase in P concentration was associated with follicular development, and implied some luteinization of follicles was occurring.

Casida (1968) observed that most early formed CL are small in size and have been formed from small follicles, and suggested that the ovarian ster dogenic relationship may not be normal at the very early estrous periods.

A common occurrence with the first PP ovulation is the absence of estrus. Follicle rupture and CL formation without signs of estrus apparently are normal for the cow during the first 20 days postpartum (Morrow et al., 1968).

A number of researchers have also observed the phenomena of a short first PP cycle (Morrow et al., 1966, 1968; Menge et al., 1962; Wagner and Hansel, 1969; Wagner and Oxenreider, 1971). The suggested reason for the short first PP cycle is the failure of the first CL to be maintained. This could be due to a failure of the luteotrophic factors or due to an enhancement of luteolytic factors (Morrow et al., 1966). Lauderdale et al. (1968) found significant correlations between the weight of the first cyclic CL at 15 days PP and the length of the PP interval ($r=0.41$). This signifies lesser development of the CL when the estrous cycle is initiated early after parturition. However, Wagner and Hansel (1969) and Wagner and Oxenreider (1971) have found indications that adequate P may be present in the cyclic CL formed soon after parturition. Lauderdale et al. (1968) did not find good CL formation and found that the CL formed soon after parturition were lighter in weight at day 15 than CL formed later. Wagner and Hansel (1969) did not consider that differences in P content are of particular significance in this regard, since the P

contents of the CL decline rather sharply at the end of the cycle. At this stage of the cycle, the number of days until estrus is of more importance than days past estrus in determining luteal function, and there is considerable variability in the P content of the 18 to 20 day old corpus luteum.

Follicular Development and Estrogen Levels Leading up to Ovulation

At the time of parturition the cow shows as little follicular development as at any time in her adult life (Casida, 1968). There is a decrease in follicular size during the course of pregnancy, which is presumably due to the inhibition of the pituitary gonadotrophic hormone secretion by the high levels of estrogen and P during the latter part of pregnancy (Casida, 1968). What happens in the last month of pregnancy is not clear, but a slight increase in follicle stimulating hormone (FSH) of the pituitary was reported during the last 10 days of pregnancy. However, the quantity of FSH secreted presumably was not yet enough to initiate new follicular development (Casida, 1968; Morrow et al., 1966).

Estrogens are predominantly derived from the fetal cotyledons during pregnancy and parturition and for several days thereafter. At parturition there are very few follicles that are palpable. Ovarian follicles then provide a source of estrogen several days after calving

when they become palpable (Erb et al., 1971b). In the last 3 weeks of gestation, excretion of urinary estrogens, especially estradiol-17β, increase rapidly. However, the rate of excretion of estrogen in urine decreases rapidly as measured at 0.5 days and 3 days after calving (Hunter et al., 1970) presumably because the influence of the fetal cotyledons has been lost. Randel and Erb (1971) observed however, that during this early period, estrogen excretion rates generally are several times higher than those observed during estrous cycles occuring 60 or more days PP (Erb. et al., 1971b). It was suggested by Erb et al. (1971) that PP infertility was associated with high levels of estrogen, and that this is normal for at least 42 days PP in healthy dairy cows milked twice daily.

The renewed follicular development after parturition is presumably due to the release of FSH (Casida, 1968; Labhsetwar et al., 1964; Foote, 1971; Erb et al., 1971b). A decline in pituitary levels of FSH was shown between parturition and 21 days later (Labhsetwar et al., 1964). Casida (1968) observed a decrease in FSH pituitary content by 10 days PP with a further decrease by 20 days. There appeared to be appreciable storage of FSH at parturition, in as much as it was higher than at the sixth day of the estrous cycle and approximately as high as at day 15 (Casida, 1968).

FSH release could overstimulate ovarian follicles and account for the persistently high rates of excretion of estrogen as compared to later in the PP period. High estrogen, in addition to temporarily inhibiting FSH, causes morphological alteration of the follicles and alters steroid synthesis to favour P instead of estrogen, thereby initiating further release of FSH (Erb et al., 1971b). Foote (1971) observes that as FSH activity slowly decreases, LH activity slowly increases. His results were interpreted as a pituitary accumulation of LH preparatory for release for ovulation, and a continual more gradual release of FSH to stimulate ovarian development in preparation for ovulation. Other workers have observed the same phenomena (Labhsetwar, 1964; Saiduddin, 1964; Sawhney, 1966; Saiduddin et al., 1968; Wagner and Oxenreider, 1971).

A considerable number of observations have been made in an attempt to determine the time scale of increasing follicular size following calving. Results vary according to the type of cattle, to the amount of uterine involution, and to the stress of milk removal, but Casida (1968) approximated the interval to be 4 weeks. The development of follicles to approximately mature size was noted at 21 days PP. Labhsetwar et al. (1964) and Casida (1968) noted that there is increased development as early as 10 days PP. Casida (1968) also noted that follicular fluid weight did not vary signi-

ficantly between 10, 20 and 30 days PP, and was not affected by suckling. Wagner and Oxenreider (1971) however, found that suckled cows had smaller follicles at 30 days PP. Their data suggests that follicles large enough to mature and ovulate are present by 1 to 2 weeks PP in lactating cows. Wagner and Hansel (1969) observed follicular development in milked cows; being 9.6, 11.3 and 13.1 mm in diameter at 7, 14 and 30 days PP, respectively. Concurrent with observations of follicular size, a number of researchers have observed that follicles develop more rapidly in the ovary opposite to the one that contains the CL of pregnancy (Casida and Venzke, 1936; Morrow et al., 1966; Saiduddin et al., 1968).

Saiduddin et al. (1968) suggested that there was some form of interference by the CL of pregnancy, or the uterine horn of the previous pregnancy, on maturation of follicles following parturition. If the uterine horn of the previous pregnancy blocks development of follicles in the ovary on the same side, particularly in the early stages PP, then this effect should wane as the uterus returns to normal. Saiduddin et al. (1968) concluded from their results that it was not possible to determine if this unilateral block to follicular development and ovulation was due to a carry-over effect of the post-gravid uterine horn, or the CL of pregnancy, or to the contemporary involuting state of the uterine horn.

Gonadotrophic Hormone Levels

Because of the importance of LH in initiating luteal formation, there is a considerable amount of information on PP LH levels. The majority of information available generally acknowledges that gonadotrophic activity is low during PP anestrus (Morrow et al., 1966; Casida, 1968; Saiduddin et al., 1968; Callahan et al., 1971; Foote, 1971). Generally, pituitary FSH content is high on the day after calving and decreases appreciably by day 20 PP, while LH is shown to be low at parturition but increases during the early PP interval in an inverse pattern to FSH. This indicates a pituitary accumulation of LH preparatory for release for ovulation, and an increase in follicular development generally concurrent with pituitary FSH depletion (Saiduddin and Foote, 1964; Wagner and Oxenreider, 1971; Morrow et al., 1966; Sawhney, 1966; Saiduddin et al., 1968; Foote, 1971).

Evidence suggests an increase in basal levels of circulatory LH occurring during the first 6 weeks PP. The occurence of three or more consecutive peaks above prepartum levels has been observed (Edgerton and Hafs, 1971). Prepartum levels of LH have been reported to be low since synthesis by the pituitary is inhibited by high estrogen and P during late pregnancy (Erb et al., 1971; Edgerton and Hafs, 1971).

Edgerton and Hafs (1971) conducted a study on LH

levels in pre- and postpartum dairy cattle. LH averaged 0.5 and 0.04 ng/ml during the prepartum period and remained at that level during the 24 h period after parturition. Less than 5% of the cows showed prepartum and immediate PP levels exceeding 1.0 ng/ml. By 1 week PP the mean level increased to 0.8 ± 0.1 ng/ml, with 20% of the animals exceeding 1.0 ng/ml, and the average at 2 weeks was 1.4 ± 0.2 ng/ml. The average LH remained above 1.0 ng/ml through 6 weeks before dropping to an average of 0.6 ± 0.1 ng/ml at 7 and 8 weeks, a level equivalent to that which was observed in cows 2 to 18 days after successful inseminations. The results indicate that LH release is inhibited during the month preceeding parturition, but this inhibition is removed or reduced during the early portion of the PP period (Casida, 1968; Erb et al., 1971b).

Wagner and Hansel (1969) reported that the considerable activity seen in the ovaries of nursed cows that did not ovulate suggests that adequate FSH is present in such cows. The continued presence of nearly mature follicles and the absence of ovulations indicates a possible deficiency of LH. The thickening and infolding of granulosa cells seen in a few follicles may represent unsuccessful attempts of luteinization in intact follicles. Saiduddin et al. (1968) suggested that ovarian inactivity for an indefinite period after calving may be due to decreased levels of gonadotrophin being released from the

pituitary. However, it is not known whether ovarian sensitivity to gonadotrophin is the same at this time as at other reproductive states (Morrow et al., 1968; Erb et al., 1971a; Callahan et al., 1971). Wagner and Oxenreider (1971) suggested that an increase of adrenal steroids (cortisol and P) may interrupt normal luteal development by affecting pituitary luteotrophin production or release.

Another phenomenon associated with decreased gonadotrophic activity is the occurrence of a short estrous cycle succeeding the first ovulation. Olds et al. (1949) observed that 14/141 cows that came into estrus within 18 days after parturition, had a second estrus in less than 18 days with a mean of 13 days. This was followed by a normal cycle of 18 to 21 days. Erb et al. (1959) and Morrow et al. (1968a) reported the mean interval from first to second ovulation was 17.6 days, which was significantly shorter than 21.3 day-interval from second to third ovulation. It was suggested that this short cycle resulted from failure of the CL to be maintained, due either to a failure of luteotrophic factors or an enhancement of luteolytic factors.

Ovulation without Estrus

One of the most apparent problems caused by the hormone imbalance of anestrus, is the considerable variability in the length of the anestrous period and the oc-

currence of one or more ovulations not accompanied by overt estrus. The incidence of ovulation without estrus ranges from 10 to 70% according to a number of reports (Casida and Wisnicky, 1950; Kidder et al., 1952; Trimberger and Fincher, 1956; Fosgate et al., 1962; Labhsetwar et al., 1963; Menge et al., 1962; Casida, 1968; Saiduddin et al., 1968; Marion and Gier, 1968; Callahan et al., 1971; Wagner and Oxenreider, 1971; Fosgate et al., 1962).

There has been little information speculating on the reasons for the occurrence of "silent" ovulation. It has been mentioned that variably high levels of plasma P and excretory estrogen are observed after parturition. Although these levels are high, they do not appear to inhibit FSH release soon after parturition. Although P levels may inhibit estrus during the first 20 days PP, P levels appear to be sufficiently low to permit follicles to develope. It is not known which factor may block LH release, however, it has been suggested that the pituitary may not be capable of synthesizing LH after parturition, or that LH release at parturition was so intensive that the pituitary had insufficient levels later on to support ovulation and CL maintenance.

Pope et al. (1969) reported that quiet ovulation occurred in the early PP period when plasma P levels were relatively low, and suggested that a period of P priming is necessary before cows will show overt estrus. King

et al. (1976) also suggested that "silent" estrus may be due to deficiencies in the herdsman or management system, rather than problems with the cows.

Interval to First Estrus

It has already been mentioned that the interval to first estrus after parturition is longer than the interval to first ovulation. One to three ovarian cycles may occur before manifestation of estrus. There have been a number of reports on the interval length to first estrus and the data shows considerable variation (Table 1). Variation in the interval is to be expected since there are many factors which affect the length of the interval to first estrus, such as uterine involution, suckling and milking, ovarian pathology, nutritional status, age and environment.

Uterine Involution

Detailed studies of uterine involution have been reported by Hansel (1969) and Gier and Marion (1968), and may be outlined as follows: return of the uterus to a normal location in the pelvic cavity; normal and approximately equal size of the uterine horns; and normal uterine tone and consistency. A number of studies have reported on the length of the interval to uterine involution, and variation is evident (Table 2). This variation may be due to a number of factors such as parity,

TABLE 1. Postpartum Interval to First Ovulation and Estrus

Reference	Breed*	Days to First Estrus	Days to First Ovulation
Casida and Wisnicky (1950)	D	60.4	35.0
Warnick (1955)	B	59.2	--
	B	62.7	--
Foote et al. (1960)	B	65.6	41.7
Fosgate et al. (1962)	D	47.9	40.7
Menge et al. (1962)	D	32.4	18.9
Foote and Hunter (1964)	B	49.0	44.0
Marion and Gier (1968)	D	28.4 ± 36.9	13.1 ± 15.5
Morrow et al. (1968a)	D	--	16.1 ± 16.7
Saiduddin et al. (1968)	B	46.0 ± 19.7	38.0 ± 12.2
Callahan et al. (1971)	D	34.0 ± 3.3	17.0 ± 1.2
Erb et al. (1971a)	D	33.0 ± 3.7	17.3 ± 1.1
Foote (1971)	B	60.0 ± 16.8	49.0 ± 13.2
Wagner and Oxenreider (1971)	D	48.0	39.0 ± 8.7

TABLE 1. (continued)

Reference	Breed*	Days to First Estrus	Days to First Ovulation
Whitmore et al. (1974)	D	39.0	30.0
King et al. (1976)	D	34.5 ± 12.8	19.5
Stevenson and Britt (1977)	D	28.4 ± 2.1	17.6 ± 1.0

* D=Dairy and B=Beef

TABLE 2. Interval from Parturition to Uterine Involution as Determined by Rectal Palpation

Reference	Breed	Parity	Number of Observations	Interval to Involution (days)
Buch et al. (1955)	Fresian	Primiparous	88	42.0 ± 16.7
	Fresian	Pluriparous	164	50.0 ± 16.7
Foote et al. (1960)	Hereford	--	61	44.0 ± 10.3
Fosgate et al. (1962)	Fresian	--	10	28.0 ± 7.1
	Jersey	--	8	27.0 ± 6.2
Menge et al. (1962)	Fresian	--	256	45.0 ± 15.3
Perkins and Kidder (1963)	Hereford	--	118	36.0 ± 14.0
	Angus	--	137	39.0 ± 14.9
Foote et al. (1964)	Hereford	--	20	47.0 ± 11.4
Foote and Saiduddin (1964)	Hereford	--	18	46.0 ± 14.4
Quevedo et al. (1965)	Fresian	Primiparous	24	45.0 ± 7.5
	Fresian	Pluriparous	28	50.3 ± 11.4

* Table taken from "Studies on the Postpartum Cow", Agri. Res. Bul. 270, U. of Wisc.1968

season, and breed or type of cattle. When considering the effect of involution on the PP interval to ovulation and estrus, one must be aware that there is little information indicating the exact effect of the uterus on the ovary and pituitary gland, although there is much speculation

Morrow et al. (1968) suggested that pregnancy and the post-gravid involuting uterus do not exert a unilateral influence on the interval to first PP estrus and ovulation, and the length of the subsequent estrous cycle. However, there seems to be a bilateral carry-over effect early in the PP period which shortens the interval from first to second ovulation. Other workers have suggested a greater influence. Saiduddin et al. (1968a) indicated that in early stages following calving there is a greater tendency for ovulation to occur opposite the uterine horn previously pregnant. However, from these results it was not possible to determine if this unilateral block to follicular development and ovulation was due to a carry-over effect of the gravid horn or the CL of pregnancy, or to the contemporary involuting state of the uterine horn. Morrow et al, (1968b) also reported that previous pregnancy appeared to affect the side of CL formation during the first 20 days PP. The CL occurred on the ovary opposite the post-gravid horn in 62.3% of 256 ovulations observed prior to 21 days PP. This unilateral inhibitory influence may possibly

be due to the CL of pregnancy, blood supply or sensitivity of the ovaries. However, it has been suggested to be more likely due to carry-over effect of the previous pregnancy, manifested by the size of the post-gravid uterine horn and cytological changes of the endometrium (Menge et al., 1962; Marion and Gier, 1968; Wagner and Oxenreider, 1971; Callahan et al., 1971).

Uterine involution affects not only the PP interval to ovulation and estrus, but also affects fertility rates. A number of studies have been carried out to determine the gravity of this effect. Casida (1968) indicated that at first estrus the degree of involution as expressed by uterine horn diameter, is more of a fertility factor if ovulation is on the same side as the previously pregnant horn. However, Perkins and Kidder (1963) indicated that conception rate was not affected by involutionary states of the uterus at the time of breeding. They suggested that the length of the PP interval prior to breeding was of greater importance in gaining satisfactory conception than was the involutionary state of the uterus; a view also held by Foote et al. (1960) and Morrow et al. (1966).

The suckling of a calf has been shown to accelerate uterine involution (Casida, 1968; Lauderdale et al., 1968). Also, it has been previously shown by Lynn et al. (1966) that suckling of a calf lesened the severity of endometritis resulting from experi-

mental innoculation of the uterus with E. coli.

There is also the suggestion that primiparous cows may involute faster than pluriparous cows (Table 2). Marion et al. (1968) reported that the interval from parturition to complete uterine regression was significantly longer in pluriparous cows than in primiparous cows (40.6 vs 34.0 days). The same report also suggested that uterine regression in the fall and winter took longer than in the spring or summer.

Suckling and Milking

It has been apparent, especially when comparing beef cattle to dairy cattle, that the frequency and type of milk removal has a marked effect upon the reproductive performance of the cow. A number of studies have acknowledged that the interval from calving to first estrus is longer in suckled than in milked cows (Wiltbank and Cook, 1958; Saiduddin et al., 1968; Graves et al., 1968; Rieson et al., 1968; Wagner and Oxenreider, 1971). The frequency of milk removal in dairy cows has also been investigated (Casida, 1971), and it was reported that the interval to first estrus was delayed when the cows were milked four times a day, as compared to two times a day. Britt et al. (1975b) studied whether altering the suckling intensity of beef cows would cause them to begin cycling earlier. Neither separating the cows from their calves for 48 h prior to the breeding season, nor separating them from

their calves except for 2 h daily, significantly changed their reproductive performance compared with cows suckled continuously. In all cases in this study, cows were in sight of their separated calves and it is likely that such stimuli as sight or sound might have affected their reproductive performance. Wetteman et al. (1976) also studied suckling intensity and concluded that increasing suckling intensity increased the PP anestrus period.

Another parameter of the effect of suckling is the rate of uterine involution. It has been mentioned previously that suckling of a calf accelerated uterine involution. Rieson et al. (1968) indicated that the rate of uterine involution was more rapid in suckled than in non-suckled cows. This increased rate resulted in the suckled cows being nearly involuted by 30 days PP, while non-suckled cows were not involuted at either 30 days PP or during the first estrous cycle. However, Morrow et al. (1967) found that suckling did not affect uterine involution, although the interval to first PP ovulation and estrus was increased by suckling.

A number of workers have investigated the pituitary gonadotrophic activity with respect to ovarian function in suckled and non-suckled cows. It has been suggested that the difference in reproductive performance between suckled and milked cows might be either the result of a decreased supply of gonadotrophic hormone, or an insensitivity of the ovaries to usual levels of gonado-

trophin. Observers in other species have indicated that suckling decreases ovarian activity and that injection of gonadotrophic hormone in suckled animals results in increased activity. Pituitary hormone levels have been studied in order to evaluate this phenomenon (Wiltbank, 1970). Wagner and Oxenreider (1969) suggested that nursed cows have adequate amounts of FSH but inadequate amounts of LH. Randel et al (1976) reported that suckling depressed serum LH levels, lengthened the PP interval, and modified serum P levels in beef cows. However, Graves et al. (1968) reported a decrease in FSH content of the pituitary and no effect of LH in suckled cows. Saiduddin et al. (1968) also found no effect of suckling on pituitary LH content or LH potency. Wagner and Oxenreider (1971) tend to support these reports. Their data suggests that follicles large enough to mature and ovulate are present 1 or 2 weeks PP in lactating cows. However, Casida (1971) stated that no effect of suckling has been shown on FSH and LH, although pituitary prolactin levels were decreased by suckling. Most other workers also have observed that pituitary prolactin levels in suckled cows are lower than in non-suckled cows (Riesen et al., 1968; Casida, 1968, 1971).

Other hormonal influences have been suggested by Wagner and Hansel (1969) who reported that suckled cows had lower adrenal contents of P and cortisol than did milked cows. This could occur as a result of increased

secretion of decreased synthesis of adrenal steroids in the suckled cow.

Ovarian Pathology

One factor that cannot be overlooked is the incidence of anestrus due to some ovarian pathological condition. There are a number of pathological conditions which may occur but several reports suggest that the most common condition is cystic ovarian degeneration (cystic follicles) (Casida and Chapman, 1951; Wiltbank et al., 1953; Trimberger and Fincher, 1956; Menge et al., 1962; Morrow et al., 1966; King et al., 1976). Marion and Gier (1968) in a study of otherwise clinically normal cows, reported that follicular cysts were the most important pathological factor correlated with the lengthening of intervals to first ovulation, estrus and conception. Although the occurrence of cystic follicles is significant, their incidence is variable; ranging from 5 to almost 15% according to reports cited above.

One probable cause of cystic follicles and cystic CL has been associated with stress. Marion and Gier (1968) suggested that seasonal stress and affects of production are the major reasons for the delay in ovarian cyclic activity. Stress caused from abnormal parturition is also a factor in increasing the incidence of cystic follicles (Morrow et al., 1966).

Casida (1971) suggests that the reason for the high incidence of cysts, is that in some cows there is an abnormal rebound of anterior pituitary function from the prior inhibition caused by the high levels of sex steroids during late pregnancy. Thus, the most likely time for follicular cysts would be in the early (0-30day) PP period, rather than in the later (31-60 day) PP period (Morrow et al., 1966; Wiltbank et al., 1958). The occurance of cystic follicles has been associated with nymphomania, however, Morrow et al. (1966) has reported that 82% of the affected cows were in anestrus rather than showing nymphomania, and that spontaneous recoveries occurred in many affected cattle. Parity has been cited as a factor in increased incidence of follicular cysts, as the greatest frequency occurs from 4 to 6 years of age (Wiltbank et al., 1958; Roberts, 1955). One other factor that has been reported as significant in a study by Morrow et al, (1962), is that the incidence of cystic ovaries is affected by sire lines.

Nutritional Status

A low level of energy before or after calving lengthens the interval from parturition to estrus (Wiltbank et al., 1962; Dunn et al., 1969). It has been shown by Wiltbank et al. (1962) that if a high proportion of young cows are to show estrus by 60 to 80 days PP, they must receive adequate levels of energy. In later studies it was shown that the lowest conception rates occurred in cows that were in

good condition at parturition but were losing weight after calving. Cows which were thin at calving but making rapid gains, had the highest conception rates (Wiltbank, 1970). Wagner and Oxenreider (1971) reported that PP follicular activity was linearly related to the level of energy provided. However, Whitmore et al. (1974) observed that a very high nutritional plane will cause a higher incidence of silent ovulations. McClure (1968b) reported that insulin-induced hypoglycemia resulted in impaired fertility in dairy cows. He suggested that poor nutrition may cause hypoglycemia, and this affects hypothalamic function.

Age and Environmental Effects

A number of reports have shown that age affects reproductive performance, and that young cows have a longer interval to first estrus than older cows (Wiltbank, 1970; Hammond and Sanders, 1923). Herman and Edmondson (1950) also reported that PP intervals were longer in primiparous cows (75 days), was shortest in middle-aged cows (50-60 days), and then increased in cows over 7 years of age (60-90 days). However, Casida and Wisnicky (1950) have observed the opposite effect to that seen by Herman and Edmondson (1950) and others. Involution of the uterus has also been shown to be shorter in primiparous cows (20 days) as compared tp pluriparous cows (20-25 days) (Rasbech 1950; Buch et al., 1955).

Season has been reported to have an effect on the length of the PP interval. Buch et al. (1955) reported that cows which calved in the winter had the longest interval, while the shortest interval occurred in the summer calving group. Spring and fall groups showed a medium length PP interval (Marion et al., 1968).

Another reported effect on the PP interval is the observed interaction of sire line with system of mating. This interaction had a significant effect on the interval to first estrus (Menge et al., 1962). It was also observed that inbred cows involuted earlier than outbred cows.

Finally, it must be acknowledged that there is always considerable variation amoung cows in sexual activity. King et al. (1976) observed that the nature and intensity of sexual activity demonstrated by an indivual cow was significantly influenced by the presence of one or more additional cows that were in or near estrus.

Effect of Prostaglandins on the Postpartum Cow

Prostaglandins lead a nearly ubiquitous existance in mammalian tissue. To this date, more than 18 different types of natural prostaglandin (PG) have been isolated. The potential use of PG in human and veterinary medicine is enormous. Reproductive implications include: uterine motility; fallopian tube motility; sperm transport; menstruation and labour; and particularly, luteolysis.

All PG are unsaturated hydroxy fatty acids characterized by a five-membered ring on a 20-carbon skeleton indicative of the 20-carbon parent substance known as prostanoic acid.

As well as natural PG, analogues exist which selectively affect only the target tissue, and thereby reduce the chance of side affects after administration. ICI-80996 is one such analogue which has been shown to be consistantly effective as a luteolytic agent in cattle (Cooper et al., 1973).

Effect on Hormone Patterns in Cycling Animals

It is generally accepted that the CL is the major component in the natural control of the estrous cycle in cattle. While the CL continues to function by secreting P, there is no ovulatory surge of LH. When natural luteolysis occurs the inhibition of the LH surge is ceased, ovulation occurs and a new estrous cycle begins. Researchers have realized that if luteolysis could be artificially induced, then new possibilities in livestock management would arise from estrous synchronization. Consequently, in the last decade there has been a large amount of research dedicated to the determination of the exact mechanism of luteolysis.

The concept of uterine control of luteolysis has been apparent since Loeb (1923) made the observation that

total hysterectomy of the guinea pig during the luteal phase of the estrous cycle prolonged the life-span of the CL. This suggested that the uterus may provide a substance which is capable of causing luteolysis. In 1956, Wiltbank and Casida confirmed that hysterectomy prolonged the life-span of the CL in cattle and sheep. Babcock (1966) first suggested that a PG might be the agent from the uterus that causes the luteolytic affect (Pharriss and Wyngarten, 1969; Pharriss, 1970).

However, researchers have not yet determined the exact mechanism of transfer of PG from the uterus to the ovary, or the exact mechanism of PG-induced luteolysis. Generally, the transfer seems to be through a vascular connection between the uterine vein and the ovarian artery. Ginther and Bisgard (1972) have reported that the main uterine vein is the major component of the direct pathway between the uterus and the ovary in sheep. Whether the luteolytic effect of the uterus is local or systemic, differs according to the vascular patterns in the various species (Del Campo and Ginther, 1972; Ginther et al., 1972).

A number of different theories have been suggested for the effect of PG on the ovary, yet there is no clear cut answer to the mechanism of luteolysis. This review will be confined only to the response of the cow to exogenous PG.

Effect on Corpus Luteum and Progesterone Levels

The response of the ovary to PG depends upon a number of factors such as dosage level, site of administration, time of administration with respect to day PP or day post-estrus, and the type of cow. It is accepted that the only way exogenous luteolytic substances can be successful is that a functional CL be present. In other words, the cow must be cycling before luteolysis can be artificially induced and it is imperative that if a management program of estrous synchronization is to be successful, all cattle must be cycling at the time of PG injection.

The general response of the cow to PG is immediate luteolysis of the functional CL. This response is apparent when the blood P level and CL diameter is monitored (Louis et al., 1972; Chamley et al., 1972; Henricks et al., 1971; Louis, Hafs and Sequin, 1973; Stelflug et al., 1973; Henricks et al., 1974; Welch et al., 1975; Turman et al., 1975; Dobson et al., 1975; Hafs, 1976).

To determine the minimun effective dosage, Stelflug et al. (1973) administered 15, 30 and 60 mg $PGF_{2\alpha}$ during diestrus by intramuscular (im) injection. Blood P dropped from 4.4 ng/ml before treatment to 2.1, 1.5 and 1.1 ng/ml at 6, 12 and 18 h after injection and then plateaued near 0.5 ng/ml from 48 to 72 h. Louis et al. (1974b) observed that response was similar regardless of the day

of diestrus that $PGF_{2\alpha}$ was administered.

Liehr et al. (1972) found that the site of deposition of $PGF_{2\alpha}$ affected the luteal response on day 9 of the estrous cycle. The P levels dropped to non-detectable levels within 2 days after ipsilateral uterine infusion, but remained relatively high after contralateral treatment with 6 mg $PGF_{2\alpha}$.

Cooper (1974) and Henricks et al. (1974) compared natural $PGF_{2\alpha}$ and the analogue ICI 80996 in inducing luteolysis. The predominant physiological effect was to induce both functional and morphological regression of the CL. The subsequent response of the ovary, with follicular development and ovulation, was similar both morphologically and endocrinologically to the response following spontaneous luteal regression. It was also suggested that the induced ovulation seemed to be normal, in that it was followed by normal luteal development.

Hixon and Hansel (1974) performed an intensive study on the response of the ovary to $PGF_{2\alpha}$. After $PGF_{2\alpha}$ treatment certain fluctuations occurred in P concentration which may be explained by recognized or postulated actions of $PGF_{2\alpha}$ as follows: (a) an initial increase in the concentration of P was observed which may be the result of the steroidogenic action of $PGF_{2\alpha}$ which has been observed in vitro (Speroff and Ramwell, 1970; Hansel et al., 1972); (b) the initial increase of P concentration may result from a proposed vasoconstrictive action

(Thorburn and Hales 1972); (c) the subsequent decline in P concentration may reflect a second luteolytic action of $PGF_{2\alpha}$, or the effect of another luteolytic factor induced by $PGF_{2\alpha}$. Hixon and Hansel's (1974) observations indicate that estrogen may be this second factor involved in $PGF_{2\alpha}$-induced luteolysis. Estrogens began to increase before the P concentration finally began to decline and they suggested that there is a close relationship between P and estrogen in the response to $PGF_{2\alpha}$.

Effect on Estrogen and Follicular Development

The changes in estrogen level after administration of PG seems to be an indirect response. Generally, estrogen levels show no change until the dramatic decrease in P concentration has occurred. Once luteolysis has begun, rapid follicular growth and secretion of estradiol-17β ensues with a return to estrus within 2 to 4 days.

A large number of workers have established the pattern of estradiol secretion after $PGF_{2\alpha}$ injection. Basically, blood estradiol nearly doubles within 24 h and peaks at 48 h, then declines gradually until estrus (Tervit et al., 1973; Louis et al., 1972; Henricks et al., 1974; Henricks, 1974; Thatcher and Chenault, 1976; Hafs, 1976).

It has also been generally established that estra-

diol and P secretion pattern after estrus is the same as the pattern in untreated animals during the following natural estrus (Dobson et al., 1975; Louis et al., 1974; Thatcher and Chenault, 1976). Thatcher and Chenault (1976) have also carried out a least squares regression analysis to show the general relation of P, estrogen and LH to each other from the time of $PGF_{2\alpha}$ administration. They have synchronized their data in order to relate the secretion patterns to the peak of LH. Again, these profiles are similar to those collected in their laboratory from animals undergoing natural luteolysis.

Effect on Luteinizing Hormone

From Figure 2, one can see the normal LH profile relative to P and estrogen. Once P has fallen to a certain level and estrogen has increased to a certain level, a surge of LH is initiated from the pituitary to cause ovulation. This pre-ovulatory surge of LH occurs coincidental with the onset of estrus and prior to ovulation (Louis et al., 1972).

Louis et al. (1974b) administered an intrauterine luteolytic dosage of $PGF_{2\alpha}$ to dairy cows and observed the hormone pattern. Serum LH averaged 1.3 $\pm$ 0.1 ng/ml from $PGF_{2\alpha}$ administration until approximately 14 h before the peak of the ovulatory surge of LH. LH rose slowly from 12 to 4 h before the peak of the ovulatory surge, then rapidly to a peak of 10.4 $\pm$ 1.7 ng/ml. On the average,

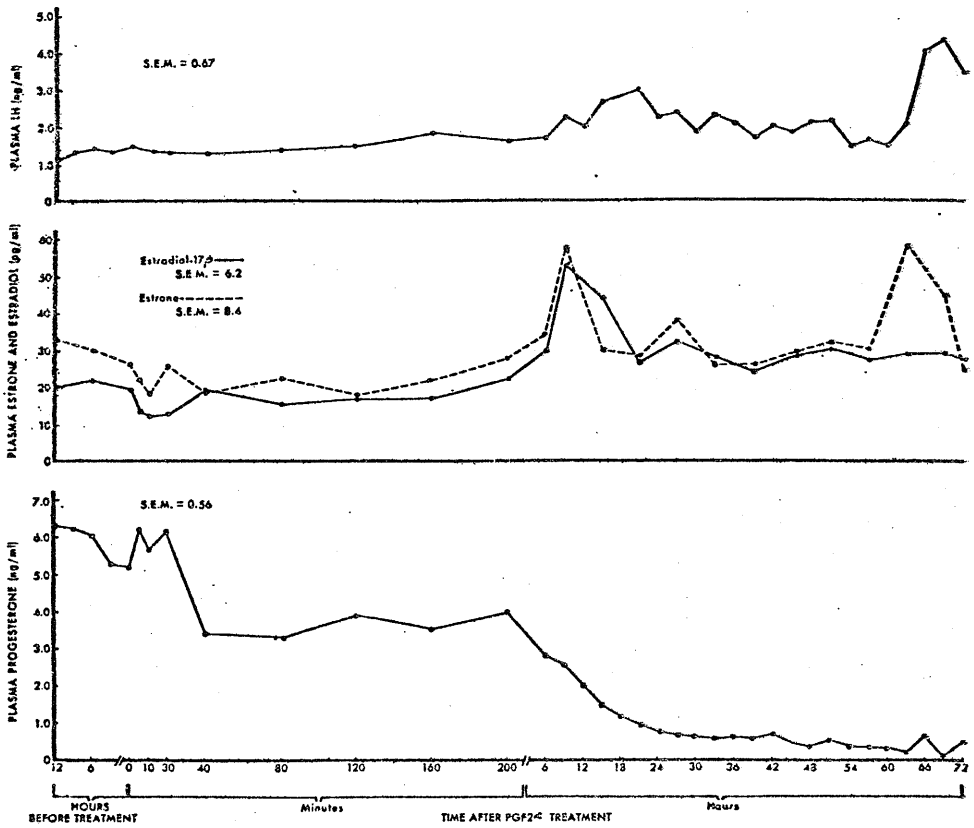

FIG. 2 Plasma concentration of progesterone, estrone, estradiol-17β, and LH before and after intrauterine injection of 6 mg $PGF_{2\alpha}$. Bottom graph: Mean plasma concentration of progesterone. Middle graph: Mean plasma concentration of estrone and estradiol-17β. Top graph: Mean plasma LH concentration expressed as ng NIH-LH-B7/ml.
Taken from Hixon and Hansel (1974).

the surge of LH persisted for at least 8 h, similar to the untreated cows (Schams and Karg, 1969; Henricks et al., 1970; Swanson and Hafs, 1971). LH then returned to basal levels and averaged 1.1 ± 0.1 ng/ml during the subsequent diestrus.

Hixon and Hansel (1974) observed that the concentration of LH did not change significantly until the increase of estrogens observed at 9 h post-treatment. However, a non-significant increase in the mean LH concentration (from pre-treatment level of 1.55 ng/ml to 2.33 ng/ml) did not occur at 9 h. Plasma LH levels in the $PGF_{2\alpha}$ treated cows were not significantly different than plasma LH in the control cows. A surprising observation was the presence of recent ovulations in several cows in the absence of or very shortly after the characteristic pre-ovulatory surges of LH.

Dobson et al. (1975) also observed that in all animals tested, there was a small increase in LH 6 h after $PGF_{2\alpha}$ treatment. This was similar to the increase seen by Louis et al. (1974b), and was thought to be due to the rapid withdrawl of P, rather than to the direct action of the PG on the hypothalamic-pituitary axis. Louis et al. (1975) tested and concluded this hypothesis to be correct. Hafs (1976) reiterated this concept and affirmed that the increase in LH within 12 h after treatment was not caused by blood estradiol.

The LH peak usually occurs between 69 and 78 h

after $PGF_{2\alpha}$ administration and generally occurs about 3 to 4 h prior to the onset of the induced estrus (Louis et al., 1972, 1974a,b; Hixon and Hansel, 1974; Chenault et al., 1974).

Other Hormonal Responses

As yet, there is little information on the levels of other hormones such as prolactin (PRL), growth hormone (GH) and glucocorticoids after $PGF_{2\alpha}$ treatment. However, it has been postulated that PG may be mediators in the release of several hypothalamic hormones and/or intermediates in the intracellular mechanism of action of several hormones (Louis et al., 1974b).

Louis et al. (1974b) investigated the levels of PRL, GH and glucocorticoids after $PGF_{2\alpha}$ treatment. Blood plasma PRL, GH and glucocorticoids in heifers increased several-fold within 5 to 15 minutes after im injections of 15, 30 and 60 mg $PGF_{2\alpha}$ or a single iv injection of 5 mg $PGF_{2\alpha}$. Constant iv infusion of $PGF_{2\alpha}$ at the rate of 0.5 mg/min for 30 minutes produced greater plasma concentrations of PRL, GH and glucocorticoids than those found after im injections. Plasma glucose increased from 59 to 67% above pretreatment values between 30 and 60 minutes after iv $PGF_{2\alpha}$. Plasma insulin increased more than twofold over basal levels at 45 minutes after $PGF_{2\alpha}$ administration.

Hafs (1976) also reported on these hormones. The

release of glucocorticoids and GH were proportional to the dosage of $PGF_{2\alpha}$, and disappeared within 4 h after treatment. He suggested that the increase in these hormones probably represented the action of $PGF_{2\alpha}$ on the pituitary or hypothalamus rather than directly on the adrenal gland.

Other Physiological Responses

Little work has been done on the other physiological responses following $PGF_{2\alpha}$ treatment. Thatcher and Chenault (1976) however, reported in a preliminary investigation that a luteolytic dosage of $PGF_{2\alpha}$ (im) caused no major alterations in blood pressure, heart rate, and uterine or aortic blood temperatures. However, the same dosage (33.5 mg) given as an iv jugular infusion over a 2 minute period, caused major alterations in circulatory homeostasis and body temperature. This change in thermal regulation resulted in an ultimate heat loss from the animal, and it was concluded that the $PGF_{2\alpha}$ effects on uterine blood flow and contractility warranted further investigation.

Interval to Estrus After Prostaglandin Treatment

Variation due to Route of Administration

Although there has been a considerable amount of research pertaining to the interval to estrus, LH surge and ovulation, one must relate this information to dosage level and site of deposition (Table 3).

The main routes of $PGF_{2\alpha}$ administration have been intrauterine, intravaginal, intramuscular or subcutaneous. According to the studies carried out, there seems to be no difference in the interval lengths after infusion of $PGF_{2\alpha}$ into the uterine horn ipsilateral or contralateral to the CL. However, when $PGF_{2\alpha}$ is infused into the vagina rather than the uterus, the intervals to estrus, LH surge and ovulation seem to be delayed 1 or 2 days. Perhaps intravaginal $PGF_{2\alpha}$ is not absorbed as rapidly or as completely as uterine $PGF_{2\alpha}$ (Louis et al., 1972b). Also, intravaginal $PGF_{2\alpha}$ seems to be absorbed 1 to 2 days slower when compared to intramuscular $PGF_{2\alpha}$ (Louis et al., 1973).

Intramuscular administration has received more attention in recent research. It is evident that it is just as effective as intrauterine $PGF_{2\alpha}$. Although the dosage is considerably larger, the procedure for a single injection of im $PGF_{2\alpha}$ is much less cumbersome than intrauterine infusion. Studies in determining the most effective dosage have revealed that as dosage increases, the interval length decreases. Doses of 60 mg $PGF_{2\alpha}$ seem to initiate estrus sooner than doses of 30 mg or less (Table 3). Low doses of 20 mg $PGF_{2\alpha}$ (or 2x15 mg) show

TABLE 3. Effect of Route of Administration of PG on Interval to Estrus, LH Surge and Ovulation.

Reference	PG Dosage and Route of Administration	Interval to Estrus (h)	Interval to LH Surge (h)	Interval to Ovulation (h)
Louis et al. (1972a)	5mg ipsilat. infus. on:			
	1) day 11	68 ± 15	69 ± 15	94 ± 14
	2) day 15	73 ± 7	69 ± 15	99 ± 4
Louis et al. (1972b)	5mg contra. infus. on day 11 or 15	75 ± 9	78 ± 6	99 ± 12
	30mg vaginal infus. on day 11	117 ± 18	128 ± 19	138 ± 20
Stelflug et al. (1973)	30mg im on day 11	55 ± 2	67 ± 1	89 ± 4
	2x15mg im on day 11	60 ± 4	65 ± 3	90 ± 4
	60mg im on day 11	50 ± 3	57 ± 3	78 ± 3
Louis et al. (1973)	30mg im in diestrus	54 ± 3	64 ± 4	104 ± 6
	30mg im in metestrus		Not Luteolytic	

TABLE 3. (continued)

Reference	PG Dosage and Route of Administration	Interval to Estrus (h)	Interval to LH Surge (h)	Interval to Ovulation (h)
Louis et al. (1973)	30mg intravag. in diestrus	117 ±18	128 ± 19	138 ± 20
Louis et al. (1974)	5mg ipsilat. infus. on:			
	1) day 7	71 ± 7	69 ± 7	86 ± 11
	2) day 11	68 ± 15	68 ± 15	94 ± 13
	3) day 15	70 ± 7	72 ± 6	97 ± 5
	5mg contra. deposit on day 11	76 ± 10	77 ± 7	100 ± 13
Ellicott et al. (1974)	2x30mg im on:			
	1) days 1-4	Not Luteolytic		
	2) days 6-7	47 ± 1.9	--	--
	3) days 8-9	79.6 ± 12.5	--	--
	4) days 10-15	74 ± 3.4	--	--

TABLE 3. (continued)

Reference	PG Dosage and Route of Administration	Interval to Estrus (h)	Interval to LH Surge (h)	Interval to Ovulation (h)
Chenault et al. (1974)	30mg im or 10mg uterine deposit in diestrus	74.9 ± 21	78.8 ± 21	99.5 ± 19
Roche (1974)	30mg im in diestrus	59 ± 3.3	--	--
	20mg im in diestrus	64 ± 8.9	--	--
Stelflug et al. (1975a)	30mg im in diestrus	56 ± 2	65 ± 5	90 ± 5
	2x15mg im in diestrus	66 ± 7	67 ± 6	92 ± 8
	60mg im in diestrus	54 ± 4	61 ± 5	79 ± 5
Welch et al. (1975)	1mg uterine infus.	65 ± 2	67 ± 3	--
	1mg uterine infus. with Estradiol Benzoate im 48 h post PG	64 ± 1	66 ± 1	--
	2mg uterine infus.	65 ± 4	67 ± 4	--

TABLE 3. (continued)

Reference	PG Dosage and Route of Administration	Interval to Estrus (h)	Interval to LH Surge (h)	Interval to Ovulation (h)
Welch et al. (1975)	2mg uterine infus. with Estradiol Benzoate im 48 h post-PG	65 ± 1	66 ± 1	--

a slower luteolytic effect and more variation in response. Therefore the ideal dosage for estrous synchronization is approximately 30 mg $PGF_{2\alpha}$ (im). This dosage causes luteolysis quickly and effectively for adequate estrous synchronization.

Milking and Suckling

The fact that suckled, non-suckled and milked cows show variation in their PP anestrus period does not directly relate to the effect of $PGF_{2\alpha}$. However, it is now definitely apparent that $PGF_{2\alpha}$ does not induce estrus in anestrus cows. Therefore, the prolonged anestrus in suckled cows in comparison to milked cows may rest the efficacy of ovulation control with $PGF_{2\alpha}$ in beef cows (Casida, 1968; Hafs, 1976).

$PGF_{2\alpha}$ and EstrousSynchronization

Double Injection System

The main problem in the effectiveness of $PGF_{2\alpha}$ lies in the certainty the $PGF_{2\alpha}$ can only be luteolytic if a functional CL is present at the time of injection. As previously mentioned, a functional CL exists between days 5 and 17 of the estrous cycle. Therefore a single injection of $PGF_{2\alpha}$ will not cause luteolysis in every individual in any random group of cycling cows. Consequently, an injection scheme has been devised to cause

luteolysis in all cows in synchrony. This scheme consists of two separate injections of $PGF_{2\alpha}$ approximately 10 to 12 days apart. Cows that did not respond to the first injection will have a functional CL 12 days later. Therefore, all cows treated should be effectively synchronized after the second injection. A number of experiments have been completed to demonstrate the effectiveness of the double injection system (Table 4).

A few problems have arisen from the use of the double injection method. One problem was evident when Britt et al. (1975a) conducted a study which indicated that low fertility rates followed a timed insemination at 80 h after the last injection of $PGF_{2\alpha}$. It was suggested that the 10 day interval between the two injections was not sufficiently long enough to allow a high percentage of cows to ovulate and establish a functional CL.

Seguin et al. (1975) encountered the problem of PP anestrus. They reported that estrous control was very low due to the fact that half the herd was still in PP anestrus at the time of the breeding trial. They attributed the anestrus to two major factors. Nutrition was the most apparent factor, since neither cows fed the all hay diet, nor the cows fed the hay plus corn diet gained any weight during the PP anestrous period. The second major factor for anestrus was reported to be the interval length from calving to $PGF_{2\alpha}$ treatment. The influence

TABLE 4. Effect of $PGF_{2\alpha}$ Double Injection System on Fertility

Reference	Injection Scheme*	Cattle Type	Results
Cooper (1974)	500ug ICI80996 11days apart	Fresian heifers	91% (159) in estrus between 48 and 72 h
King and Robertson (1974)	$PGF_{2\alpha}$ 10 days apart	Fresian heifers	83% (25) in estrus within 2-4 days
Cooper and Furr (1974)	$PGF_{2\alpha}$ 11 days apart	Fresian heifers	Most in estrus between 48 and 72 h
Sequin et al. (1975)	$PGF_{2\alpha}$ 11 days apart	Beef cows	Estrus controled in 33%
Britt et al. (1975)	$PGF_{2\alpha}$ 10 days apart	Beef cows	42% conceived to timed AI at 80 h
Dobson et al. (1975)	750ug ICI79939 10 days apart	Fresian heifers	100% (6) in estrus between 48 and 55 h
Ellicott et al. (1975)	$PGF_{2\alpha}$ 10 days apart	Angus and Hereford heifers	33% pregnant to timed AI at 60 h
Hafs et al. (1975)	0.5mg ICI80996 intrauterine or $PGF_{2\alpha}$ 12 days apart	960 heifers, 392 suckled cows	57% - 58% fertility to timed AI at 70 & 80 h, was equal to controls

TABLE 4. (continued)

Reference	Injection Scheme*	Cattle Type	Results
Hearnshaw (1976)	400ug ICI80996 12 days apart	Hereford cross heifers	46% pregnant to timed AI at 72 & 96 h

* Intramuscular injection unless otherwise stated.

of this factor is increased by inadequate nutrition. Intervals to treatment in the reported experiment were too short, even if nutrition were optimal. It is suggested that 70 days is the required interval after calving in order that 90% of the beef cows may cycle (Sequin et al., 1975).

Unfortunately, problems exist even after estrus is synchronized. The major problem is that of estrous detection. The likely solution to this problem, is the use of a timed insemination after estrous synchronization.

Timed Insemination without Regard to Estrus

This concept is simply to inseminate the cow at a pre-set time following estrous synchronization. The pre-set time(s) should ideally, coincide with ovulation. However, there is much variation in recent information on the length of the interval from last PG treatment to ovulation. Therefore, it is difficult to determine the optimum time for artificial insemination (AI) after estrous synchronization. Fertility rates have given a good indication of the effectiveness of different regimes of PG use and AI. Again, because of the variation between studies, it is difficult to establish the most ideal system. Recently, there have been a number of investigations on the use of a double or single AI after estrous synchronization (Table 5). Double AI seems to be the most ideal system since it covers the time of ovulation

TABLE 5. Effect of Timed Insemination on Fertility

Reference	Insemination Scheme	Treatment	Cattle Type	Fertility (%)	
				Control	Treated
Lauderdale et al. (1973)	Double at 72 & 90 h	30mg $PGF_{2\alpha}$ im during diestrus	All types	58	58
	Single at detected estrus	30mg $PGF_{2\alpha}$ im during diestrus	All types	58	57
Lauderdale et al. (1974)	Single at detected estrus	30mg $PGF_{2\alpha}$ im during diestrus	All types	53.3	52.2
	Double at 72 & 90 h	30mg $PGF_{2\alpha}$ im during diestrus	All types	53.3	55.8
Cooper (1974)	Double at 72 & 96 h	ICI80996	Heifers	55	55
Sequin et al. (1975)	Single at 74 or at 86 h	Double inj. 30mg $PGF_{2\alpha}$ 11 days apart	Beef cows and heifers	77	82
Britt et al. (1975)	Single at 80 h	Double inj. 30mg $PGF_{2\alpha}$ 10 days apart	Suckling beef cows	35	42

TABLE 5. (continued)

Reference	Insemination Scheme	Treatment	Cattle Type	Fertility (%)	
				Control	Treated
Ellicott et al. (1975)	Single at 60 h	Double inj. 30mg $PGF_{2\alpha}$ 10 days apart	Angus or Hereford cows	62.5	33
	Single at 60 h	Double inj. 30mg $PGF_{2\alpha}$ 10 days, & 200ug GnRH at 12 h post-AI	Angus or Hereford cows	62.5	43.8
Turman et al. (1975)	Double at 64 & 88 h	30mg $PGF_{2\alpha}$ im during diestrus	Range cows	92.3	76.9
	Single at detected estrus	30mg $PGF_{2\alpha}$ im during diestrus	Range cows	92.3	84.6
Hafs et al. (1975)	Single at 80 h	Double 0.5mg ICI-80996 at 10-12 days apart	All types	67	57
	Double at 70 & 88 h	Double 0.5mg ICI-80996 at 10-12 days apart	All types	67	58

TABLE 5. (continued)

Reference	Insemination Scheme	Treatment	Cattle Type	Fertility (%) Control	Treated
Hearnshaw (1976)	Double at 72 & 96 h	Double 400ug ICI-80996 (subcut.) at 12 days apart or single dose if cow reacts	Hereford cross heifers	53 for single 57 for double	
Roche (1977)	Double at 72 & 96 h	Double inj. Estrumate, 11 days apart	Fresian	45	69
	Single at detected estrus	Double inj. Estrumate, 11 days apart	Fresian	--	47
Schultz (1977)	1) control	Double inj. Cloprostenol, 11 days apart	Beef cows	40.6	--
	2) double at 72 & 96 h			--	39.4
	3) single at 72 h			--	33.1
	4) single at detected estrus			--	40.1

TABLE 5. (continued)

Reference	Insemination Scheme	Treatment	Cattle Type	Fertility (%) Control	Fertility (%) Treated
Moody and Lauderdale (1977)	1) control	Double inj. im 25mg $PGF_{2\alpha}$ at 11 days apart	All types	41	--
	2) Single at 80 h			--	43
	3) single at detected estrus			--	47

more completely. However, if timed correctly, two inseminations may not be necessary. Investigators have demonstrated that a single AI at approximately 80 h post-$PGF_{2\alpha}$ treatment, is comparable to a double AI at 72 and 96 h post-$PGF_{2\alpha}$ treatment (Seguin et al., 1975; Hafs et al., 1975). Again it is clear that a large amount of variation exists between investigations (Table 5). Although these differences may not be significant, it seems that fertility from AI following detected estrus is somewhat higher, if not comparable to a timed AI regime (Ellicott et al., 1975; Turman et al., 1975; Hafs et al., 1975; Hearnshaw, 1976).

Without further investigation with larger field trials, one cannot be sure which AI scheme is the best. It is clear however, if implemented, that a timed AI scheme will be advantageous to the cattleman. It will eliminate the need for estrous detection after $PGF_{2\alpha}$ treatment in order to breed successfully.

MATERIALS AND METHODS

Introduction

The study was completed over the course of two breeding seasons. The first year of the study was concerned with the primary purpose of determining the progesterone (P) profile during the postpartum (PP) anestrous period, and the efficacy of $PGF_{2\alpha}$ as an estrous synchronization agent. The second year of the study was concerned with the same purpose, but in addition, the fertility to a timed insemination after estrous synchronization was determined.

The study took place at the beef facility of the Glenlea Research Station, University of Manitoba. The protocol of the study is a modification of an experiment also conducted by Dr. J. G. Manns, School of Veterinary Medicine, Saskatoon, Saskatchewan, in collaboration with ICI United States Inc., Wilmington, Delaware.

Year One

Fifteen suckling Angus X Charolais pluriparous cows ranging from 5 to 6 years of age, were put on test in order of parturition. All cows experienced a normal parturition and were suckled by healthy calves. To fa-

cilitate blood collection, all animals remained in dry-lot (with a maximum of four cows per pen), until after treatment. All animals were allowed good quality corn silage, hay and water, ad libitum. Cows and calves were weighed at parturition and every 3 weeks thereafter until 9 weeks PP. Beginning at 7 ± 3 days PP, jugular blood samples were obtained by venepuncture every Monday and Thursday at approximately 13:30 hours. Additional blood samples were obtained 24 h after each $PGF_{2\alpha}$ treatment to determine the level of P in response to treatment. Sampling was terminated following treatment and at the time the cow and calf were removed to pasture.

In order to determine ovarian activity, rectal palpations were carried out every week, commencing at approximately 30 days PP. Treatment was given to any cow that exhibited a corpus luteum (CL) on palpation. Treatment consisted of intramuscular (im) injection of $PGF_{2\alpha}$ - Tham salt dissolved in distilled water. The compound was stored in a powdered condition and prepared for use on the morning of the intended treatment. Each injection of 2 ml distilled water contained 20 mg $PGF_{2\alpha}$ equivalent and each cow received two injections 12 days apart.

After the second injection a K-Mar estrous indicator was applied to the cow and she and her calf were transported to pasture. While on pasture, the cows were observed twice daily for signs of estrus and/or mating, with the aid of the K-Mar estrous detectors. All bree-

ding was accomplished naturally by a Devon bull of proven fertility.

Once blood samples were obtained, they were placed in an ice-packed container and allowed to clot. They were then transported to the laboratory and stored at 4 to 5°C for approximately 20 h. On the morning after the samples were obtained, the serum was extracted after centrifugation (20 min at 10,000 cpm), and was then stored at appoximately 20°C until assayed.

Year Two

The primary purpose of the experiment in Year 2 remained the same as in Year 1. However, an additional study was carried out to determine the effect of timed artificial insemination (AI), after estrous synchronization, on fertility.

Thirty suckling Angus X Charolais pluriparous cows ranging from 6 to 7 years of age, were divided into two groups as they calved. Group I cows were to receive AI at 72 and 96 h after the last PG treatment. Group II cows were removed to pasture immediately after the last PG treatment and bred naturally as in Year 1. Both groups were subjected to the same environmental conditions throughout the summer. All animals received the same housing, nutrition, handling, blood sampling, body weight measurement and rectal palpation as in Year 1.

PG was administered as the $PGF_{2\alpha}$ analogue, ICI-80996. Treatment of each cow consisted of two im injections of a 2 ml solution containing 0.5 mg ICI-80996 with injections being 11 days apart. The compound was packaged in the solution form for administration, and provided through the courtesy of ICI United States Inc.

After treatment, cows in group II were fitted with K-Mar estrous detectors and removed to pasture. Once in pasture, the cows were observed for signs of estrus and/or mating once daily and were bred to the same Devon bull as used in Year 1.

Cows in Group I remained in drylot until treatment and AI were completed. At 72 and 96 h after the last PG treatment they were artificially inseminated with semen from a Devon bull (Champson Royal II) of proven fertility. After breeding, these cows were retained in drylot for 10 days to prevent double breeding. After this time, K-Mar estrous indicators were applied to the cows and they were transported to the same pasture as the Group II cows. Any cows in Group I which did not conceive to AI were then bred to the Devon bull in pasture.

Progesterone Analysis

The assay for P was carried out in the Department of Veterinary and Physiological Science, College of Veterinary Medicine, University of Saskatchewan.

Serum P was assayed by a standard radioimmunological procedure (Abraham et al., 1971a, b, c; Tulchinski and Abraham, 1971; Abraham et al., 1972) as modified by Dr. J. G. Manns, using antibody purchased from Dr. G. Abraham, Harbor General Hospital, Torrance, California. The specificity of the antiserum has been published (Abraham et al., 1971) and was used at a dilution of 1:20,000.

Recovery was 85.6 ± 2.0 % and all samples were corrected for procedural losses. Standards were assayed in triplicate at the beginning and end of each assay; unknowns were assayed in duplicate. Phosphate buffered saline (PBS), (Manns et al., 1975) was used for preparation of antibody, progesterone solutions and charcoal suspension. The intra- and inter-assay coefficients of variation were 7.2 % (n=10) and 17.8 % (n=7) for samples with P concentrations of 1.95 and 2.90 ng/ml, respectively.

Statistical Procedures

Procedures used for interpretation of data were: (a) computation of sample mean and standard error of the mean, and (b) matched pair group analysis for comparisons between years, as outlined by Schefler (1969) and Snedecor and Cochran (1973).

RESULTS

Progesterone Profiles

Results of the progesterone (P) radioimmunoassays were individually plotted. Two representative profiles are shown in Figures 3 and 4. From inspection of the P-profile an estimation was made for the date of the first functional corpus luteum (CL).

It is understood that large prolonged surges of P concentration can only be the product of a fully functional CL. Although a large P surge cannot pinpoint the time of first ovulation, one can estimate that ovulation probably occured 4 to 5 days prior to that rise. Therefore, the time of the first PP ovulation was estimated to have occured by subtracting 4 days from the time of the first substantial rise in P level. The time of the first substantial P rise was 53.3 $\pm$ 2.1 and 48.4 $\pm$ 3.3 days for Year 1 and Year 2, respectively (individual cow data shown in Appendix Table 1A). From this it can be estimated that first ovulation occured 49.3 $\pm$ 2.1 and 44.4 $\pm$ 3.3 days PP for Year 1 and Year 2, respectively.

A summary of the P data for Year 1 and Year 2 is presented in Table 6. This summary shows considerable

TABLE 6. Progesterone Levels

Days Postpartum	Progesterone Level (ng/ml) Year 1 Number of Observations*	Year 1 Mean ± S.E.	Year 2 Number of Observations*	Year 2 Mean ± S.E.
0-10	18(0)	0.34 ± 0.04	54(0)	0.46 ± 0.05
11-20	46(5)	0.39 ± 0.04	81(2)	0.44 ± 0.04
21-30	40(2)	0.42 ± 0.04	70(3)	0.47 ± 0.06
31-40	38(4)	0.47 ± 0.08	60(3)	0.41 ± 0.06
41-50	33(5)	0.64 ± 0.10	45(5)	0.34 ± 0.07
51-60	18(2)	0.59 ± 0.12	33(2)	0.24 ± 0.03
61-70	3(0)	0.20 ± 0.00	15(2)	0.60 ± 0.21
71-80	---	---	6(0)	0.41 ± 0.09

* Figure in brackets gives the number of P surges within the time period

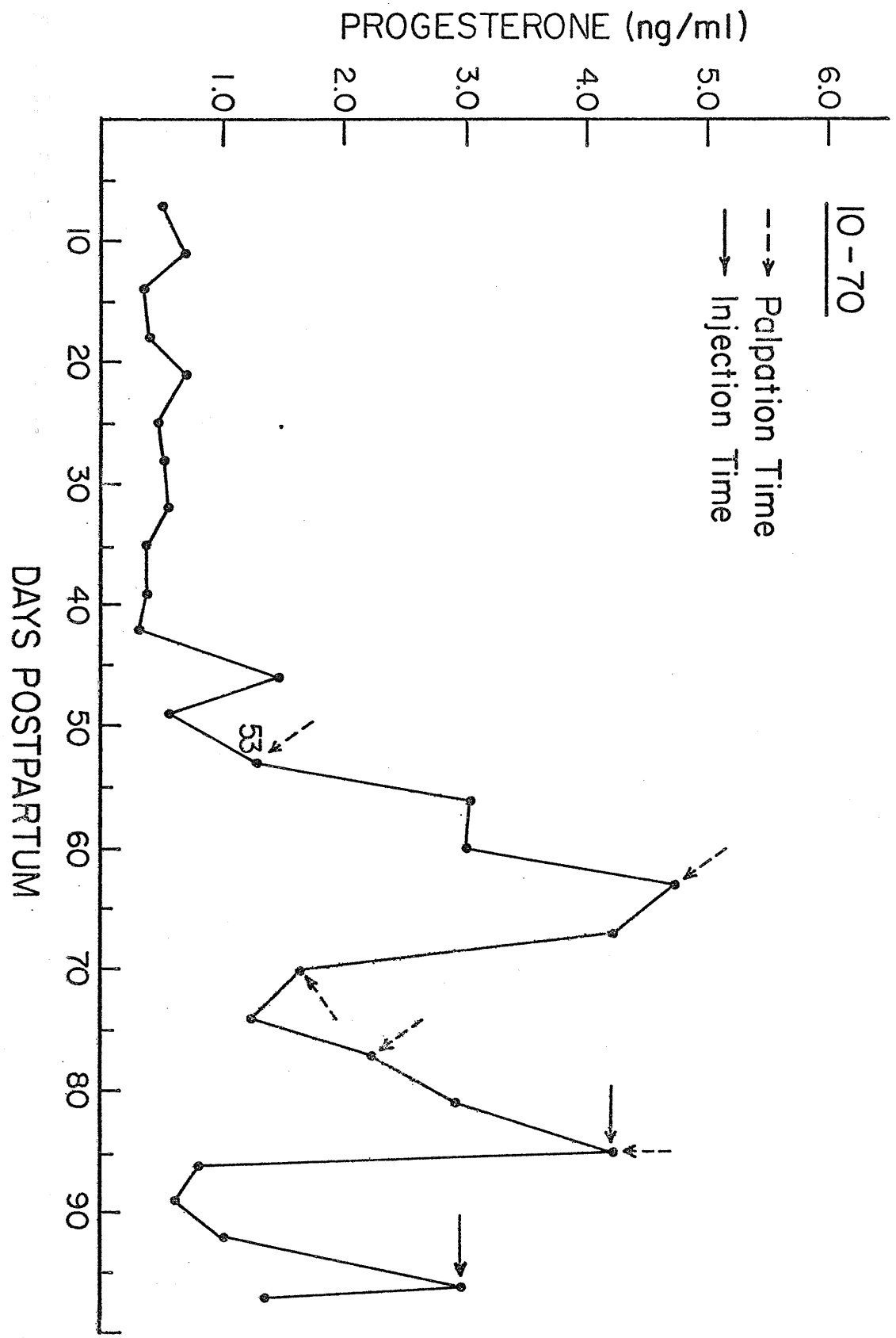

FIG. 3. Postpartum Progesterone Profile of Cow 10-70.

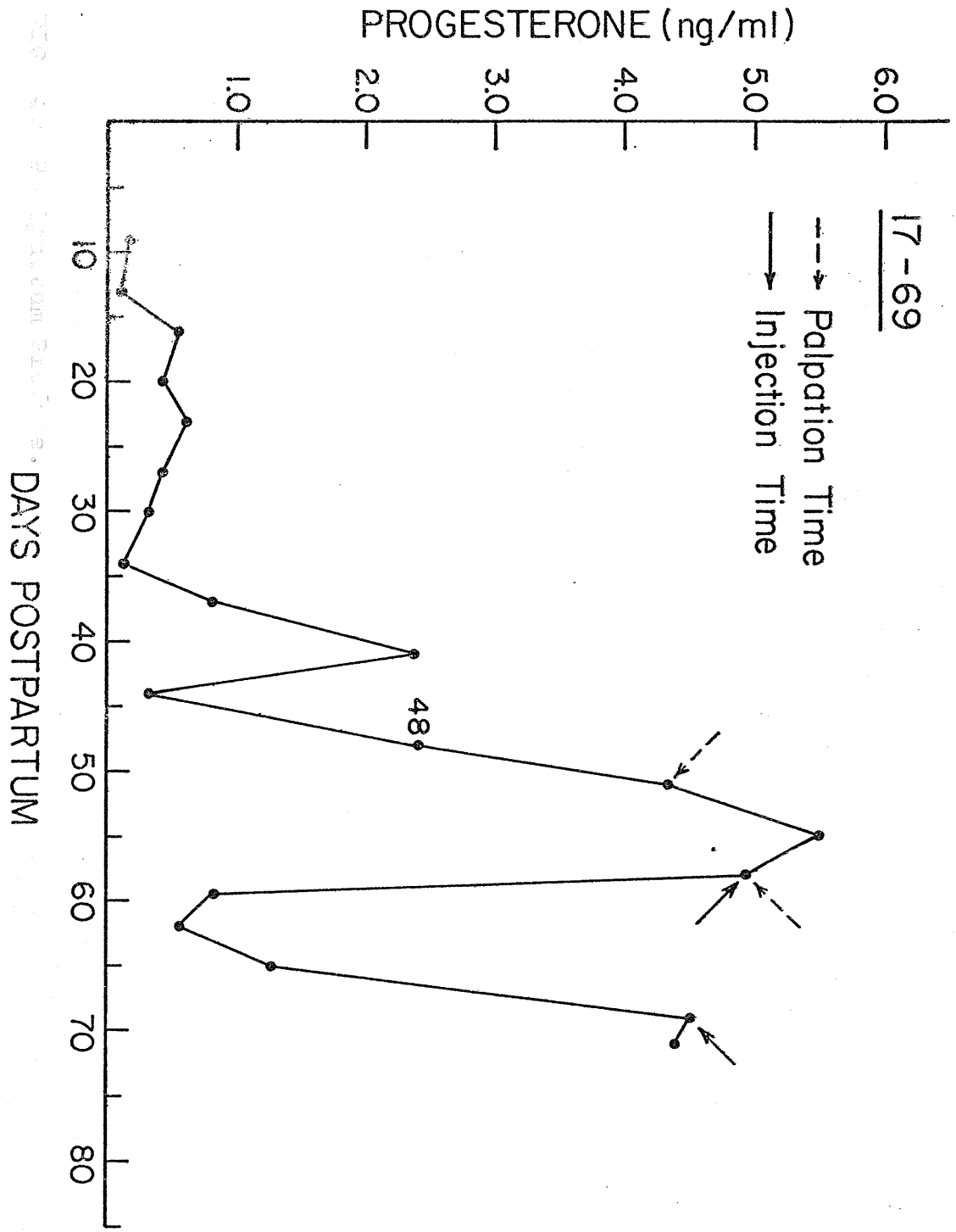

FIG. 4. Postpartum Progesterone Profile of Cow 17-69.

variation. The greatest contributing factor in this variation was that a number of relatively small surges of P appeared prior to the first presumed ovulation and were therefore included in the average. Some profiles included as many as five of these surges. The basal P level ranged from 0.20 to 0.64 ng/ml in Year 1, and from 0.24 to 0.64 ng/ml in Year 2.

Palpation Results

During this study, no cow was injected with PG until a CL was observed on palpation. Thus, the date of first treatment with PG depended solely upon the palpation result. Since there is an expected period of quiesence during the early PP period, palpations were not begun until 40 days PP.

Palpations were begun an average of 43.0 $\pm$ 1.7 and 47.0 $\pm$ 1.3 days PP for Year 1 and Year 2, respectively. There is always some doubt as to the accuracy of ovarian palpation which is dependent upon the skill of the operator. In retrospect, one can judge the effectiveness of the palpation by comparing the observations with the P-profiles. Table 7 shows the result of the palpations in relation to the estimated time of a functional CL for cows in Year 1. Table 8 shows the same information for cows in Year 2.

The time until detection of a CL in Year 1 was 56.7 $\pm$ 4.4 days PP. According to the P-profiles, the

TABLE 7. Palpation Accuracy: Year 1

Cow Number	Estimated Time of a Functional CL (days)	Palpation Result at Corresponding Time	First Palpable CL (days PP)
14-69	54	Near first estrus	61
4-70	60	CL each ovary	60
2-70	62	CL each ovary	65
16-70	48	Large follicle	62
10-70	68	CL right ovary	61
5-70	47	CL right ovary	54
21-70	55	CL right ovary	55
16-69	55	CL right ovary	58
17-70	52	CL left ovary	55
4-69	34	Small follicle left ovary	55
24-69	58	CL right ovary	58
17-69	48	Follicle right ovary	58
28-70	60	CL right ovary	52
20-69	45	CL right ovary	48
3-69	55	Follicle each ovary	52
Mean	53.3 $\pm$ 2.1		56.7 $\pm$ 1.1

TABLE 8. Palpation Accuracy: Year 2

Cow Number	Estimated Time of a Functional CL (days)	Palpation Result at Corresponding Time	First Palpable CL (days PP)
2-70	32	No palpation till 53 days	74
7-70	63	Large follicle left ovary	88
8-70	42	No palpation till 53 days	70
9-70	38	Follicle each ovary	45
10-70	53	Nil	85
13-70	79	Possible ovulation right ovary	97
15-70	59	Possible ovulation right ovary	63
16-70	33	No palpation till 61 days	68
17-70	22	No palpation till 43 days	50
19-70	52	CL right ovary	52
20-70	61	CL right ovary	61
21-70	66	Just ovulated	73
24-70	55	Just ovulated	59
27-70	69	No palpation after 57 days	57
28-70	22	No palpation till 43 days	50
31-70	22	No palpation till 47 days	54
32-70	66	CL right ovary	66
33-70	64	No palpation after 57 days	57
4-69	28	No palpation till 59 days	59
5-69	42	No palpation till 59 days	73
7-69	28	No palpation till 45 days	73
8-69	70	Small follicle rightovary	84
10-69	56	Follicle on each ovary	80

TABLE 8. (continued)

Cow Number	Estimated Time of a Functional CL (days)	Palpation Result at Corresponding Time	First Palpable CL (days PP)
14-69	46	Nil	74
15-69	84	CL right ovary	84
16-69	46	Follicle right ovary	70
17-69	29	No palpation till 54 days	61
18-69	60	Follicle right ovary	77
20-69	41	Follicle right ovary	72
24-69	23	No palpation till 44 days	51
Mean	48.4 ± 3.3		67.6 ± 2.3

P surge occured at 53.3 ± 2.1 days PP. On the average, the CL detection followed the initial P surge by 3.5 days. The time until detection of a palpable CL in Year 2 was 67.6 ± 2.3 days PP. According to the P-profiles however, ovulation occurred at 48.4 ± 3.3 days PP. On the average, the CL detection followed the initial P rise by 19.2 days.

Evidence for Partial Luteinization Prior to Ovulation

As mentioned earlier, some indication was seen of low surges of P a few days prior to first presumed ovulation. In some cases there seemed to be more than one low surge prior to ovulation. Appendix Table 2A lists the cows exhibiting low P surges just prior to the first presumed ovulation. In Year 1, in all but three cows, the P level rose for a short period of time before first ovulation (5.9 ± 0.6 days) to a mean peak magnitude of 1.4 ± 0.2 ng/ml; well above the basal level.

Again in Year 2, a low P surge occurred a short time prior to first ovulation (4.4 ± 0.4 days) in 21 of the 30 cows sampled. This P rise was usually only sustained for one sample period (6 - 7 days) and averaged 1.6 ± 0.2 ng/ml in magnitude. Seven of the animals which showed no rise in P prior to first ovulation apparently ovulated earlier in the PP period (less than 25 days PP), while in the other two, the first PG treatment preceeded the first apparent ovulation.

Because of the low frequency of blood sampling (two times a week) it was not possible to gain an accurate profile of this briefly maintained surge. If sampling had been carried out more frequently, a more accurate account could have been t ken of the length and level of the low P surge prior to first ovulation. In a number of cases, the true peak magnitude and length of the surge was not accurately depicted. Possibly in some cases, the surge was missed altogether. It appears from this data however, that this phenomenin truly exists in this group of cows.

Interval from First PG Treatment to Estrus

From the previously outlined procedure it is apparent that the time to first treatment with PG depended upon the palpation result. If for any reason the CL was missed on palpation, treatment would have been delayed.

The mean interval to the first $PGF_{2\alpha}$ treatment in Year 1 was 56.9 $\pm$ 1.3 days (individual cow data in Appendix Table 3A). In Year 1, treatment was effective in synchronizing estrus in all but two cows (Nos. 17-69 and 3-69). The mean interval from the second $PGF_{2\alpha}$ injection to estrus was 4.4 $\pm$ 0.8 days. Of the two animals which did not respond to treatment, one (No. 17-69) exhibited estrus 14 days after $PGF_{2\alpha}$ injection, while the other (No. 3-69) did not exhibit estrus or subsequently conceive. From inspection of her P-profile, it appeared

that she had ovulated normally at 51 days PP. The mean interval to mating in Year 1 was 73.6 ± 1.6 days PP.

Appendix Table 3A lists the results for Year 2 - Group II. Two aspects of treatment in Year 2 are different than Year 1. Firstly, the type of PG used was the analogue ICI-80996, and secondly, injections were given 11 days apart. One cow in this group showed no sign of estrus or mating behavior after treatment (No. 20-69) and subsequently did not conceive. Two cows in this group showed signs of estrus beyond the normal time of PG-induced estrus and can be considered non-responsive to estrous synchronization (Nos. 21-70 and 7-69). The average time to first PG injection in Year 2 - Group II animals was 66.9 ± 2.7 days PP; second treatment was at 77.9 ± 2.7 days. The mean interval to breeding (estrus) after the second PG treatment was 5.4 ± 0.9 days. Therefore, the average interval to breeding was 82.9 ± 4.3 days.

The other group of cows in Year 2 were bred by AI at a pre-set time of 72 and 96 h post-PG injection. Treatment in this group on the average of 70.2 ± 4.1 days PP with the second treatment at 81.2 ± 4.1 days PP (11 days apart). The breeding plan for this group of cows was AI so the interval to breeding was a standard 3 and 4 days post-PG. This resulted in a total PP interval to breeding of 85.2 ± 4.1 days.

Cow and Calf Weight Changes

Individual cow and calf weights are listed in Appendix Tables 4A to 7A. Mean weight changes are shown in Table 9.

Fertility Rates

Fertility rates were determined by observation of estrus and/or mating and subsequent calving dates. From this data the estrous period following treatment at which conception occurred was estimated. From the data in Year 1, it appeared that 11 of the 15 cows conceived at the first estrus following treatment (73.3%). One cow conceived at second estrus (No. 17-70), while three cows did not conceive (Nos. 4-70, 5-70 and 3-69). Appendix Table 8A lists the individual data for Year 1 and Year 2.

From the data in Year 2 - Group II, it appeared that 9 of the 15 cows conceived at the first estrus following treatment (60.0%). Three cows appeared to conceive to the second estrus following treatment (Nos. 33-70, 9-70 and 24-70). Three cows did not conceive (Nos. 24-69, 5-69 and 20-69).

After insemination, Year 2 - Group I cows remained in drylot for 10 days and then were removed to pasture. It appeared that six cows conceived to the timed AI, while one cow was observed to have been bred in pasture at second estrus following treatment, and subsequently conceived.

TABLE 9. Cow and Calf Mean Weights (± S.E.M.) During the Postpartum Period (kg)

	Cows			
	Parturition	3 Weeks	6 Weeks	9 Weeks
Year 1	608.6 ± 19.4	589.4 ± 21.4	576.4 ± 21.9	579.5 ± 20.4
Year 2	575.0 ± 11.4	573.2 ± 12.7	563.6 ± 12.3	564.1 ± 11.8

	Calves				
	Birth	3 Weeks	6 Weeks	9 Weeks	R.O.G. * (kg/day)
Year 1	39.0 ± 1.50	59.5 ± 2.00	75.5 ± 2.50	91.8 ± 3.40	0.85 ± 0.05
Year 2	39.9 ± 0.73	67.5 ± 1.41	86.5 ± 1.64	104.4 ± 1.77	1.05 ± 0.03

Rate of Gain *

It is unusual that eight of the nine cows that did not conceive to the timed AI, were not bred back in pasture.

Statistical Comparisons

To determine the degree of repeatability of PP ovarian activity, a comparison was made with 12 cows that repeated treatment from Year 1 to Year 2, by matched pair analysis. Table 10 presents the matched pairs for comparison of the time of first PP ovulation.

The comparison of Year 1 to Year 2 in days to first ovulation, demonstrated a significant difference ($P < 0.01$) between years. Year 1 cows ovulated at 49.1 ± 2.5 days PP, while the same 12 cows in Year 2 ovulated at 32.8 ± 4.0 days PP.

Table 10 also includes the comparison of time of first PG treatment. This comparison clearly points out the need for a more efficient means of determining PP ovarian activity. The current palpation scheme was not adequate in Year 2, thus causing a delay to treatment. In Year 1, the delay was 7.8 days, but in Year 2, the delay was 33.4 days. This difference is significant ($P < 0.01$).

As a consequence of the late detection of ovarian activity in Year 2, the group of 12 cows was bred significantly later ($P < 0.01$) than in Year 1. Year 1 cows were bred on the average at 74.0 ± 2.0 days PP, while the same cows in Year 2 were bred an average of 81.6 ± 3.8 days PP.

TABLE 10. Yearly Difference in First PP Ovulation and Treatment

Cow Number	Days to First Ovulation PP		Days to First PG Treatment PP	
	Year 1	Year 2	Year 1	Year 2
4-69	30	24	55	59
14-69	50	42	61	74
16-69	51	42	58	70
17-69	44	25	58	68
20-69	41	37	48	72
24-69	54	19	58	51
2-70	58	28	65	74
10-70	64	49	61	85
16-70	44	29	62	68
17-70	48	18	55	50
21-70	51	62	54	73
28-70	54	18	48	50
Mean	49.1 $\pm$ 2.5	32.8 $\pm$ 4.0	56.9 $\pm$ 2.0	66.2 $\pm$ 3.0

DISCUSSION

Postpartum Interval to Ovulation

The interval to first presumed ovulation was 49.3 ± 2.1 days in Year 1, and 44.4 ± 3.3 days in Year 2 in this study. These figures show considerable variation, but are consistent with a number of studies (Saiduddin et al., 1968, 1971; Foote et al., 1960a, b; Foote, 1971; Foote and Hunter, 1964; Foote and Saiduddin, 1964; Robertson, 1972; Wiltbank and Cook, 1958). On the average, ovulation occurred before 55 to 60 days PP. After this interval, attempts to induce estrus with luteolytic agents should be almost 95% effective. Out of 45 PP cycles, only eight cows had not ovulated before 60 days, and only two cows had not ovulated before 70 days PP.

Progesterone Profiles

According to the P-profiles, the basal P level ranged from 0.20 to 0.64 ng/ml in Year 1, and from 0.24 to 0.60 ng/ml in Year 2 in this study. This is consistent with previous reports on P levels during PP anestrus (Donaldson et al., 1970; Balfour et al., 1957; Morrow et al., 1968;

Erb et al., 1971a,b).

Although partial luteinization, as indicated by small P rises just prior to ovulation, have been observed before, there is yet no explanation as to its physiological role. It has been suggested (Manns 1976, unpublished data) that the P produced from the partial luteinization could possibly, under the correct endocrine balance, signal the initiation of the first PP ovulation. However, a clear picture has yet to be defined. To obtain a clear evaluation of the phenomenon, not only P, but all other reproductive associated hormones must be mapped out. Also, in order to achieve a more accurate picture of the phenomenon, succeeding studies should include a more frequent blood sampling regime. This study sampled only two times a week; a daily sampling regime should be the minimum frequency to achieve a proper observation. It is likely that the current sampling regime perhaps missed the phenomenon in the cows that displayed no surge in their profile.

Palpation Effectiveness

Palpation can be a valuable aid to the research scientist or clinician. However, in order to have an accurate observation by ovarian palpation, the individual must be experienced. Without detection of a CL, treatment may be delayed for days and even weeks.

Year 1 results indicate that palpations were

effective in determining ovarian activity. On the average, ovulation took place at 53.3 ± 2.1 days PP; the palpations indicated the existence of a CL by 56.7 ± 4.4 days PP. Usually, a CL cannot be detected until 3 to 4 days after ovulation, therefore, these results were quite accurate.

Two types of error can be made by palpation with respect to the existance of a CL. The first type is when the palpation does not detect a CL when in fact one is present (as indicated by the blood P levels in the case of this study). This type of error occurred in two cows in Year 1. In this study, treatment was not given until a CL was detected on palpation, therefore the first type of error would extend the time interval from ovulation to treatment even though the animal is cycling. This type of error was very evident in Year 2. Of the 11 cows which were missed, four exhibited no apparent ovarian activity. In the other cows follicular activity was evident but no CL was palpable. Perhaps these animals were palpated when the CL was either too small to detect, or the cow was in early luteal phase of the cycle shortly after estrus and ovulation. The incidence of this first type of error in Year 2 was high (37%); subsequently, the interval from the time of first ovulation to treatment was much longer than in Year 1 (3.3 days for Year 1 vs 19.2 days for Year 2).

The second type of error occurs when the palpation detects a CL, yet the P-profile indicates only a

basal P level (no functional CL). This error occurred in three cows in Year 1 and in two cows in Year 2. This second type of error could eventually cause a large wastage of PG if not checked, because the injections would have no effect upon a CL that does not exist. In Year 1, it is unusual that in the three cows that were treated too early (as judged by their P-profiles), all of them responded to the second injection of PG. One of these cows however, was never observed in estrus, and was never bred. The second type of error only occurred in two cows in Year 2. According to the P-profile, the cows did not show luteolysis after both the first and the second injection. It is again unusual that both cows showed estrous behavior 5 days after the second injection. Each cow conceived; one at first estrus, the other at second estrus following treatment.

Effect of Prostaglandins

The effects of $PGF_{2\alpha}$ and its analogues on the bovine have been well documented. The treatment regime in this study follows along the same line as those used in recent research studies and the results are comparable to others using $PGF_{2\alpha}$ or ICI-80996 to synchronize estrus.

There are a number of problems associated with the use of PG, particularly in the PP cow. Foremost, is the problem of no response during PP anestrus. The results of this study will add to those of other workers in determining the length of the anestrous period. Once the length

is known, relative to certain standard conditions (nutritional plane, cattle type and management practices), a certain interval length may be employed beyond which one may be confident (95% level) that the treatment will be successful.

In Year 1, the interval to estrus following PG injection was 4.4 ± 0.8 days (104.6 ± 20.2h), and treatment was completely effective in all but two cows. One cow showed no signs of estrus, and the other cow did not show estrus until 14 days after treatment. The average interval to estrus after $PGF_{2\alpha}$ would be 3.62 ± 0.41 days (86.8 ± 9.8h) if these two cows were not included in the calculation. This observation is somewhat longer than other intervals reported after administration during a normal cycle. Ellicott et al. (1974) reported 79.6 ± 12.5 h to first estrus after a 2 x 30 mg im injection scheme in Hereford heifers. Roche (1974) reported 59 ± 3.3 h after a single 30 mg im injection during diestrus, and 64 ± 8.9 h after a single 20 mg im injection during diestrus in Hereford-cross heifers. Welch et al. (1975) used a 1 mg uterine infusion to achieve an interval of 65 ± 2 h in lactating beef cows. With an im injection of estradiol benzoate 48 h after $PGF_{2\alpha}$, the interval was shortened and showed less variation (64 ± 1 h). A 2 mg uterine infusion of $PGF_{2\alpha}$ did not improve on the synchrony or decrease the interval to first estrus.

In several reports it seems apparent that dosage level of $PGF_{2\alpha}$ can affect the variation in response. As dosage level increases from 2 x 15 mg and 2 x 30 mg injections to 2 x 60 mg injections, the variation in synchrony decreases (Roche, 1974; Stelflug et al., 1973, 1975a). Although this study used a dosage of 20 mg $PGF_{2\alpha}$, the ideal dosage seems to be 30 mg $PGF_{2\alpha}$. This could account for some of the variation observed in response to treatment in this study.

Another important factor in responsiveness is nutritional health. This study indicates that cows showed no appreciable weight loss while suckling healthy growing calves. Thus, the nutritional contribution to variation in response can be ruled out. There are however, some non-measurable factors which could have contributed to the variation in response. The effects of suckling and environmental stress, particularly repeated handling for blood sampling and palpation, upon the cows is unknown, but not unrelated to response.

Treatment was effective in synchronizing estrus in all but three cows in Year 2 - Group II, which received the PG analogue, ICI-80996. One cow showed an unusual response (No. 20-69); according to the P-profile the cow began cycling at 38 days PP. Although the cow showed a normal response to both injections (according to the P-profile) she exhibited no signs of estrus or mating and subsequently, did not conceive. Two cows (Nos. 7-69 and

21-70) showed normal responses to $PGF_{2\alpha}$ according to the P profile, yet failed to show estrus until well after the normal response interval (12 and 13 days, respectively). Both cows conceived during the second estrus following treatment.

The interval from last treatment to observed estrus was 4.2 ± 1.0 days (100.1 ± 24.2 h) excluding the animals which did not respond. This interval from treatment to estrus did not appear to differ greatly from that in Year 1 (86.9 ± 9.9 h) when the natural $PGF_{2\alpha}$ was used.

When using a double injection regime one must be sure that all cows are cycling normally (21 day cycle), if not, the effect of the drug will be decreased. Two of the five non-responsive cows were treated directly after the first PP ovulation. There is reason to believe that the first PP cycle is shorter than normal (Morrow et al., 1966, 1968; Menge et al., 1962; Wagner and Hansel, 1969; Wagner and Oxenreider, 1971). If this phenomenon existed in this group of cows, it is possible that the double injection of $PGF_{2\alpha}$ would not be effective in causing synchronization during this short PP cycle. Despite the failure in five cows, the results of the double injection regime in this study are good. Treatment was effective in 83.3% of all treated animals.

Timed Insemination

A necessity of any timed insemination scheme is

the success of the PG in causing estrous synchronization. Researchers have been using a number of different methods recently to achieve synchronization of estrus with a minimum amount of variation. Most methods are based on the use of PG, however, some workers have been evaluating the use of a combination of PG with (Gn-RH) and/or estradiol to decrease the variation in response. Generally, workers using gonadotrophin releasing hormone (Gn-RH), present results that indicate relatively low conception rates (22.0 to 43.8%) to timed single inseminations around 60 h post-PG (Britt et al., 1975; Ellicott et al., 1975; Graves et al., 1975; Rodriquez et al., 1975). However, Gn-RH was shown to be effective in decreasing the variation in time of ovulation. Welch et al. (1975) observed that estradiol benzoate reduced the variation in time of LH release and onset of estrus when injected 48 h after $PGF_{2\alpha}$.

Other workers have received somewhat better fertility results with timed insemination. Lauderdale et al. (1973) inseminated at 72 and 90 h post-$PGF_{2\alpha}$ and observed a 58% pregnancy rate (comparable to control). Lauderdale et al. (1974) inseminated at 72 and 90 h post-$PGF_{2\alpha}$ and observed a 55.8% pregnancy rate (comparable to control). Cooper (1974) inseminated at 72 and 96 h post-$PGF_{2\alpha}$ and observed a 54.5% pregnancy rate. Seguin et al. (1975) singly inseminated at 74 or 84 h post-$PGF_{2\alpha}$ and observed an 82% pregnancy rate. It is clear that the results vary

considerably between studies, but most results indicate that fertility from timed insemination is comparable to control breeding plans.

One possible cause of the low fertility could be the non-synchrony of the post-PG ovulation with the double insemination scheme used. The AI regime was designed to cover the predicted time of ovulation, but it may be that in this study it did not blanket the ovulation time as well as in other reports.

It is difficult to determine with a high degree of accuracy when ovulation takes place after synchronization. Estrous detection in this study was at most, only twice a day. Therefore, it is also difficult to depend upon the accuracy of this value for the purpose of estimating ovulation time. However, it seemed from the results that the interval from PG to estrus in these cows was somewhat longer than in other reports. In Year 1, the interval to estrus was 86.9 h, and in Year 2, the interval was 100.0 h. Other reports indicate a slightly shorter interval to estrus (Ellicott et al., 1974; Roche, 1974; Welch et al., 1975). If the usual interval to ovulation was approximately 18 h, then the projected time of ovulation in these cows was at least between 105 to 118 h after PG treatment. Therefore the protocol which called for AI at 72 and 96 h in this study may not have been correct to achieve high conception rates.

Yearly Differences

Nutritional Monitor

A prominent factor in determining the length of PP anestrus, is that of nutrition. During this study the nutritional status of all the animals on test was monitored by periodically obtaining body weights. Results show that throughout the study, cows lost no appreciable amount of weight. Body weight of the cows had decreased by 27.1 and 10.9 kg by 9 weeks PP in Years 1 and 2, respectively. However, the rate of gain (ROG) for calves in Year 1 and Year 2 were significantly different ($P < 0.01$), being 0.85 ± 0.05 and 1.05 ± 0.03 kg/day, respectively. This implies that the Year 2 diet was of a higher quality than the Year 1 diet, since the cows in Year 2 were able to support higher calf gains. The diet however, was not subjected to feed analysis during the study. The corn silage - alfalfa hay diet was the same in both years. It is possible that the forage and silage in Year 2 was of a higher quality than in Year 1, therefore causing a higher milk production and a higher calf ROG in Year 2. Forage quality could also be implicated in the yearly difference in the time of first ovulation between years.

Time of First Postpartum Ovulation

According to the P-profiles, cows in Year 2 ovulated 6.3 days earlier after calving than did the same 12

animals in the previous year. The factors that could have contributed to this difference are difficult to isolate. The main factors which could account for this result are: the nutritional plane; environmental and management practices, suckling stress, and age. Since the cows had aged only 1 year, this factor should have only minimal influence when the cows are 6 and 7 years of age. The housing, handling and management remained the same from year to year. As previously mentioned, the nutritional plane of the cows may have been different in quality. This difference in quality could conceivably have had an effect on the general reproductive activity of the cow, as well as on the health and ROG of the calf. If indeed there was a nutritional difference, this could then have been a major factor in the difference in time of the first ovulation between Year 1 and Year 2. If investigation is continued, there should be a much closer monitor on nutritional factors. Greater attempts should also be made to more precisely determine the time of first PP ovulation, and a more detailed and systematic method of estrous detection would be advisable.

CONCLUSION

The length of the PP interval to first ovulation, as indicated by P-profile and ovarian palpation, in this 2 year study was esimated to be 49.3 and 44.4 days for Year 1 and Year 2, respectively. Results indicate that the PG treatments used were 83.3% effective in synchronizing estrus. The interval from treatment to onset of observed estrus was 3.62 $\pm$ 0.41 and 4.20 $\pm$ 1.01 hours in Years 1 and 2, respectively.

Evidence was observed in this study for the phenomenon of partial luteinization. However, there is yet no explanation as to its physiological role.

Rectal palpation as a tool for observation of PP ovarian activity is helpful, but the technique requires a considerable amount of labour and the availability of a skilled and well experienced palpator.

Results indicate that timed insemination at 72 and 96 h after PG treatment did not adequately blanket the time of synchronized ovulation. Pregnancy rate to timed insemination was 40%, yet the prgnancy rate to natural service after estrous synchronization was 73.3% and 60.0% for Years 1 and 2, respectively.

Matched-pair analysis of 12 cows studied in both years suggest that the interval to first PP ovulation was significantly different ($P < 0.01$) between years. The same type of analysis also indicated that the difference between years in calf ROG was statistically significant ($P < 0.05$). In both cases, Year 2 performance by cows and calves was greater than in Year 1. The major contributing factor to this difference may be the nutritional quality change from Year 1 to Year 2.

Results of this study indicate that further research is required in order to explain some of the phenomena observed. In order to achieve a clear understanding of the phenomenon of partial luteinization, succeeding projects should include a more frequent blood sampling regime, as well as analysis for estrogen, LH and FSH to complement the P-profile. Also, it is apparent that although the nutritional monitor indicated no change in nutritional plane from Year 1 to Year 2, results in reproductive performance indicate otherwise. In future a closer monitor such as periodic feed analysis, must be carried out in order to eliminate any doubt as to the standard of nutrition throughout the study.

APPENDIX

TABLE 1A. First Substantial Rise in Progesterone Level (days postpartum)

Cow Number	Year 1	Year 2
4-69	34	28
14-69	54	46
16-69	55	46
17-69	48	29
20-69	45	41
24-69	58	28
2-70	62	32
10-70	68	53
16-70	48	33
17-70	52	22
21-70	55	66
28-70	58	22*
4-70	60	--*
5-70	47	--*
3-69	55**	--*
5-69	--**	42
7-69	--**	28
8-69	--	70
10-69	--	56
15-69	--	84
18-69	--	60
7-70	--	63
8-70	--	42
9-70	--	38
13-70	--	79
15-70	--	59
19-70	--	52
20-70	--	61
24-70	--	55
27-70	--	69
31-70	--	22
32-70	--	66
33-70	--	64

* Cows not on test in Year 2

** Cows not on test in Year 1

TABLE 2A. Occurrence of Low Progesterone Surges Just Prior to First Ovulation

Cow Number	Time of Presumed Ovulation (days PP)	Prior Progesterone Peak	
		Days Prior to Ovulation	Peak Magnitude (ng/ml)
Year 1			
14-69	50	6	0.70
4-70	56	-	--
2-70	58	7	2.45
16-70	44	3	1.10
10-70	64	6	0.90
5-70	43	3	1.10
21-70	51	7	0.80
16-69	51	7	2.30
17-70	48	7	2.00
4-69	30	-	--
24-69	54	6	0.50
17-69	44	3	2.40
28-70	54	9	2.00
20-69	41	-	--
3-69	51	7	0.55
Mean	49.3 ± 2.1	5.9 ± 0.6	1.4 ± 0.2
Year 2			
2-70	28	4	2.10
7-70	59	6	0.35
8-70	38	3	2.50
9-70	34	7	2.45

Table 2A. (continued)

Year 2

Cow Number	Time of Presumed Ovulation (days PP)	Prior Progesterone Peak	
		Days Prior to Ovulation	Peak Magnitude (ng/ml)
10-70	49	3	1.45
13-70	75	6	2.75
15-70	55	6	1.10
16-70	29	3	2.50
17-70	18	-	--
19-70	48	7	0.80
20-70	57	7	0.80
21-70	62	3	0.70
24-70	51	3	0.70
27-70	65	-	--
28-70	18	-	--
31-70	18	-	--
32-70	62	3	0.90
33-70	60	-	--
4-69	24	-	--
5-69	38	3	1.30
8-69	66	3	2.40
10-69	52	3	2.75
14-69	42	3	1.65
15-69	80	6	0.50
16-69	42	7	1.00
17-69	25	-	--
18-69	56	3	2.65
20-69	37	7	0.90
24-69	19	-	--
7-69	24	-	--
Mean	44.4 ± 3.3	4.4 ± 0.4	1.65 ± 0.2

TABLE 3A. Postpartum Interval to $PGF_{2\alpha}$ Treatment and Interval from Second $PGF_{2\alpha}$ Injection to Estrus

Year 1

Cow Number	PP Interval to First PG Injection (days)	Interval from Last Treatment to Estrus (days)	Total PP Interval to Breeding (days)
14-69	61	2	75
4-70	60	2	74
2-70	65	5	82
16-70	62	7	81
10-70	61	3	76
5-70	59	4	75
21-70	54	3	69
16-69	58	3	73
17-70	55	3	70
4-69	55	2	69
24-69	58	5	75
17-69	58	14	84
28-70	48	3	63
20-69	48	5	65
3-69	51	-	--
Mean	56.9 ± 1.3	4.4 ± 0.8	73.6 ± 1.6

Year 2 - Group I

14-69	74	-	89
2-70	74	-	89
10-70	85	-	100
17-70	50	-	65
4-69	59	-	74

TABLE 3A. (continued)

Year 2 - Group I

Cow Number	PP Interval to First PG Injection (days)	Interval from Last Treatment to Estrus (days)	Total PP Interval to Breeding (days)
28-70	50	-	65
13-70	100	-	115
7-70	91	-	106
20-70	61	-	76
19-70	52	-	67
10-69	80	-	95
8-69	84	-	99
32-70	69	-	84
8-70	70	-	85
31-70	54	-	69
Mean	70.2 ± 4.1		85.2 ± 4.1

Year 2 - Group II

16-70	68	4	83
21-70	73	13	97
16-69	70	3	84
24-69	51	4	66
17-69	68	7	86
20-69	72	-	--
15-69	88	4	103
33-70	57	4	72
27-70	57	5	73
9-70	48	5	64
15-70	66	3	80

TABLE 3A. (continued)

Year 2 - Group II

Cow Number	PP Interval to First PG Injection (days)	Interval from Last Treatment to Estrus (days)	Total PP Interval to Breeding (days)
24-70	62	4	77
7-69	73	12	96
18-69	77	3	91
5-69	73	4	88
Mean	66.9 ± 2.7	5.4 ± 0.9	82.6 ± 4.3

TABLE 4A. Postpartum Cow Weights: Year 1 (kg)

Cow Number	Year 1			
	Parturition	3 Weeks	6 Weeks	9 Weeks
20-69	755.5	768.2	764.5	750.9
4-69	721.8	701.8	680.0	684.1
4-70	669.1	658.2	650.9	647.3
28-70	663.6	639.1	638.2	646.4
17-69	639.1	621.8	616.4	622.7
2-70	612.7	616.4	578.2	587.3
16-69	598.2	587.3	599.5	595.5
16-70	610.0	579.1	568.2	547.3
24-69	611.8	577.3	568.2	555.0
14-69	585.5	561.4	535.5	541.8
5-70	578.2	553.6	531.8	512.7
21-70	575.5	545.5	494.5	535.5
10-70	520.0	494.5	496.4	499.1
17-70	516.7	485.5	467.3	509.1
3-69	474.5	452.7	456.4	457.3

TABLE 5A. Calf Weights: Year 1 (kg)

Year 1					
Calf Number	Birth	3 Weeks	6 Weeks	9 Weeks	R.O.G.* (kg/day)
65	40.9	65.5	72.7	88.2	0.814
43	49.5	70.9	86.4	106.4	0.918
12	42.7	65.9	84.5	110.9	1.050
64	36.4	58.2	75.9	82.7	0.800
53	42.7	65.5	86.4	102.7	0.923
27	49.1	73.6	100.9	122.7	1.194
39	40.5	56.4	69.1	78.2	0.609
30	38.2	55.0	69.1	83.6	0.732
52	33.2	47.3	67.7	81.8	0.750
20	33.6	52.7	70.0	92.7	0.955
34	38.2	58.2	73.2	89.1	0.809
35	29.1	52.7	74.5	94.5	1.009
32	35.0	53.6	68.2	85.0	0.768
44	41.8	54.5	65.5	77.1	0.600
62	34.5	63.6	68.2	80.0	0.732

* Rate of Gain

TABLE 6A. Postpartum Cow Weights: Year 2 (kg)

Year 2				
Cow Number	Parturition	3 Weeks	6 Weeks	9 Weeks
14-69	521.8	524.1	530.9	510.0
2-70	591.8	603.3	596.4	586.4
16-70	586.4	578.2	570.9	570.9
10-70	544.5	548.6	545.5	534.5
21-70	527.3	548.6	545.5	534.5
16-69	586.4	602.7	611.8	600.0
17-70	536.4	537.3	511.8	512.7
4-69	655.5	674.5	645.5	643.6
24-69	550.9	566.4	556.4	547.3
17-69	623.6	610.9	607.3	613.6
28-70	704.5	710.9	686.4	687.3
20-69	727.3	754.5	742.7	727.3
15-69	490.9	461.8	450.0	443.6
13-70	541.8	472.7	460.0	472.7
33-70	554.5	522.7	512.7	529.1
27-70	579.5	559.1	554.5	547.3
7-70	463.6	527.3	532.7	559.1
9-70	609.1	575.0	570.9	556.4
20-70	629.5	612.7	604.5	592.7
19-70	593.2	607.3	592.7	616.4
15-70	583.6	605.5	572.7	604.5
10-69	545.5	534.5	514.5	514.5
8-69	483.6	481.8	480.0	470.9
24-70	674.5	672.7	656.4	650.0
32-70	568.2	576.4	540.0	531.8
7-69	600.0	599.1	569.1	570.9
18-69	494.5	469.1	467.3	465.5
8-70	572.7	563.6	581.8	585.5
5-69	621.8	602.7	611.8	600.0
31-70	500.0	515.5	523.6	544.5

TABLE 7A. Calf Weights: Year 2 (kg)

Year 2					
Calf Number	Birth	3 Weeks	6 Weeks	9 Weeks	R.O.G.* (kg/day)
39	33.6	58.2	79.1	93.6	0.895
67	44.5	73.6	89.1	107.3	1.118
53	33.6	55.5	73.6	89.1	0.868
51	42.7	65.5	76.4	98.2	0.882
40	34.1	58.6	85.5	103.6	1.105
46	37.3	70.9	90.0	107.3	0.945
75	39.1	55.5	71.8	91.8	0.863
57	45.5	80.0	108.2	123.6	1.327
73	40.9	58.2	80.9	106.4	1.055
66	40.0	63.6	77.3	93.6	0.923
74	39.1	68.2	90.9	111.8	1.173
68	40.9	60.0	66.4	78.2	0.677
1	40.0	81.4	92.7	104.5	1.009
2	37.3	74.5	91.8	100.0	1.013
3	37.3	70.9	87.3	101.8	1.077
4	44.5	81.8	93.6	113.6	1.082
7	39.1	70.9	86.4	102.3	1.005
8	42.7	75.0	93.6	118.2	1.259
10	32.7	69.1	89.1	109.1	1.195
12	38.6	61.8	81.8	104.5	1.118
17	46.8	70.9	92.7	114.5	1.077
18	49.1	81.8	106.8	121.8	1.155
19	37.3	64.5	83.6	99.1	1.050
28	37.3	63.6	88.2	110.0	1.323
29	37.7	59.1	84.5	94.5	0.918
32	40.0	67.3	85.5	109.1	2.232
36	37.3	64.5	83.6	104.5	1.068
42	40.0	62.7	89.5	108.2	1.082
54	44.5	70.9	90.0	107.3	0.995
72	44.1	66.8	90.9	103.6	0.900

* Rate of Gain

TABLE 8A. Conception and Gestation Length

Year 1

Cow Number	Date of Breeding at Estrus 1975	Date of Calving 1976	Assumed Post-treatment Estrus at Which Conception Occured
14-69	July 17	May 3	First
4-70	July 10	- - -	- - -
2-70	July 27	May 31	First
16-70	July 29	May 15	First
10-70	July 29	May 13	First
5-70	July 26	- - -	- - -
21-70	July 18	May 3	First
16-69	July 26	May 6	First
17-70	July 27	June 9	Second
4-69	July 24	May 17	First
24-69	August 8	June 8	First
17-69	August 12	May 30	First
28-70	August 8	June 9	First
20-69	August 10	June 1	First
3-69	- - -	- - -	- - -

Year 2 - Group 1

2-70	August 27	- - -	- - -
7-70	July 23	May 3	First
8-70	July 30	May 3	First
10-70	August 20	- - -	- - -
13-70	July 23	May 3	First
17-70	August 13	- - -	- - -
19-70	June 22	March 27	First
20-70	June 29	April 3	First
28-70	August 13	- - -	- - -
31-70	August 13	- - -	- - -

TABLE 8A. (Continued)

Year 2 - Group 1

Cow Number	Date of Breeding at Estrus 1975	Date of Calving 1976	Assumed Post-treatment Estrus at Which Conception Occured
32-70	July 16	April 25	First
4-69	July 30	- - -	- - -
8-69	July 30	- - -	- - -
10-69 *	July 23	May 29	Second
14-69	July 30	- - -	- - -

Year 2 - Group II

15-69	July 9	April 21	First
33-70	June 15	April 16	Second
27-70	June 16	March 31	First
9-70	June 12	April 5	Second
15-70	July 8	April 21	First
24-70	July 8	May 9	Second
7-69	July 31	May 20	First
18-69	August 1	May 14	First
24-69	August 13	- - -	- - -
17-69 **	August 23	- - -	First
5-69	August 13	- - -	- - -
20-69	- - -	- - -	- - -
16-70	August 6	May 17	First
21-70	August 8	May 6	First
16-69	July 29	May 11	First

* Cow 10-69 actually seen being bred during second estrus.

** Cow 17-69 died just prior to parturition.

BIBLIOGRAPHY

Abraham, G.E., R. Swerdloff, D. Tulchisky and W.D. Odell. 1971a. Radioimmunoassay of plasma progesterone. J. Clin. Endocr. 32:619.

Abraham, G.E., R. Swerdloff, D. Tulchinsky, K. Hopper and W.D. Odell. 1971b. Radioimmunoassay of 17-hydroxyprogesterone. J. Clin. Endocr.

Abraham, G.E., K. Hopper, D. Tulchinsky, R. Swerdloff and W.D. Odell. 1971c. Simultaneous measurement of plasma progesterone, 17-hydroxyprogesterone and estradiol-17β by radioimmunoassay. Analytical Letters. 4:325.

Abraham, G.E. 1972. Radioimmunoassay of plasma estradiol-17 . In: Methods of Hormone Analysis. Breuer, H. and H.L. Kruskemper, (eds.). George Thieme Verlag, Stuttgart.

Babcock, J.C. 1966. In: Hansel, W. Luteotrophic and luteolytic mechanisms in bovine corpora lutea. In: Ovarian Regulatory Mechanisms. J. Reprod. Fert. Suppl. 1:47.

Balfour, W.E., R.S. Comline and R.V. Short. 1957. Secretion of progesterone by the adrenal gland. Nature 180:1480.

Britt, J.H., T.E. Kiser, H.D. Hafs and H.D. Ritchie. 1975a. Effect of altering the suckling intensity on reproductive performance of cows. Mich. State Univ. Res. Rep. 288:16.

Britt, J.H., T.E. Kiser, B.E. Seguin, H.D. Hafs, W.D. Oxender and H.D. Ritchie. 1975b. Fertility after gonadotrophin releasing hormone and $PGF_{2\alpha}$ in suckling beef cows. Mich. State Univ. Res. Rep. 288:11.

Buch, N.C., W.J. Tyler and L.E. Casida. 1955. Postpartum estrus and involution of the uterus in an experimental herd of Holstein-Fresian cows. J. Dairy Sci. 38:73.

Callahan, C.J., R.E. Erb, A.H. Surve and R.D. Randel. 1971. Variables influencing ovarian cycles in postpartum dairy cows. J. Anim. Sci. 33:1053.

Casida, L.E. 1968. The postpartum cow: A resume. Wis. R Res. Bul. 270:48.

Casida, L.E. 1971. The postpartum interval and its relation to fertility in the cow, sow and ewe. J. Anim. Sci. 39:202.

Casida, L.E. and A.B. Chapman. 1951. Factors affecting the incidence of cystic ovaries in a herd of Holstein cows. J. Dairy Sci. 34:1200.

Casida, L.E. and W.G. Venzke. 1936. Observations in reproductive processes in dairy cattle and their relation to breeding efficiency. Proc. of Am. Soc. Anim. Prod. 36:221.

Casida, L.E. and W. Wisnicky. 1950. Effects of diethylstilbestrol dipropionate upon postpartum changes in the cow. J. Anim. Sci. 9:238.

Chamley, W.A., J.M. Buckmaster, M.D. Cain, J. Cerini, M.E. Cerini, I.A. Cumming and J.R. Goding. 1972b. The effect of prostaglandin $F_{2\alpha}$ on progesterone, oestradiol, and luteinizing hormone secretion in sheep with ovarian transplants. J. Endocr. 55:253.

Chenault, M.J., W.W. Thatcher, P.S. Kalra, R.M. Abrams and C.J. Wilcox. 1974. Hormonal changes in the bovine induced by $PGF_{2\alpha}$. J. Anim. Sci. 39:202 (abstract).

Cooper, M.J. 1974. Control of oestrous cycles of heifers with synthetic prostaglandin analogue. Vet. Record. 95:200.

Cooper, M.J. and B.J.A. Furr. 1974. The role of prostaglandins in animal breeding. Vet. Record. 94:161 (abstract).

Cooper, M.J., S.R. Slater, H. Dobson and B.J.A. Furr. 1973. Data presented at the winter meeting of the Soc. for the Study of Fert., Zoo. Soc. London.

Del Campo, C.H. and O.J. Ginther. 1972. Vascular anatomy of the uterus and the ovaries, and the unilateral luteolytic effect of the uterus. I. Guinea pigs, hamsters, rabbits and rats. Am. J. Vet. Res. 33:2561.

Dobson, H., M.J. Cooper, and B.J.A. Furr. 1975. Synchronization of oestrus with ICI-79,939 an analogue of $PGF_{2\alpha}$ and associated changes in plasma progesterone, oestradiol-17β and LH in heifers. J. Reprod. Fert. 42:141.

Donaldson, L.E. 1977. Synchronization of oestrus in beef cattle artificial insemination programs using $PGF_{2\alpha}$. Aust. Vet. J. 53:72.

Donaldson, L.E., J.M. Bassett and G.D. Thorburn. 1970. Periferal plasma progesterone concentration of cows during puberty, oestrus cycles, pregnancy and lactation, and the effects of undernutrition or exogenous oxytocin on progesterone concentration. Endocrinology. 48:599.

Dunn, T.G., J.E. Ingalls, D.R. Zimmerman and J.N. Wiltbank. 1969. Reproductive performance of 2-year old Hereford and Angus heifers as influenced by pre- and post-calving energy intake. J. Anim. Sci. 29:719.

Edgerton, L.A. and H.D. Hafs. 1971. Bovine sera luteinizing hormone and prolactin, pre and postpartum. J. Anim. Sci. 33:252 (abstract).

Ellicott, A.R., J.R. Hill Jr. and C.E. Thompson. 1975. Appointed hour of mating in the cow. J. Anim. Sci. 41:351 (abstract).

Ellicott. A.R., J.R. Scoggins, J.R. Hill Jr. and D.M. Henricks. 1974. Estrus control using $PGF_{2\alpha}$. I. Luteinizing hormone and fertility. J. Anim. Sci. 39:207 (abstract).

Erb, R.E., R.D. Randel and C.J. Callahan. 1971a. Female sex steroid changes during the reproductive cycle. IX. Biennial Symposium on Animal Reproduction. J. Anim. Sci. 32:80.

Erb, R.E., A.H. Surve, C.J. Callahan, R.D. Randel and H.A. Garverick. 1971b. Reproductive steroids in the bovine. VII. Changes postpartum. J. Anim. Sci. 33:1060.

Foote, W.D. 1971. Endocrine changes in the bovine during the postpartum period. J. Anim. Sci. 32:73.

Foote, W.D., E.R. Hauser and L.E. Casida. 1960a. Influence of progesterone on postpartum reproductive activity in beef cattle. J. Anim. Sci. 19:674.

Foote, W.D. and J.E. Hunter. 1964. Postpartum intervals of beef cows treated with progesterone and estrogen. J. Anim. Sci. 23:517.

Foote, W.D. and S. Saiduddin. 1964. Hormone treatment of postpartum beef cows. J. Anim. Sci. 23:592 (abstract).

Foote, W.D., H.J. Weeth and J.E. Hunter. 1960b. Effects of ovarian hormones on postpartum reproductive activity in beef cows. J. Anim. Sci. 19:1321 (abstract).

Fosgate, O.T., N.W. Cameron and R.J. McLeod. 1962. Influence of 17-β hydroxyprogesterone-N-caporate upon postpartum reproductive activity in th bovine. J. Anim. Sci. 21:791.

Gier, H.T. and G.B. Marion. 1968. Uterus of the cow after parturition: involutional changes. Am. J. Vet. Res. 29:83.

Ginther, O.J. and G.E. Bisgard. 1972. Role of the main uterine vein in local action of an intra-uterine device on the corpus luteum in sheep. Am. J. Vet. Res. 33:1583.

Ginther, O.J., M.C. Garcia, E.L. Squires and W.P. Steffenhagen. 1972. Anatomy of the vasculature of the uterus ovaries in mares. Am. J. Vet. Res. 33:1561.

Graves, N.W., T.G. Dunn, C.C. Kaltenbach, R.E. Short and J. B. Carr. 1975. Estrus and ovulation with $PGF_{2\alpha}$, SC-21009 and gonadotrophin releasing hormone. J. Anim. Sci. 41:354 (abstract).

Graves, N.W., J.W. Lauderdale, E.R. Hauser and L.E. Casida. 1968. Relation of postpartum interval to pituitary gonadotrophins, ovarian follicular development and fertility in beef cows. Wis. Res. Bul. 270:23.

Hafs, H.D. 1976. Ovulation control and release of hormones with prostaglandin $F_{2\alpha}$ in cattle. VIII International Congress on Animal Reproduction and Artificial Insemination. P. 17.

Hafs, H.D. and J.G. Manns. 1975. Onset of oestrus and fertility of dairy heifers and suckled beef cows treated with $PGF_{2\alpha}$. Vet. Record. 96:134 (abstract).

Hafs, H.D., J.G. Manns and G.E. Lamming. 1975. Fertility of cattle from artificial insemination after $PGF_{2\alpha}$ in beef cows. J. Anim. Sci. 38:1335 (abstract).

Hammond, J. 1927. The Physiology of Reproduction in the Cow. Cambridge Press. London.

Hammond J. and H.G. Sanders. 1923. Some factors affecting milk yield. J. Agri. Sci. 13:74.

Hearnshaw, H. 1976. Synchronization of oestrus and subsequent fertility in cattle using $PGF_{2\alpha}$ analogue, ICI-80996 (Cloprostenol). Aust. J. Exp. Agri. Anim. Husb. 16:437.

Henricks, D.M., A.R. Ellicott, J.R. Hill and J.F. Dickey. 1974. Estrus control using $PGF_{2\alpha}$. II. Gonadal hormones. J. Anim. Sci. 39:211 (abstract).

Henricks, D.M., J.T. Long, J.R. Hill and J.F. Dickey. 1974. The effect of $PGF_{2\alpha}$ during various stages of the oestrus cycle of beef heifers. J. Reprod. Fert. 41:113.

Herman, H.A. and J.H. Edmondson. 1950. Factors affecting the interval between parturition and first estrus in dairy cattle. Mo. Agri. Exp. Sta. Res. Bul. 462.

Hixon, J.E. and W. Hansel. 1974. Evidence for preferential transfer of $PGF_{2\alpha}$ in the ovarian artery following intra-uterine administration in cattle. Biol. Reprod. 11:543.

Hunter, D.L., R.E. Erb, R.D. Randel, H.A. Garverick, C.J. Callahan and R.B. Harrington. 1970. Reproductive steroids in the bovine. I. Relationships during late gestation. J. Anim. Sci. 30:47.

Inskeep, E.K. 1973. Potential uses of prostaglandins in control of reproductive cycles of domestic animals. J. Anim. Sci. 36:1149.

Kidder, P.S., W.W. Thatcher, M.M. Casey and C.J. Wilcox. 1952. A study of ovulation in six families of Holstein-Fresians. J. Dairy Sci. 35:436.

King, G.J., J.F. Hurnick and H.A. Robertson. 1976. Ovarian function and estrus in dairy cows during early lactation. J. Anim. Sci. 42:688.

King, G.J. and H.A. Robertson. 1974. A two injection schedual with $PGF_{2\alpha}$ for the regulation of the ovulatory cycle of cattle. Theriogenology. 1:123.

Labhsetwar, A.P., W.E. Collins, W.J. Tyler and L.E. Casida, 1964. Some pituitary-ovarian relationships in the periparturient cow. J. Reprod. Fert. 8:85.

Labhsetwar, A.P., W.J. Tyler and L.E. Casida. 1963. Genetic and enviornmental factors affecting quiet ovulations in Holstein cattle. J. Dairy Sci. XLVI:843.

Lauderdale, J.W., J.R. Chenault, B.E. Seguin and W.W. Thatcher. 1973. Fertility of cattle after $PGF_{2\alpha}$ treatment. J. Anim. Sci. 37:319 (abstract).

Lauderdale, J.W., W.E. Graves, E.R. Hauser and L.E. Casida. 1968. Relation of postpartum interval to corpus luteum development, pituitary prolactin activity, and uterine involution in beef cows. Wis. Res. Bul. 270:42.

Lauderdale, J.W., B.E. Seguin, J.N. Stelflug, J.R. Chenault, W.W. Thatcher, C.K. Vincent and A.F. Loyancano. 1974. Fertility of cattle following PGF_2 injection. J. Anim. Sci. 38:964.

Liehr, R.A., G.B. Marion and H.H. Olson. 1972. Effect of prostaglandin on cattle estrous cycles. J. Anim. Sci. 35:247 (abstract).

Loeb, L. 1923. The exterpation of the uterine horn on the life and function of the corpus luteum in the guinea-pig. Proc. Soc. Exp. Biol. Med. 20:441.

Louis, T.M., H.D. Hafs and D.A. Morrow. 1972a. Estrus and ovulation after uterine $PGF_{2\alpha}$ in cows. J. Anim. Sci. 35:247 (abstract).

Louis, T.M., H.D. Hafs and D.A. Morrow. 1972b. Estrus and ovulation after $PGF_{2\alpha}$ in cows. J. Anim. Sci. 35:1121 (abstract).

Louis, T.M., H.D. Hafs and D.A. Morrow. 1974. Intrauterine administration of $PGF_{2\alpha}$ in cows: progesterone, estrogen, luteinizing hormone, estrus and ovulation. J. Anim. Sci. 38:347.

Lynn, J.E., S.H. McNutt and L.E. Casida. 1966. Effects of intra-uterine bacterial inoculation and suckling on the bovine corpus and uterus. Am. J. Vet. Res. 27:1521.

Manns, J.G., H.D.Hafs and G.E. Lamming. 1975. Influence of thyrotropin-releasing hormone on plasma progesterone and pituitary hormone concentrations in cattle. Can. J. Anim. Sci. 55:653.

Marion, G.B., and H.T. Gier. 1968. Factors affecting bovine ovarian activity after parturition. J. Anim. Sci. 27:1621.

Marion, G.B., J.S. Norwood and H.T. Gier. 1968. Uterus of the cow after parturition: factors affecting regression. Am. J. Vet. Res. 29:71.

McClure, T.J. 1968b. Hypoglycaemia, an apparent cause of infertility of lactating cows. Brit. Vet. J. 124:3.

Menge, A.C., S.E. Mares, W.J. Tyler and L.E. Casida. 1962. Variation and association among postpartum reproduction and production characteristics in Holstein-Fresian cattle. J. Dairy Sci. 45:233.

Moody, E.L. and J.W. Lauderdale. 1977. Fertility of cattle following $PGF_{2\alpha}$ controlled ovulation. Am. Soc. of Anim. Sci. 65th Annual Meeting (abstract). P. 189.

Morrow, D.A., S.J. Roberts and K. McEntee. 1968a. Latent effects of pregnancy on postpartum estrous cycles in dairy cattle. J. Anim. Sci. 27:1404.

Morrow, D.A., S.J. Roberts and K. McEntee. 1968b. Latent effects of pregnancy on ovarian activity in dairy cattle. J. Anim. Sci. 27:1408.

Morrow, D.A., S.J. Roberts, K. McEntee and H.G. Gray. 1966. Postpartum ovarian activity and uterine involution in dairy cattle. J. Am. Vet. Ass. 149:1596.

Olds, D., H.B. Morrison and D.M. Seath. 1949. Efficiency of natural breeding in dairy cattle. Ken. Agri. Exp. Sta. Bul. 539.

Oxenreider, S.L. 1968. Effects of suckling and ovarian function on postpartum reproductive activity in beef cows. Am. J. Vet. Res. 29:2099.

Perkins, J.L. and H.E. Kidder. 1963. Relation of uterine involution and postpartum interval to reproductive efficiency in beef cattle. J. Anim. Sci. 22:313.

Pharriss, B.B. 1970. The possible vascular regulation of luteal function. Persp. Biol. Med. 13:434.

Pharriss, B.B. and L.J. Wyngarten. 1969. The effect of prostaglandin $F_{2\alpha}$ on the progesterone content of ovaries from pseudo-pregnant rats. Proc. Soc. Exp. Biol. Med. 130:92.

Pope, G.S., S.K. Gupta and I.B. Munro. 1969. Progesterone levels in the systemic plasma of pregnant, cycling and ovariectomized cows. J. Reprod. Fert. 20:369.

Quevedo, M.M., S. Saiduddin and W.D. Foote. 1965. Influence of estradiol on reproductive activity in postpartum dairy cattle. J. Anim. Sci. 24:587 (abstract).

Randel, R.D. and R.E. Erb. 1971. Reproductive steroids in the bovine. VI. Changes and interrelationships from 0 to 260 days of pregnancy. J. Anim. Sci. 33:115.

Randel, R.D., R.E. Short and R.A. Bellows. 1976. Suckling effect on luteinizing hormone and progesterone in beef cows. J. Anim. Sci. 42:267 (abstract).

Rasbech, N.O. 1950. The normal involution of the uterus in the cow. Nord. Vet. Med. 2:655.

Rieson, J.W., S. Saiduddin, W.J. Tyler and L.E. Casida. 1968. Relation of postpartum interval to corpus luteum development, pituitary prolactin activity and uterine involution in dairy cows. Wis. Res. Bul. 270:27.

Roberts, S.J. 1955. Clinical observations on cystic ovaries in dairy cattle. Cornell Vet. 45:497.

Robertson, H.A. 1972. Plasma progesterone in cows during the estrous cycle, pregnancy, at parturition and postpartum. J. Anim. Sci. 52:645.

Roche, J.F. 1974. Synchronization of oestrus and fertility following artificial insemination in heifers given $PGF_{2\alpha}$. J. Reprod. Fert. 37:135.

Roche, J.F. 1977. Control of oestrus in dairy cows with a synthetic analogue of $PGF_{2\alpha}$ (Estrumate). Am. Soc. of Anim. Sci. 69th Annual Meeting.(abstract). P. 202.

Rodriquez, T.R., M.J. Fields, W.C. Burns, D.E. Franke, J. F. Hentges, W.W. Thatcher and A.C. Warnick. 1975. Breeding at a pre-determined time in the bovine following $PGF_{2\alpha}$ and gonadotrophin releasing hormone. J. Anim. Sci. 40:188 (abstract).

Rowson, L.E.A., R. Tervit and A. Brand. 1972. The use of prostaglandins for synchronization of oestrus in cattle. J. Reprod. Fert. 29:145 (abstract).

Saiduddin, S. 1964. Bovine pituitary content of gonadotrophin during postpartum anestrus. M.S. Thesis. Univ. of Nevada.

Saiduddin, S. and W.D. Foote. 1964. Pituitary luteinizing hormone activity of postpartum bovine. J. Anim. Sci. 23:592.

Saiduddin, S., M.M. Quevedo and W.D. Foote. 1968a. Response of beef cows to exogenous progesterone and estradiol at various stages postpartum. J. Anim. Sci. 27:1015.

Saiduddin, S., J.W. Rieson, W.J. Tyler and L.E. Casida. 1968b. Relation of postpartum interval to pituitary gonadotrophins, ovarian follicular development and fertility in dairy cows. Wis. Res. Bul. 270:15.

Sawhney, D.S. 1966. Pituitary and ovarian activities and interrelationships in beef cows before and after parturition. M.S. Thesis. Univ. of Nevada.

Schams, D. and H. Karg. 1969. Radioimmunologische bestimmung von prolaktin im blutserum von rind. Milchwissenschaft. 24:263.

Schefler, W.C. 1969. Statistics for the Biological Sciences. Addison-Wesley Pub. Com. Don Mills, Ontario.

Schultz, R.H. 1977. Synchronizing beef cows with Cloprostenol (multi-location trial). Am. Soc. of Anim. Sci. 69th Annual Meeting (abstract). P. 206.

Seguin, B.E., T.E. Kiser and H.D. Ritchie. 1975. Further trials with $PGF_{2\alpha}$ for estrous synchronization in beef cattle. Mich. State Univ. Res. Rep. 288:5.

Snedecor, G.W. and W.G. Cochran. 1973. Statistical Methods. 6th ed. The Iowa State Univ. Press. Ames Iowa.

Speroff, L. and P.W. Ramwell. 1970. Prostaglandin stimulation of in vitro progesterone synthesis. J. Clin. Endocr. 30:345.

Stelflug, J.N., T.M. Louis, R.C. Garewit, W.D. Oxender and H.D. Hafs. 1975. Luteolysis after $PGF_{2\alpha}$ in hysterectomized cattle. J. Anim. Sci. 41:380 (abstract).

Stelflug, J.N., T.M. Louis and B.E. Seguin. 1973. Luteolysis after 30 or 60 mg $PGF_{2\alpha}$ in heifers. J. Anim. Sci. 37:330 (abstract).

Stevenson, J.S. and J.H. Britt. 1977. Luteinizing hormone, estradiol and progesterone before first ovulation in postpartum cows. Am. Soc. of Anim. Sci. 69th Annual Meeting (abstract).

Swanson, L.V. and H.D. Hafs. 1971. Luteinizing hormone and prolactin in blood serum from estrus to ovulation in Holstein heifers. J. Anim. Sci. 37:330.

Tervit, H.R., L.E.A. Rowson and A. Brand. 1973. Synchronization of oestrus in cattle using $PGF_{2\alpha}$ analogue (ICI-79939). J. Reprod. Fert. 34:179.

Thatcher, W.W. and J.R. Chenault. 1976. Reproductive physiological reponses of cattle to exogenous $PGF_{2\alpha}$. J. Dairy Sci. 59:1366.

Thorburn, G.D. and J.R.S. Hales. 1972. Selective reduction in blood flow to the ovine corpus luteum after infusion of $PGF_{2\alpha}$ into a uterine vein. Proc. Aust. Phy. Pharma. Soc. 3:145.

Trimberger, G.W. and M.G. Fincher. 1956. Regularity of estrus, ,ovarian function and conception rates in dairy cattle. Cornell Univ. Agri. Exp. Sta. Bul. 911.

Tulchinsky, D. and G.E. Abraham. 1971. Radioimmunoassay of plasma estriol. J. Clin. Endocr. 33:772.

Turman, E.J., R.P. Wetteman, M.P. Fournier and T.D. Rich. 1976. Response of cows to pregnant mares serum gonadotrophin and $PGF_{2\alpha}$. J. Anim. Sci. 42:267 (abstract).

Turman, E.J., R.P. Wetteman, T.D. Rich and R. Totusek. 1975. Estrous synchronization of range cows with $PGF_{2\alpha}$. J. Anim. Sci. 41:382 (abstract).

Wagner, W.C. and W. Hansel. 1969. Reproductive physiology of the postpartum cow. I. Cinical and Histological findings. J. Reprod. Fert. 18:493.

Wagner, W.C. and S.L. Oxenreider. 1971. Endocrine physiology following parturition. J. Anim. Sci. Suppl. 1:1.

Warnick, A.C. 1955. Factors associated with the interval from parturition to first estrus in beef cattle. J. Anim. Sci. 14:1003.

Welch, J.A., A.J. Hacket, C.J. Cunningham, J.O. Heishman, S.P. Ford, R. Nadaraja, W. Hansel and E.K. Inskeep. 1975. Control of estrus in lactating beef cows with $PGF_{2\alpha}$ and estradiol benzoate. J. Anim. Sci. 41:1686.

Welch, R.A.S., H.A. Tucker, W.D. Oxender, S. Porteus and K.T. Kirton. 1975. Plasma prostaglandin at parturition in cows. J. Anim. Sci. 41:386 (abstract).

Wetteman, R.P., E.J. Turman and R. Totusek. 1976. Suckling intensity and reproduction in range cows. J. Anim. Sci. 42:267 (abstract).

Whitmore, H.L., W.J. Taylor and L.E. Casida. 1974. Effects of early postpartum breeding in dairy cattle. J. Anim. Sci. 38:339.

Wiltbank, J.N. 1970. Research needs in beef cattle production: improving reproductive performance. J. Anim. Sci. 31:755.

Wiltbank, J.N. and A.C. Cook. 1958. The comparative reproductive performance of nursed cows and milked cows. J. Anim. Sci. 17:640.

Wiltbank, J.N., W.W. Rowden, J.E. Ingalls, K.E. Gregory and R.M. Koch. 1962. Effect of energy level on reproductive phenomena of mature Hereford cows. J. Anim. Sci. 21:219.