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**STUDIES ON THE REPRODUCTIVE PERFORMANCE OF
DAIRY COWS IN NEW ZEALAND AND SOME FACTORS
WHICH MAY INFLUENCE REPRODUCTIVE EFFICIENCY**

*A THESIS PRESENTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF PHILOSOPHY
AT MASSEY UNIVERSITY*

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GENERAL ABSTRACT

This thesis is comprised of a series of studies on aspects of the reproductive performance of dairy cows in New Zealand.

The studies of ovarian activity in post-partum dairy cows by ultrasound examinations were conducted in a spring- and an autumn-calving herd. This study showed that there is seasonal variation in the initiation of post-partum ovarian function in dairy cows in New Zealand, and this influences some aspects of reproduction. The interval from calving to the first post-partum ovulation in the autumn-calving herd was significantly shorter than that in the spring calving herd. Other reproductive indices were shorter in the spring-calving herd. The mean milk progesterone concentration during the dioestrous phase (Day 7-16) of the normal first cycle for cows in the spring-calving herd was significantly higher than in animals in the autumn-calving herd. In addition, the mean number of follicles in each of the follicle-size categories from 11 days before the first ovulation in spring-calving cows was significantly higher than in autumn-calving cows. There were three wave-like patterns in the mean size of the largest follicle during the first normal cycle. The patterns of the mean number of each follicle category and the mean size of the largest follicle in cows which had a shortened first cycle were similar to those seen in the first two stages of a normal first cycle. The follicular patterns in cows which had a short first cycle were also the same as those in the first stage of a normal first cycle.

The use of gonadotrophin releasing hormone (GnRH) in post-partum anoestrous dairy cows in a spring-calving herd showed that the GnRH injection could induce luteinising hormone (LH) release and ovulations. The study of ovarian activity post-injection showed that the GnRH-induced LH release was associated with an increase in average number of medium follicles (MF's) and a decrease in large follicles (LF's) in the ovaries of treated cows. Treated cows ovulated 4.7 ± 2.6 days post-injection, while only one control cow ovulated on the equivalent of Day 5 post-injection. The reproductive indices in treated cows were improved, compared with untreated controls.

Oestrous behaviour was studied in a group of sixteen Taurindicus heifers (Sahiwal x Holstein Friesian crossbreds) after oestrus synchronisation treatment by using a CIDR (Control Intravaginal Drug Release) device. It was found that these animals preferred to be mounted rather than to mount when in oestrus. The mean interval from CIDR removal to the onset of oestrus was 31.5 ± 2.3 h, with the mean duration of oestrus (8.3 ± 1.9 h). The use of visual observation in combination with tailpaint scoring could detect all oestrous animals.

The DairyMAN programme was used to analyse breeding records from two intensively managed research dairy herds. Results from analyses produced by the programme were used to monitor and compare against standard or target values. The results showed that reproductive performance in the two herds was above target values. The increase in the use of hormonal treatment such as prostaglandin $F_{2\alpha}$ to synchronise oestrus and/or to increase fertility of a herd, concomitantly with improvement in oestrus detection efficiency, resulted in an increase in submission rates and conception rates in these herds.

Nutritional supply before and after calving can reduce reproductive performance of a herd. Relatively low reproductive performances were obtained in both herds during the 1985 season in which pasture growth was badly affected by climatic conditions. This was reflected in the lower occurrence of +PMH (behavioural oestrus events recorded before the mating period commences) in the No2 herd in 1985 (61%), compared with a target value of 85%, whereas the average of all 7 years was 80%. The conception rates of the herd were also affected as the first service pregnancy rate (PR) was only 43%, compared with a target value of 59%. The average of all 7 years was 56%. Relatively high reproductive performance was obtained in 1986. The submission rates (SR) at 3 and 4 weeks after Planned Start of Mating (PSM) were 94 and 100%, respectively, compared with target values of 90 and 100%, respectively. In addition, the occurrence of +PMH was high in 1986 (90%), compared with a target value of 85% and an average of all 7 years (80%). The first service PR was also high in 1986 (71%).

The proportional incidences of short return to service intervals (1-17 days) were high (32 to 57%) in the No1 herd which used natural mating, compared with 6 to 22% in the No2 herd which used artificial insemination.

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GENERAL INTRODUCTION

This thesis is presented as a series of projects in which some aspects of reproductive performance of cows in New Zealand dairy herds have been studied and described. It comprises four projects, and each project represents one chapter.

The first chapter specifically describes post-partum ovarian activity in autumn- and spring-calving cows. Ultrasonic examinations were performed in these animals to study ovarian follicular activity after calving, before and after first ovulation, and during the first cycle post-partum. Ovarian follicular patterns during these periods were also obtained.

The second chapter studies the use of gonadotrophin releasing hormone (GnRH) to induce ovulations post-partum in anoestrous cows in a spring-calving herd. Follicular patterns before and after GnRH injection were monitored and reproductive performance after treatment was compared with untreated controls.

Taurindicus animals (Sahiwal-Friesian crossbred) are produced in New Zealand specifically for tropical countries in South East Asia and South America. These animals have resistance to diseases, parasites and high temperature, and acceptable milk production. Previous reports showed that Taurindicus animals preferred being mounted by other cows than mounting other cows when they were in oestrus. Oestrous behaviour was studied in the taurindicus heifers by using visual observation and tailpaint scoring. This study is presented in Chapter 3.

The last Chapter concerns the use of the DairyMAN Programme which has been designed and developed in the Department of Veterinary Clinical Sciences, Massey University, New Zealand. The programme was used to analyse breeding records collected in the No1 and No2 herds at the Ruakura Agricultural Centre, Hamilton, New Zealand. Results from reproductive analysis reports produced by the DairyMAN Programme from these two herds were assessed. Important factors such as submission rate and oestrus detection which are known to influence fertility in terms of herd breeding management were also assessed.

CHAPTER 1

ULTRASONOGRAPHY

IN THE STUDY OF OVARIAN FOLLICULAR ACTIVITY

IN POST-PARTUM DAIRY COWS

ABSTRACT

Twenty-five autumn-calving dairy cows and twenty spring-calving cows were used to study ovarian follicular activity preceding and following first post-partum ovulation. These cows were scanned ultrasonographically from Day 7 post-partum until each cow had ovulated at least once. A milk sample was collected on each day on which an ultrasound examination occurred after the afternoon milking. Samples were tested for milk progesterone analysis by radioimmunoassay. Ovarian follicles were classified into 3 categories as: small(SF: 2-5mm in diameter), medium(MF: 6-9mm in diameter) and large follicles(LF: ≥ 10 mm in diameter). Total follicles(TF = SF + MF + LF) were also counted.

Based on the number of days post-partum at which first ovulation occurred, the cows in each herd were divided into 3 groups: cows which had a first ovulation within 30 days post-partum(OV1 ≤ 30 days pp), cows which had a first ovulation from 31-60 days post-partum(OV1-31-60 days pp) and those which had a first ovulation more than 60 days post-partum(OV1 > 60 days pp). The intervals between the first and second ovulations were also classified as: short(7-12 days), shortened(13-18 days), normal(18-24 days) or long cycles(> 24 days).

The interval from calving to first post-partum ovulation in the autumn-calving herd was significantly shorter than that in the spring-calving herd(23.7 ± 2.4 days vs 36.6 ± 4.1 days, $p < 0.01$). There were no differences in the interval from calving to first oestrus between the autumn- and spring-calving cows(41.6 ± 3.4 days vs 40.7 ± 3.9 days). The percentage of the spring-calving cows which showed oestrus at their first post-partum ovulation was higher than that of the autumn-calving cows(62.9% vs 45.4%). The spring-calving cows had a higher percentage of cows with a short first cycle(44.4%) than the autumn-calving cows(10%), while the autumn-calving cows had a higher percentage of shortened first cycles(30%) than the spring-calving cows(11.1%). Spring-calving cows which ovulated within 30 days pp had a higher percentage of short cycles(35%) than the autumn-calving cows(10%), while spring-calving cows had a lower percentage of normal first cycles(15%) than autumn-calving cows(40%).

There was a significant difference in the mean interval from Planned Start of Mating(PSM) to first service in the main herd between the autumn- and spring-calving herds(20.5 ± 1.9 days vs 15.0 ± 0.9 days, $p < 0.01$). The intervals from PSM to conception and first service to conception for the main herd were also significantly shorter in the spring herd(28.3 ± 1.5 days and 13.9 ± 2.6 days, respectively) than in the autumn herd(36.5 ± 2.9 days and 18.5 ± 2.6 days, respectively, $p < 0.001$).

In the autumn-calving herd, the mean numbers of SF's and TF's in cycling cows(CC) were significantly higher than those in non-cycling cows(NC)(19.0 and 22.8, compared with 16.3 and 19.3, respectively, $p < 0.0001$). There were no group x week interactions for the mean number of each follicle category and the mean size of LF's between CC and NC. The CC in the spring-calving herd had a significantly higher mean number of SF's and TF's than the NC(21.1 vs 19.3 and 24.7 vs 23.7, respectively, $p < 0.05$). The NC also had significantly higher mean numbers of MF's and LF's than the CC(3.0 vs 2.3 and 1.4 vs 1.3, respectively, $p < 0.005$). There were

significant group x week interactions in the mean number of SF's and TF's ($p < 0.05$) between CC and NC.

There were two peaks of the mean size of LF's during the first two weeks before the first ovulation, as seen clearly in cows which ovulated 31-60 days pp. It was observed that cows which ovulated within 20 days pp developed only one large follicle and this resulted in ovulation. The mean numbers of follicles in each category (SF's, MF's, LF's, TF's) 11 days before the first ovulation (Pre-OV1) in spring-calving cows were significantly higher than those in the autumn-calving cows.

There were three wave-like patterns in the mean size of the largest follicle during the first normal cycle. The patterns of the mean number of each follicle category and the mean size of the largest follicle in cows which had a shortened first cycle were similar to those seen in the first two stages of a normal first cycle. The follicular patterns in cows which had a short first cycle were also the same as those in the first stage of a normal first cycle.

The mean milk progesterone concentrations during the dioestrous phase (Day 7-16 of the normal first cycle) in the spring-calving cows, which had a normal first cycle, were significantly higher than those for cows in the autumn-calving herd ($23.3 \pm 1.7 \text{ ng/ml}$ vs $14.1 \pm 0.5 \text{ ng/ml}$, $p < 0.0005$).

One spring-calving cow (5%) and 3 autumn-calving cows (12%) developed cystic ovaries post-partum.

These results show that seasonality does occur in dairy cows in New Zealand and does influence aspects of their reproduction.

INTRODUCTION

Pasture is the main source of feed for animals in New Zealand. Its availability varies throughout the year because of climatic conditions which influence pasture growth patterns. Pasture hay or silage, conserved during periods of pasture surplus, is fed out during periods of low pasture supply.

The primary objective of the breeding programme in New Zealand seasonal dairy herds is to produce a calving pattern which is linked to pasture growth. Calving is therefore concentrated into the period which precedes an expected surplus of pasture growth. No cows in a seasonal dairy herd are milked for a 4 to 8 week period preceding the Planned Start of Calving(PSC) as lactations of almost all cows end on the same date in the preceding autumn. In seasonal dairy herds cows start to calve shortly before the date selected as the planned Start of Calving(PSC) and then over the ensuing 8 to 12 weeks. Calving is usually planned to commence in late winter, with a high proportion of cows calving during the ensuing 4 weeks after the PSC. The concentrated calving pattern will be the result of an intensive breeding programme in which most cows are detected in oestrus, inseminated and conceive within a 3 to 6 weeks period from the start of the programme. Late calving cows which conceive later in the breeding period must be induced to calve prematurely in order to maintain the condensed calving pattern. Therefore, the post-partum interval from calving to first ovulation and oestrus is of critical importance.

The Planned Start of Mating(PSM) is the selected date when the breeding programme commences. The PSM date is usually about 80 to 85 days after the PSC date. Premating Heat(PMH) dates are recorded for dairy cows in most herds before the breeding programme starts, so that non-cycling cows in the herd will be identified and treated. Tailpainting is commonly used to detect oestrus in most herds. When the breeding programme of a herd starts, cows which exhibit oestrus(irrespective of their calving date) are inseminated.

The terms, submission rate(SR) which is the proportion of cows presented for first insemination during the first 3 weeks of the PSM, and conception rate(CR) which is the proportion of cows conceived to first or subsequent inseminations, are important indicators of the seasonal breeding programme and consequently influence the conception pattern of the herd. The post-partum interval from calving to first ovulation and oestrus, and oestrus detection are also important factors which influence the SR and CR. The percentage of cycling cows in the herd is influenced by the length of post-partum anoestrus, and by the interval from actual calving date to the PSM date. Macmillan and Clayton(1980) have reported that the interval from calving to first recorded oestrus in New Zealand dairy cows is 47 to 50 days. As mentioned earlier, seasonal-calving cows have less than 80-85 days to cycle before the breeding programme starts. Early calving cows usually exhibit oestrus at least once before the PSM, while late calving cows have no chance to cycle before the PSM, or possibly are mated at first oestrus after the PSM. In addition, Macmillan(1985) has shown that cows which had at least one PMH before the PSM date, had pregnancy rates increased by seven percentage points.

In an autumn-calving herd (a town milk-supply herd), calving are planned throughout the year when feed supply during early lactation as in winter can be poor. These autumn-calving animals are relatively well fed during mid or late lactation in spring. The price for town-supply milk is higher than milk for processing into dairy products in spring-calving herds. The higher price for milk in a town-supply herd is to compensate farmers for higher production costs incurred for producing milk. This includes pasture hay or silage which is fed out to cows when supply of feed is limited in winter. When feed supply does not keep up with feed demand during early lactation and mating, the incidence of anoestrus will increase, contributing to the subsequent lower submission rates and conception rates (Macmillan, 1985). These will influence the conception pattern of the herd this season, and consequently the spread of the calving pattern next season.

The interval from the PSM date to mean first insemination date (MFID) and interval from the PSM date to mean conception date (MConD), are usually used to measure reproductive efficiency in seasonal dairy herds. The two parameters are influenced by oestrus detection efficiency and post-partum anoestrus (Macmillan, 1985). Whereas the interval from PSM to MFID in a herd with a high oestrus detection rate (100%) was 12 days, it was 16.2 days in a herd with an oestrus detection rate of 80%. The variable incidence of anoestrus in the herd will also delay the interval from PSM to MFID.

Hormonal treatments (for example, intravaginal progesterone devices (CIDR)) are used in treating anoestrous cows (usually late calving cows and poor condition cows) detected before the PSM. The use of these devices together with the improvement of oestrus detection reduce the interval from PSM to MFID and MConD.

The present study was conducted in both autumn- and spring-calving herds using ovarian ultrasonography and milk progesterone changes to study the following subjects:

1. To determine and compare the interval from calving to first ovulation in autumn-calving cows with that of spring-calving cows.
2. To determine the post-partum interval to first oestrus in the autumn- and spring calving cows by using tailpainting as a method for oestrus detection
3. To study ovarian follicular patterns in the autumn- and spring-calving cows preceding and following first ovulation.
4. To measure milk progesterone patterns preceding and following first ovulation.
5. To compare reproductive performance in the autumn- and spring-calving herds.

LITERATURE REVIEW

NEUROENDOCRINE REGULATION OF POST-PARTUM PITUITARY AND OVARIAN FUNCTION

During pregnancy, the hypothalamic-hypophyseal axis is suppressed by the high plasma concentrations of progesterone and oestrogen (Schallenberger *et al.*, 1985; Smith *et al.*, 1973; Thatcher *et al.*, 1980). These high concentrations inhibit the release of Gonadotropin Releasing Hormone (GnRH) from the hypothalamus, resulting in inadequate synthesis of Luteinising Hormone (LH) by the anterior pituitary gland and/or a decreased pituitary responsiveness to GnRH release (Schallenberger *et al.*, 1978). Therefore, the LH stored in the pituitary gland becomes depleted and the basal release of LH, as well as the frequency and/or amplitude of episodic release are decreased (Schallenberger *et al.*, 1978, Jenkin *et al.*, 1974). This, in turn, results in insufficient release of LH to stimulate ovarian activity immediately post-partum (pp).

From 1 to 2 weeks before calving there is a gradual fall in plasma progesterone. In the early post-partum period (Azzazi *et al.*, 1983), there is also a rapid fall in plasma levels of oestradiol-17 β leading to a removal of the suppressive action of these two hormones to the hypothalamo-hypophyseal axis. This results in a gradual increase in storage and secretion of GnRH from the hypothalamus (Schallenberger *et al.*, 1978) sufficient to stimulate the anterior pituitary gland to secrete LH for the resumption of ovarian activity.

The hypothalamic content of GnRH is less in cyclic cows than in post-partum cows (Braden *et al.*, 1983), suggesting that the release of GnRH may be inhibited during the post-partum period, leading to increased stores of GnRH. Moss *et al.* (1985) and Carruthers *et al.* (1980) also demonstrated that there was no significant difference in the content of GnRH in the same areas of the hypothalamus of beef cows between days 5 and 30 post-partum. However, Carter *et al.* (1980) reported that the anterior pituitary gland was insensitive to exogenous GnRH during the early post-partum period in cattle, and that the amount of LH released in response to GnRH decreased as the gestation period progressed, remaining low during the early post-partum period (Carter *et al.*, 1980). From these reports, it can be concluded that in the early post-partum period, the pituitary gland is less sensitive to the effects of GnRH, even though there is sufficient GnRH in the hypothalamus to stimulate the pituitary to secrete gonadotropins.

In contrast, Crowder *et al.* (1982) found that the number of GnRH receptors in the anterior pituitary gland was higher at day 1 and 11 after calving than during late gestation, or on days 22 and 35 after calving. Similarly, Cermak *et al.* (1983) and Moss *et al.* (1985) reported a transient increase in the number of hypophyseal receptors for GnRH during the early post-partum period (day 1 to day 15), but the number of receptors then returned to the lower level during the late post-partum period (days 20 to 45 after calving). These results suggest that the sensitivity of the pituitary gland to GnRH may not be reduced during the early post-partum period. Therefore, this regulatory portion (the hypothalamus) for the secretion of LH does not appear to be responsible for post-partum anoestrus.

Pituitary Content of Luteinising Hormone(LH)

The amount of luteinising hormone in the anterior pituitary gland in cattle dramatically decreases during pregnancy, and slowly increases during the post-partum period (Nett *et al.*, 1988; Moss *et al.*, 1985). This is because there are high concentrations of progesterone and oestradiol in the systemic circulation during pregnancy but these two hormones decrease dramatically after calving (Henricks *et al.*, 1972). In addition, the high concentrations of these two hormones are believed to have a negative feedback to the synthesis of LH by inhibition of GnRH release (Schallenberger *et al.*, 1978), resulting in a decreased amount of LH in the anterior pituitary gland during pregnancy and the early post-partum period. Crowder *et al.* (1982) reported a high correlation between the pituitary content of LH and the amount of GnRH-induced LH release in ewes. Furthermore, receptors for oestradiol and progesterone are present in both the hypothalamus and pituitary gland (Clark *et al.*, 1981; Wise *et al.*, 1986). From this, it can be suggested that these two hormones, alone or in combination, may be responsible for the decrease in pituitary stores of LH. Moreover, it is known that progesterone reduces the frequency of pulsatile LH release, whereas oestradiol inhibits the amplitude of LH pulses in ovariectomised ewes (Goodman and Karsch, 1980).

Moss *et al.* (1981) have shown that progesterone had no effect on the hypophyseal concentrations of LH, whereas oestradiol, alone or in combination with progesterone, resulted in a dramatic reduction in the pituitary concentrations of LH. In fact, they also reported that progesterone decreased the plasma concentrations of LH in ovariectomised ewes, but did not alter the pituitary content of LH or of GnRH receptors. In addition, as in the pregnant and in the post-partum animal, the reduction in pituitary content of LH was due neither to a lack of GnRH in the hypothalamus nor to a deficiency in the number of receptors for GnRH in the anterior pituitary gland. Similarly, when the anterior pituitary gland is under the influence of progesterone, the release of LH induced by GnRH is not decreased, whereas when under the influence of oestradiol, the GnRH-induced release of LH is dramatically diminished (Goodman and Karsch, 1980; Tamanini *et al.*, 1986). Azzazi and Garverick (1984) also reported that short-term administration of exogenous oestradiol-17 β during the early post-partum period stimulated LH release following GnRH, while longer administration inhibited pituitary LH response. From these results, it seems that the effects of oestradiol appear to be at the pituitary level, while the inhibitory effect of progesterone influences higher neural centers (e.g. hypothalamus) (Moss *et al.*, 1981).

Recovery of Anterior Pituitary Gland after Parturition

There is a dramatic decrease in the concentrations of oestradiol and progesterone in circulation after parturition (Henricks *et al.*, 1972). This removes the prolonged negative feedback effects of these hormones on the hypothalamo-hypophyseal axis and initiates gradually the recovery of gonadotrophic function in the pituitary gland. The sensitivity of the hypophysis to GnRH and LH concentration in the circulation gradually increases from calving to around day 10 post-partum (Webb *et al.*, 1980; Echterkamp and Hansel, 1973; Kesler *et al.*, 1977). Furthermore, in dairy cows there is an increased pituitary response in terms of LH release to exogenous GnRH by day 10 post-partum, compared with day 5 (Kesler *et al.*, 1977; Lamming, 1978), and the response is greater between 12 and 15 days after calving (Peters *et al.*, 1981). This means that once the recovery is complete, the animals could be ready to resume

normal oestrous cycles from 15 days post-partum if there is no restrictive factor. The development of pulsatile LH pattern is a prerequisite for the onset of ovarian activity post-partum (Peters *et al.*, 1981). However, Schallenberger *et al.* (1982) indicated that ovarian function (leading to resumption of regular normal oestrous cycles post-partum) is not restored until there is a balance of the hypothalamo-pituitary-ovarian axis.

A MODEL OF ENDOCRINE ACTIVITY IN THE POST-PARTUM COW (After Lamming *et al.*, 1982)

Based on the information reviewed above, it can be postulated that the physiological events leading to the initiation of cyclical ovarian activity in the post-partum dairy cow are :

- (1) that during late pregnancy, the high plasma progesterone and oestradiol levels suppress endogenous GnRH release and the pituitary responsiveness to endogenous GnRH release at the hypothalamo-pituitary axis (Schallenberger *et al.*, 1978), resulting in a depression of basal plasma gonadotropin levels and of ovarian follicular activity in the immediate post-partum period;
- (2) that immediately pre-partum there is a fall in plasma progesterone concentrations, and in the early post-partum period there is a dramatic fall in plasma levels of oestradiol-17 β leading to removal of the suppressive effects and resulting in restoration of pituitary sensitivity to GnRH (Kesler *et al.*, 1977). Pituitary FSH content decreases between days 1 and 20 post-partum while pituitary LH content increases (Saiduddin *et al.*, 1968). Sporadic endogenous GnRH release at infrequent intervals may give rise to transient LH release with a return to basal levels of LH but with increased FSH release, causing a more sustained rise in plasma FSH levels (Dobson, 1978, Schams *et al.*, 1978). Follicular growth during the early post-partum period results from FSH secretion;
- (3) that the transition to ovarian activity involves increased GnRH release leading to more frequent plasma LH episodes. The increased levels of LH stimulate ovarian follicular activity causing increased oestradiol secretion which stimulates pituitary responsiveness to GnRH. The increased oestrogen secretion from developing follicles exerts a positive feedback effect on LH secretion and LH episodic release (Echternkamp and Hansel, 1973, Stevenson and Britt, 1979);
- (4) that increased LH secretion, accompanied by sustained levels of FSH creates the final preovulatory stimulation for follicular maturation;
- (5) that oestrogen secretion finally increases sufficiently to induce a preovulatory LH surge, resulting in the first ovulation; and
- (6) that a preovulatory LH surge causing ovulation, with a consequent significant rise in progesterone, starts the first luteal phase post-partum.

Endocrine Regulation of Post-partum Ovarian Activity

During the early post-partum period when the recovery from the negative feedback effect is incomplete, the LH pulses are not sufficient to induce follicular maturation. For a period of time after the pituitary stores of LH return to a normal

level (complete recovery of hypothalamo-hypophyseal axis), pulses of LH released into the circulation by GnRH are sufficient to stimulate follicular growth, resulting in the secretion of oestradiol from ovarian follicles (Lamming *et al.*, 1982). It has been suggested that the first effect of oestradiol is to stimulate production of its own receptor in the hypothalamus and pituitary gland, thus increasing the sensitivity of these tissues to the positive feedback effects of oestradiol (Lamming *et al.*, 1982). In addition, the positive feedback of oestradiol results in a further small increase in oestradiol in the circulation for a short period, in contrast to the prolonged, and high concentrations during late gestation that produce a strong negative feedback effect (Schallenberger *et al.*, 1978). When GnRH pulse frequency increases, pulses of LH are stimulated and produced more frequently, leading to the final stage of follicular development and ovulation (Nett, 1987).

However, even though the hypothalamo-hypophyseal axis returns to normal within a short period of time after calving (within 2 weeks), there are many factors influencing LH secretion. For example, frequent suckling (Short *et al.*, 1972; Randel *et al.*, 1976), increased milking frequency (Peters *et al.*, 1981) and low nutritional status before and after calving (Butler *et al.*, 1981, Butler and Smith, 1989) suppress the secretion of LH.

Patterns of plasma LH and FSH in Post-partum Cow

Basal plasma FSH and LH levels are low immediately post-partum, with an absence of episodic release (Lamming *et al.*, 1982). FSH levels rise by day 5 with no major change thereafter, followed by increases in basal levels of plasma LH by day 10 with the appearance of pulse episodes (Lamming *et al.*, 1982). Differences in plasma FSH are not considered to be a limiting factor to the onset of ovarian activity (Lamming *et al.*, 1981). Similarly, Schams *et al.* (1978) observed varied FSH values, FSH fluctuations and irregular FSH peaks, with no characteristic features associated with the onset of cyclic ovarian activity or the occurrence of the first oestrus. However, LH profiles varied greatly between individuals in relation to the onset of regular patterns and peak LH values (Schams *et al.*, 1978).

Lamming *et al.* (1982) observed that there was an increase in the frequency and peak height of LH episodes immediately before the first preovulatory LH surge, which may relate to increases in pituitary responsiveness to endogenous GnRH and to more frequent episodes of endogenous GnRH release (Webb *et al.*, 1980; Lamming *et al.*, 1981). Peters *et al.* (1981) also observed that an LH pulse frequency of between 0.25-1.25 pulses/hour in the post-partum dairy cow commencing several days before ovulation (with pulse frequency) was negatively correlated with time to the first ovulation. It can be concluded that this pattern of increased frequency and peak height of LH release is likely to be important for the first ovulation and the occurrence of normal luteal function.

POST-PARTUM UTERINE AND OVARIAN FUNCTION

Prostaglandin F₂α and Uterine Involution

Maternal plasma progesterone concentrations decline gradually before parturition due to increased placental metabolism to convert progesterone to androgens and oestrogens. In addition, elevated oestrogen concentrations may initiate corpus luteum regression because oestrogens are known to stimulate the release of uterine

prostaglandin $F_{2\alpha}$ (PGF $_{2\alpha}$) in cyclic heifers (Eley *et al.*, 1979; Eley *et al.*, 1981) as determined by high concentrations of PGFM (13,14-Dihydro-15-keto-PGF $_{2\alpha}$, which is the major PGF $_{2\alpha}$ metabolite) in peripheral plasma (Edqvist *et al.*, 1978). A major increase in the concentrations of PGFM in plasma occurs from 1 to 4 days post-partum, declining to basal concentrations by 2-3 weeks post-partum (Edqvist *et al.*, 1978; Eley *et al.*, 1981; Guilbault *et al.*, 1984; Thatcher *et al.*, 1980; Lindell *et al.*, 1982; Kaser *et al.*, 1984). The increases in PGFM are associated with maternal and foetal placental membrane expulsion. The decrease in uterine horn diameter has been correlated with the decrease in post-partum PGFM concentrations (Eley *et al.*, 1981; Lindell *et al.*, 1982). Thatcher *et al.* (1982) also proposed that higher concentrations of PGFM were associated with a faster rate of uterine involution.

After the calf and foetal membranes have been expelled, normal uterine involution proceeds. There are three overlapping processes to uterine involution: uterine contraction, loss of tissues, and tissue repair. An increased secretion of PGF $_{2\alpha}$ prior to parturition persists for 10 to 20 days post-partum (Edqvist *et al.*, 1978) with a significant negative correlation between the duration of elevated levels of PGF $_{2\alpha}$ post-partum and the time required to complete uterine involution (Lindell and Kindahl, 1983). The time required to complete involution is variable (Lindell *et al.*, 1982), and ranges from 26.2 to 47 days for dairy cows (Morrow *et al.*, 1969). Other studies (Marion *et al.*, 1968b; Gier and Marion, 1968; Wagner and Hansel, 1969) showed that final involution is complete by about day 40 after parturition.

Kindahl *et al.* (1982) have shown that cows without reproductive disorders, such as retained foetal membranes, had the shortest duration of elevated PGFM levels and the shortest uterine involution time, whereas animals with the disorders showed an opposite relation, long duration of PGFM release and long uterine involution time. Additionally, the exogenous injection of very high doses of PGF $_{2\alpha}$ during the early post-partum period may shorten the time required for uterine involution (Kindahl *et al.*, 1982).

Influence of the Uterus on Ovarian Function in Post-partum Cow

As mentioned above, the uterus is a major source of PGF $_{2\alpha}$ production during the post-partum period and oestrous cycle. Its action is to produce luteolysis of the corpus luteum during late pregnancy, leading to decreased progesterone levels and finally parturition. After parturition and during the early post-partum period the PGFM levels remain high until decreasing to baseline at 15-20 days post-partum in normally calving cows (Edqvist *et al.*, 1978; Thatcher *et al.*, 1980; Eley *et al.*, 1981; Guilbault *et al.*, 1984; Lindell *et al.*, 1982; Kaser *et al.*, 1984). Kindahl *et al.* (1982) indicated that the first post-partum ovulation seemed to occur irrespective of PGF $_{2\alpha}$ release profiles, although progesterone levels were elevated for the first time when PGF $_{2\alpha}$ levels were close to baseline. This means that no progesterone (P $_4$) increase occurs before PGF $_{2\alpha}$ levels have returned to low levels. Short oestrous cycles are much more frequent among cows ovulating soon after calving than in later ovulating cows. The short cycles also occur in late ovulating cows after the completion of the post-partum PGF $_{2\alpha}$ release (Kindahl *et al.*, 1982). Savio *et al.* (1990b) obtained different results that first short cycle occurred predominantly when the ovulatory dominant follicle was detected after Day 20 post-partum.

OVARIAN STEROIDS(OESTRADIOL-17 β AND PROGESTERONE)

Oestradiol-17 β

Concentrations of oestrogens(oestradiol-17 β and oestrone) of placental origin in the maternal blood plasma increase considerably in late pregnancy and are at their highest levels 24-48 hours before calving(Stellflug *et al.*, 1978). They fall after calving, but may vary widely before the first ovulation(Prakash and Madan, 1985; Pope, 1982). In addition, the peak levels of oestrogen which are also found before the first ovulation are at levels which nearly equal those in cycling cows before the onset of oestrus(Pope, 1982). This oestradiol-17 β is believed to be of follicular origin(Pope, 1982). While these high oestradiol-17 β levels during the early post-partum period vary among cows (Prakash and Madan, 1985; Pope, 1982), they seem unable to induce LH surges and ovulation because of the low sensitivity of the pituitary gland to GnRH and to sustained low levels of oestradiol. It has been proposed that the first ovulation is preceded by an LH surge(induced by a high oestradiol concentration with or without oestrous behaviour), and it is then followed by a period of elevated progesterone concentration(Lamming *et al.*, 1982).

The periodic occurrence of oestradiol-17 β peaks in the post-partum period before the first ovulation sometimes resembles that of the normal oestrous cycle, i.e. a preovulatory peak followed by a second, lower peak 6 days later as progesterone levels(P₄) rise (Pope, 1982). If the first period of elevated P₄ is brief, then the second rise in the oestradiol-17 β levels(P₄) may not lead to a subsequent decline but rather may increase further to become the first peak at the beginning of the new cycle(Pope, 1982). The oestradiol concentration declines and stays at low basal levels only when the P₄ levels are maintained as a typical normal luteal phase.

Progesterone(P₄)

Concentrations of plasma progesterone(P₄) are high throughout gestation and begin to decrease slowly during the final 3-4 weeks, before rapidly falling 2-3 days before parturition(Prakash and Madan, 1985; Smith *et al.*, 1973). P₄ concentrations are at basal levels during the early post-partum period(King *et al.*, 1976; Robertson, 1972; Schams *et al.*, 1978; Webb *et al.*, 1980). However, in most animals, there is a transient increase in plasma P₄ concentrations before a period of elevated P₄ concentrations. It has been suggested that this transient rise of P₄ may come from luteinised follicles(Tribble *et al.*, 1973).

The first period of elevated P₄ levels above basal concentrations occurs after an LH surge and the first ovulation(Webb *et al.*, 1980). Results from many studies by using milk and plasma progesterone have shown that there are two types of luteal phases after calving (Eger *et al.*, 1988; Kindahl *et al.*, 1982; Manns *et al.*, 1983; Ramirez-Gonidez *et al.*, 1982; Troxel *et al.*, 1983). The first luteal phase lasts for 6-12 days and is referred as the short luteal cycle, while the second is a luteal phase of normal duration, lasting for more than 14 days, (but accompanied by P₄ concentrations lower than normal).

SHORT OESTROUS CYCLES

A number of studies have extensively used progesterone profiles in milk (Bloomfield *et al.*, 1986; Bulman and Lamming, 1978, Lamming and Bulman, 1976) and in plasma (Radford *et al.*, 1978; Webb *et al.*, 1980) to determine ovarian activity in post-partum dairy cows. Kesler *et al.* (1980) and Lindell *et al.* (1982) reported that the mean first post-partum ovulation was approximately 20 days following parturition. Many studies have shown that short oestrous cycles frequently occur in the early post-partum period after the first ovulation (Duby *et al.*, 1985; Eger *et al.*, 1988; Kindahl *et al.*, 1982; Lamming *et al.*, 1981; Manns *et al.*, 1983; Odde *et al.*, 1980; Ramirez-Godinez *et al.*, 1982; Schams *et al.*, 1978) although they are rarely preceded by oestrus at first ovulation (Bloomfield *et al.*, 1986). However, Macmillan and Watson (1971) showed that 31.4% of short oestrous cycles of 8 to 10 days occurred after first insemination and the short cycle was most common among 3 year old cows.

Callahan *et al.* (1971) reported an increase in the first cycle length of 24 days in metritic cows compared to 18 days in normal control cows. Fagan and Roche (1986) showed the incidence of short cycles in dairy cows in Ireland was 4%.

Eger *et al.* (1988) found that the rate of short luteal cycles (< 11 days) was 54%, 24% and 20% in the first, second and third-fifth luteal cycles post-partum, respectively. Bloomfield *et al.* (1986) reported that the resumption of post-partum ovarian activity of 34% of cows in commercial dairy herds was preceded by short periods of progesterone secretion. Peters and Bosu (1987) showed that 60% of cows exhibited short oestrous cycles (6 to 14 days long) following the first ovulation post-partum.

Many researchers studying post-partum ovarian activity have suggested factors which may produce short oestrous cycles post-partum. For example, Kindahl *et al.* (1982) suggested that post-partum prostaglandin release may be the cause of the high incidence of short luteal cycles when the first ovulation occurred relatively early post-partum. Other studies suggested that the first short luteal cycles result from an inadequate formation of the corpus luteum which may be through insufficient blood supply for the first corpus luteum (Schams *et al.*, 1978) or insufficient LH availability (Niswender *et al.*, 1976). Alternatively, the corpus luteum may lose its ability to secrete progesterone because of failure to respond to gonadotrophic stimulation resulting in early regression (Manns *et al.*, 1983). Donaldson *et al.* (1970) and Robertson (1972) suggested that the first short luteal cycles post-partum may originate, in part, from luteinisation of follicles.

It has also been suggested that post-partum corpus luteum dysfunction occurs because of inadequately prepared or defective follicles (Braden *et al.*, 1989; Odde *et al.*, 1980), or lack of LH receptors on the granular cells rather than inadequate concentrations of LH (Inskeep *et al.*, 1988; Lamming *et al.*, 1981), or lower concentrations of oestradiol-17 β in the fluid from preovulatory follicles (Garcia-Winder *et al.*, 1987). Lamming *et al.* (1981) suggested that this may produce an increased sensitivity of the newly formed corpus luteum to PGF_{2 α} , or an excessive production of uterine PGF_{2 α} . Peters and Bosu (1987) and Gross *et al.* (1985) found that lack of luteotrophic stimulation was not a factor in the occurrence of short cycles post-

partum. Peters and Bosu(1987) also found that there were persistent uterine infections in some post-partum cows with short cycles and they concluded that post-partum uterine infections with gram-negative bacteria may stimulate further production of prostaglandin from the endometrium, leading to premature lysis of the corpus luteum and short cycles. Similarly, Schirar and Martinet(1982) and Kindahl *et al*(1984) observed that short luteal phases in the post-partum cows might be related to the contemporary involutionary status of the uterus and to patent or latent infection-induced release of luteolytic factors originating from the regenerating endometrium.

Since Lishman *et al*(1979) reported that subnormal luteal function occurred in anoestrous beef cows following a GnRH injection, Kesler *et al*(1981) have shown that corpora lutea from anoestrous cows, following GnRH-induced ovulation, did not produce as much progesterone in vitro in response to LH as corpora lutea from normally cycling animals.

The study of Macmillan and Watson(1971) indicated that the occurrence of return intervals of around 9 days was not the consequence of errors in oestrus detection produced by the cows experiencing a behavioural suboestrus. They also found that the incidence of short oestrous cycles increased with increasing herd size and was most common among second calving cows(3 year olds).

FACTORS INFLUENCING THE RESUMPTION OF OVARIAN CYCLE POST-PARTUM

Several studies have identified important factors influencing the resumption of ovarian activity post-partum in dairy cows. It is obvious that each factor mentioned below, could delay the first ovarian cyclic activity post-partum by influencing pulsatile secretion of LH after the normal sequence of recovery events during the immediate early post-partum period(Terqui *et al.*, 1982, Lamming *et al.*, 1982, Schallenberger, 1985, Schallenberger and Walters, 1985, Imakawa *et al.*, 1987, Butler and Smith, 1989).

1. Post-partum Uterine Infections

Post-partum uterine infections have been reported to affect post-partum reproductive function. For instance, Rudder *et al*(1981) showed that a pathogenic synergism between *Corynebacterium pyogenes* and *Fusobacterium necrophorum* may cause an increased severity of post-partum uterine infections and subsequently have a detrimental effect on the resumption of oestrous cyclicity and on conception date. Peters and Bosu(1987) also concluded from their result that post-partum uterine infections with gram-negative bacteria may stimulate further production of prostaglandin from the uterus, resulting in premature lysis of the corpus luteum and short cycles. They also proposed that post-partum uterine infections did not directly affect ovulation. Their effect is through the inflammatory process and/or release of endotoxin from the gram-negative bacteria which stimulate prostaglandin synthesis. Prolonged increased levels of PGFM have been shown to be related to endometritis(Watson, 1984).

In normal cows, first post-partum ovulations occur after prostaglandin levels return to or near basal levels(Kindahl *et al.*, 1982; Kindahl *et al.*, 1984). In fact, in

some cows ovulations may take place before prostaglandin concentrations have returned to basal levels (Kindahl *et al.*, 1982). Fredriksson *et al.* (1988) showed that repetitive PGF_{2 α} injected to mimic the post-partum prostaglandin release in cyclic cows interfered with corpus luteum formation and also inhibited ovulation.

Cows with persistent uterine infections post-partum have a longer duration of elevated levels of prostaglandins and a longer duration of uterine involution (Lindell *et al.*, 1982). Lindell *et al.* (1982) and Fredriksson *et al.* (1985) also found that there is a significant correlation between the duration of elevated prostaglandins and the duration of completed uterine involution in cows without complicated puerperia.

It is known that cows which ovulated and developed a corpus luteum in the early post-partum period were more prone to develop pyometra (Olson *et al.*, 1984). In addition, the incidence of pyometra increased when exogenous GnRH was used to induce early post-partum ovarian activity in dairy cows (Etherington *et al.*, 1984). Uterine infections occur most frequently during the immediate post-partum period and the incidence is reduced thereafter.

The incidence of retained placenta in dairy cows ranges from 2 to 11 % (Bretzlaff *et al.*, 1982; Moller *et al.*, 1967; Erb *et al.*, 1958; Roberts, 1986). It has been shown that retained placentae are closely related to post-partum uterine infections (Bretzlaff *et al.*, 1982; Roberts, 1986). There is a high incidence of retained placental membranes in cows induced to calve prematurely (Bolte *et al.*, 1977; Day, 1979; Grunert, 1984; Kesler *et al.*, 1976; Welch *et al.*, 1979). Cows with calving difficulties such as dystocia and big calves are predisposed to retained placenta (Vandeplasse and Martens, 1961; Roberts, 1986). Retained placenta and uterine infections were reported to be associated with a decreased rate of uterine involution (Laster *et al.*, 1973; Marion *et al.*, 1968; Morrow *et al.*, 1966), resulting in a longer interval to first oestrus (Erb *et al.*, 1958). However, Welch *et al.* (1979) showed that there were no significant differences between induced cows and untreated herd mates calving at similar times, in days from calving to first oestrus (38 vs 39 days).

Callahan *et al.* (1971) showed that cows with metritis and cystic ovaries had the longest interval from calving to first ovulation (33 days) compared to 29, 21 and 17 days in cystic, metritic and control cows, respectively. In addition, cows with abnormalities such as dystocia, retained placenta, metritis and acute diseases have an increased interval from calving to first oestrus (Morrow *et al.*, 1966).

2. Suckling

Many studies have shown that the first post-partum ovulation and/or oestrus are delayed in both suckling dairy and beef cows (Lamming *et al.*, 1982; Lamming *et al.*, 1981; Lamming, 1978; Peters and Riley, 1982). The first post-partum ovulation was 60 days in suckling beef cows (Peters and Riley, 1982) compared with 20 days in milked cows (Lamming *et al.*, 1982). In addition, frequently suckled cows were reported to have a longer interval to first ovulation and first oestrus than those which were machine milked or single suckled. There was a longer delay before an increase in basal LH levels or the development of LH episodes (Carruthers *et al.*, 1978; Lamming *et al.*, 1982; Radford *et al.*, 1978; Randel *et al.*, 1976; Smith *et al.*, 1977). Short *et al.* (1972) showed that mastectomised cows had a shorter interval than that of non-suckled cows, suggesting that there is an inhibitory influence from the udder influencing the resumption of ovarian activity acting on the hypothalamic-pituitary

axis. In fact, removal of the suckling stimulus by calf removal results in increased mean plasma LH concentrations and an increased GnRH-induced LH response (Troxel *et al.*, 1980). Carruthers *et al.*(1978) showed that there were differences in pituitary responsiveness to exogenous GnRH between suckled and non-suckled cows during the early post-partum period, despite the fact that the hypothalamic content of GnRH did not differ between the two groups. It has also been shown that suckling suppresses the pulsatile LH secretion by its effect on reducing GnRH secretion from the hypothalamus (Carruthers and Hafs, 1980; Carruthers *et al.*, 1980).

3. Season and Climate Effects

Seasonal factors affect fertility by increasing the interval from calving to first oestrus in the winter and spring (Montgomery *et al.*, 1980; de Kruif, 1978; Boyd, 1977). Spring calving cows had a longer interval from calving to first ovulation than autumn calving cows (Bulman and Lamming, 1978; King and Hurnik, 1982a; King and Macleod, 1984; Hansen and Hauser, 1983, Peters and Riley, 1982). Hansen and Hauser(1983) also showed that LH secretion during the post-partum period in intact cows was not different with varying photoperiod.

Friesian cows in a tropical climate have a longer interval from calving to first ovulation than those in the temperate zone(Terqui *et al.*, 1982). Season of calving was reported to influence the resumption of ovarian cycles even at constant high plane of nutrition(Mongomery *et al.*, 1985).

The influence of season on the secretion of LH in the absence of ovaries has been reported by Critser *et al.*(1983). Concentrations of LH fluctuated, with higher concentrations detected during winter-spring months than during summer and fall months. They also found that concentrations of LH were higher in oestradiol-treated cows. Day *et al.*(1986) found that the seasonal fluctuation in LH concentrations was the consequence of cyclical changes in the amplitude of LH pulses. Season did not influence the frequency of LH pulses. However, McNatty *et al.*(1984) showed that in intact cows, frequency of LH pulses was lower in winter than in spring.

4. Milk Yield

Marion and Gier(1968), Spalding *et al.*(1975) and Stevenson and Britt(1979) have reported a correlation between the post-partum interval to ovulation or oestrus and milk yield, while Bulman and Lamming(1978) found no relationship between these two variables. Butler *et al.*(1981) also concluded that milk yield was not closely related to days to first ovulation during the first 20 days of lactation, because negative energy balance occurred during this period until peak milk yield, and then began returning towards zero. Ovulation occurred approximately 10 days after net energy balance began returning toward zero. Whitmore *et al.*(1974) and Eley *et al.*(1981) found that cows with high milk yield had a longer interval to first post-partum ovulation than control cows. In addition, Eley *et al.*(1981) also showed that a more gradual decline in PGFM plasma levels occurred during the post-partum period in high yielding cows. Bulman and Lamming(1978) observed that high yielding cows often stopped cycling spontaneously.

King(1968) and Boyd(1977) suggested that it is difficult to separate the effects of milk yield from other factors, especially nutritional status. For example,

high yielding cows in early lactation are often unable to maintain positive energy balance (Coppok *et al.*, 1974).

5. Nutritional Status

Several studies have reported the relationship between nutrition and reproductive function in dairy cattle (Butler and Smith, 1989, Swanson, 1989, Butler *et al.*, 1981, Terqui *et al.*, 1982). Nutritional factors that have been reported to influence dairy cow fertility include nutrient intake, energy balance, body condition and live weight change. In addition, overfeeding and underfeeding before and after calving are well-documented to impact on post-partum reproductive performance.

5.1. Nutrient intake

5.11. Underfeeding

Underfeeding during early lactation increases the severity of a negative energy balance, increasing the interval to first ovulation (Terqui *et al.*, 1982). In addition, they reported that plasma LH and FSH concentrations in beef cows were significantly lower in underfed cows on day 5, 15 and 30 post-partum and that endogenous GnRH release decreased in underfed nursing beef cows. Imakawa *et al.* (1987) showed that energy restriction in ovariectomised heifers resulted in reduced LH pulse frequency and higher pulse amplitude. However, results from Butler and Smith (1989) showed that the first post-partum ovulation occurred in dairy cows when energy balance was still negative, but began returning towards zero.

5.12. Overfeeding

Cows that are overconditioned in late pregnancy are at a greater risk of milk fever, digestive disturbance and ketosis (Fronk *et al.*, 1980). In addition, these cows have decreased feed intake and more severe negative energy balance in early lactation than those that have moderate body condition. Butler and Smith (1989) showed that overfeeding and moderate overconditioning at calving do not adversely affect reproductive performance, especially days to first ovulation and days to first observed oestrus. However, a number of studies reported that overfeeding during early lactation, or the dry period or both increased the incidence of retained placenta (El-Keraby and Schilling, 1976), metritis (Whitmore *et al.*, 1974), cystic ovaries (MacCormack, 1987) and prolonged the post-partum interval to first ovulation and oestrus (El-Keraby and Schilling, 1976; Whitmore *et al.*, 1974). High milk potential and overcondition before and after calving are recognised as predisposing factors to the "fatty cow" syndrome (Fronk *et al.*, 1980; Reid *et al.*, 1979; Roberts *et al.*, 1981).

5.13. Weight and body condition loss

Body condition scoring is an important means for determining the relative fatness or body condition of cows. It has been used to link reproductive performance to inadequate nutrition in early lactation in dairy cows. Butler *et al.* (1981) showed an association between body weight, body condition loss and the severity of post-partum negative energy balance with a prolonged interval to the re-initiation of ovarian cyclicity. Grainger *et al.* (1978) related body condition at calving to the interval from calving to first oestrus and found that the interval decreased by 5-6 days for each

increase in condition score between scores 3 and 6. Similarly, McGowan(1981) also used the same indicator and showed that each additional unit of condition at calving reduced the interval to first oestrus by 6 days.

5.2. Energy balance

The rate of increase in milk production in dairy cows exceeds the rate of feed intake during early lactation, resulting in negative energy balance. Energy balance is defined as the relationship between dietary energy intake and energy utilisation. This negative balance is directly related to the interval to first ovulation post-partum(Butler *et al.*, 1981). Cows in negative energy balance lose body weight because body reserves are mobilized as an energy source to maintain and increase milk yield. The extent of loss of body weight has also been shown to relate to increased days to first ovulation(Stevenson and Britt, 1979; Sejrsen and Neimann-Sorensen, 1982). In fact, cows respond to negative energy balance by either increased feed intake or by mobilizing body reserves or both.

5.3. Protein

Several studies have shown that high protein rations may have detrimental effects on fertility in cattle(Jordan and Swanson, 1979; Ferguson and Chalupa, 1989). Gould(1969) indicated that cows fed high protein rations had an increased incidence of anoestrus and reduced conception rates. It is possible that high protein rations during peak lactation may indirectly affect post-partum interval in dairy cows. In addition, it has been hypothesised that excess ammonia absorbed from the rumen produces biochemical, endocrinological and tissue derangements; and secondly, that excess absorbed protein alters the balance of net protein and net energy resulting in a relative energy deficiency(Chalupa, 1984; Visek, 1984). Lastly, ammonia may alter the function of the hypothalamo-hypophyseal-ovarian axis(Ferguson and Chalupa, 1989).

Decreased protein intakes are due to poor protein rations and normally related to energy deficit or poor quality roughage. Cows fed with low crude protein rations had increased days to first observed oestrus compared with those fed with higher protein rations(Jordan and Swanson, 1979), but the conception rate effect was reversed.

5.4. Vitamins and minerals

Several vitamins and minerals may influence fertility and their effects have been reviewed by Hurley(1989).

Vitamin A is necessary for normal epithelial development in all species. Vitamin A deficiency is related to infertility by increasing the incidence of retained placenta. Folman *et al*(1987), Bremel *et al*(1982) and Ducker *et al*(1984) showed that excess **B-carotene** in rations had an adverse effect on fertility while others concluded that B-carotene could improve fertility(Ascarelli *et al.*, 1985; Snyder and Stuart, 1981).

Vitamin E and selenium deficiency were shown to be associated with a high incidence of retained placenta and metritis in some herds. Selenium deficiency alone may also be associated with increased incidence of retained placenta, metritis, follicular cysts and early embryonic death.

Phosphorus has been implicated in situations of anoestrus, silent oestrus and low conception rate in dairy cows. Results of phosphorus-restricted diets have been shown to sometimes affect reproductive performance by decreased conception rates(Call *et al.*, 1987; Carstairs and Morrow, 1980).

Calcium is the mineral needed for the growth of the skeletal system and lactation. Feeding high levels of calcium(200mg daily) and supplemental vitamin D in early lactation may hasten uterine involution and resumption of ovarian activity.

Molybdenum supplementation has been shown to delay the onset of puberty, decrease conception rate and cause anovulation and anoestrus in cattle(Phillippo *et al.*, 1987). These effects of molybdenum are believed to be associated with a decreased LH release.

Other minerals such as potassium, iodine, copper and manganese, when deficient, have also been shown to affect reproduction by delaying puberty and ovulation(potassium), and by reducing ovarian activity and conception rates or increasing the incidence of abortion(iodine, copper and manganese).

6. Ovarian Cysts

Ovarian cysts are defined as anovulatory follicular structures of at least 25mm in diameter that persist for at least 10 days in the absence of a corpus luteum.

The incidence of ovarian cysts has been reported to be from 5.6 to 18.8%(Bierschwal, 1966; Morrow *et al.*, 1966; Whitmore *et al.*, 1974; Britt *et al.*, 1977) in American dairy cattle. Whitmore *et al.*(1974) reported that 71% of the ovarian cysts developed within 45 days post-partum, especially before the first ovulation. However, the incidence of ovarian cysts may be even higher, because 60% of cows that develop ovarian cysts before the first post-partum ovulation may not be detected because the cysts are luteinised spontaneously, and then ovarian cycles occur(Morrow, 1966; Kesler *et al.*, 1979a).

The factors causing ovarian cysts are not well-understood. However, several studies have shown that they occurred during the early post-partum period because follicular development and subsequent oestradiol synthesis during this time may not be sufficient to induce an LH surge(Erb *et al.*, 1971), and the hypothalamic-pituitary axis may not be responsive in releasing an ovulatory surge of LH in response to oestradiol(Kesler *et al.*, 1977; Kesler, 1979a; Zaied *et al.*, 1981). Anovulatory follicles then become bigger and cystic follicles are formed. From the studies of Kesler *et al.*(1979a), it seems that the post-partum interval to first ovulation was delayed about 18 days in cows that developed ovarian cysts even though the interval from calving to follicular development was similar for cows that subsequently ovulated and cows that developed ovarian cysts.

Similarly, the cause of ovarian cysts that develop in cows after the first cycle is also not known. It has been suggested that the causes contributing to the cysts included subnormal availability of pituitary LH to induce ovulation(Erb *et al.*, 1971), a deficiency in synthesis or release of GnRH(Seguín *et al.*, 1976), or an endocrine imbalance(Wiltbank *et al.*, 1961; Nadaraja and Hansel, 1976; Erb *et al.*, 1973; Cupps, 1971).

7. Age Effect

A New Zealand field study showed that there was a higher incidence of anoestrus due to ovarian inactivity in first and second calvers compared with mature cows (Fielden *et al.*, 1973). In fact, twenty-one percent of the two-year old cows were presented for veterinary examination because of an anoestrous condition, compared with eighteen percent and ten percent for three-year old cows and older cows, respectively. In addition, Moller (1970) has shown that 2- and 3-year old dairy cows had longer intervals to first ovulation than adult cows. Macmillan and Clayton (1980) also showed that first calving heifers had an interval to the first post-partum oestrus which was 9 to 12 days longer than in mature cows. Stress from milking in the first lactation as well as negative energy balance during early lactation in these first calving heifers increased the interval from calving to first oestrus, and slowed the initiation of ovarian cyclicity. For example, the average interval to first oestrus in mature Jersey cows at Ruakura Agricultural Centre, Hamilton, New Zealand, was 47 days compared with 56 days in first calving heifers (Macmillan and Clayton, 1980).

8. Breed Effect

Breed may also affect post-partum ovarian activity. For example, a Ruakura study (Macmillan and Clayton, 1980) showed that the interval to first oestrus in mature Friesian-Jersey crossbreds was 50 days compared with 47 days in mature Jersey cows, 56 days for Jersey heifers and 63 days in Friesian-Jersey crossbred heifers.

DETECTION OF OESTRUS

Detection of oestrus is the major factor affecting reproductive efficiency in dairy cattle (Esslemont, 1974). Direct visual observation is the most common method used in detecting oestrus in most dairy herds. The time spent observing oestrus is usually inadequate and many attempts have been made to develop oestrus detection methods in order to increase oestrus detection rates. Several techniques have been used to aid oestrus detection, taking into account ease of use, effectiveness, accuracy and cost for practical application. In addition, the duration and intensity of oestrous behaviour is variable, and behavioural interactions change continuously (O'Farrel, 1975; Esslemont and Bryant, 1976). Tail painting is used as an aid in detect oestrus in grazing cows with seasonal calving patterns (Macmillan and Curnow, 1977; Williamson, 1980a) when many cows are in oestrus, and Sexually Active Groups (SAG) are formed. Some studies, used mounting activity of surgical vasectomised bulls (Donaldson, 1968), or hormone-treated cows or steers (McDonald *et al.*, 1976; Sawyer and Fulkerson, 1981; Stevenson and Britt, 1977). One method, not based on mounting activity, measured vaginal mucus electrical resistance (McCaughey and Paterson, 1981) to detect oestrus in cows staying in stanchion barns. Pedometers have also been used to measure the increased activity of cows at oestrus (William *et al.*, 1981). Milk progesterone techniques have been developed and have been widely used to detect post-partum ovulation events and oestrus in dairy cows (Mather *et al.*, 1978; Bulman and Lamming, 1978).

Williamson *et al.* (1972) compared the methods of oestrus detection and found that the percentage of cows detected in oestrus by heat mount detector patches, team observation 24 hours per day, herdsmen checking twice daily, and two dairymen checking at milking time were 98%, 89%, 56% and 56%, respectively. In addition, results from Mather *et al.* (1978) and Williamson *et al.* (1972) showed that the animals not detected in oestrus were cycling and had displayed signs of oestrus. Failure to detect oestrus results in lower submission rates and consequently reduced conception rates.

Silent oestrus is common at the first ovulation soon after calving, and oestrus detection rates increase with the number of post-partum ovulations (Fonseca *et al.*, 1983; King *et al.*, 1976; Lamming *et al.*, 1981; Moller, 1970; Morrow, 1969; Stevenson and Call, 1983; Helmes and Britt, 1985). For example, Fonseca *et al.* (1983) found that intervals to first ovulation were about 21 days for Holstein cows and only 12 % of the first post-partum ovulations were associated with detected oestrus. The detection rates increased by an average of 10 % at each subsequent oestrus. Results from Moller (1970) and King *et al.* (1976) showed the percentages of cows that showed oestrus at first ovulation were 57% and 50%, respectively. Additionally, result from Morris *et al.* (1976) showed that by using a television system the percentage of cows in free-stalls showing oestrous symptoms at first, second and third ovulations were 39, 94 and 100, respectively which were higher than those of tie-stall cows (16, 50 and 61, respectively). The lower detection rates at the first ovulation may be related to a true absence of oestrus, or reduced duration and/or intensity of oestrus and/or physiological, biochemical or environmental factors (seasonal effect ?), or interval from calving to first ovulation (or short oestrous cycles post-partum preceded by expressed oestrus). Malven (1984) proposed that the increased probability of behavioural oestrus with the number of post-partum ovulations may result from: (a) prior exposure to progesterone; and, (b) a longer period of recovery from pregnancy and/or metabolic adjustments to lactational drain.

OVARIAN FOLLICULAR DEVELOPMENT

Folliculogenesis can be defined as the formation of graafian (mature, preovulatory) follicles from a pool of primordial (non-growing) follicles (Erickson, 1966). The pool of primordial follicles remains stable, averaging 133,000 follicles from birth until about the fourth year of life, but numbers then subsequently decline until approximately 3,000 remain in the ovaries of cows which are 15 to 20 years of age. Erickson (1966) also separated growing follicles into two groups: preantral and antral. The numbers of preantral growing follicles are constant in cows until 4 years of age, and then declined in accordance with the decrease in primordial follicles. In contrast, antral follicle numbers remained constant in cows to 10 year of age, and then declined to less than 50% at 15 to 20 years of age. Follicular growth to 1.0 mm in diameter is rapid, and the development from 1.0 to 12 mm in diameter is continuous (Marion *et al.*, 1968)

Measurements such as numbers of various size follicles and mean sizes of various types of follicles have been used to assess follicular growth patterns in cattle (Dufour and Roy, 1985; Marion *et al.*, 1968) by using micromorphological measurement (Lussier *et al.*, 1987). Ultrasonography has been recently developed to study reproductive organs in animals (See ultrasonographical review). However, the limitation of this technique is an inability to measure follicular size less than 1 mm in diameter (5.0 Hz frequency) when compared with the micromorphological technique. The equipment for ultrasonography is also expensive.

Numbers of antral follicles within a particular size category or stage of growth are related to:

1. the rate of progression of growing, preantral follicles into the pool of antral follicles;
2. the rate of growth of these antral follicles into a larger size category; and
3. the rate of atresia of these follicles from a large-size category into a smaller-size category.

Follicular Development during Post-partum Period

Matton *et al.* (1981) found that most large follicles in the ovaries of cyclic cows persist on the ovarian surface for at least 5 days between day 3 (oestrus = day 0) and day 13 of the oestrous cycle. After day 13, most of these large follicles disappear (or turn over), again within a 5-day period, and are replaced by new, previously small follicles. Growth of medium-sized follicles (3-6 mm in diameter) occurs only when the largest antral follicle fails to continue its growth. It has been suggested that the largest antral follicle present on the ovary after day 17 enlarges as oestrus approaches (Ireland and Roche, 1983) and finally ovulates (Dufour *et al.*, 1972; Matton *et al.*, 1981).

In post-partum cows, follicular growth and development increase considerably after the first week post-partum (Kesler *et al.*, 1980; Wagner and Hansel, 1969; Morrow *et al.*, 1969). Results from Spicer *et al.* (1983) indicate that large follicles (> 8

mm) are present on the ovarian surface as early as day 7 post-partum. The average number of small follicles(3-5mm) decreased, while the number of large follicles(> 10mm) increased with increasing days post-partum and the number of medium follicles(6-9mm) remains unchanged(Ireland and Roche, 1987; Lucy *et al.*, 1990a). Lucy *et al.*(1990a) also showed that the number of small and medium-sized follicles decreased when the net energy balance began returning towards zero, suggesting that small follicles move into larger-sized follicles. However, the mean interval from parturition to having ovarian follicles of 5 to 10 mm in diameter was about 15 to 16 days(Kesler *et al.*, 1978). This means that these animals could be ready to ovulate, since the follicle that is destined to ovulate from among those about 10 mm in diameter, increases to the ovulatory size of 16 to 20 mm within 24 hours (Marion *et al.*, 1968). However, these follicles may not ovulate, and consequently undergo atresia. Another follicle may grow and take over as the major source of oestradiol and be sufficient to induce a preovulatory LH surge and ovulation (Spicer and Echterkamp, 1986).

FSH may stimulate some follicular development resulting in increased oestradiol levels. This may trigger the positive feedback and accelerate LH and FSH release up to a normal amplitude and frequency of pulsatile release. Oestradiol levels do trigger the final preovulatory LH surge leading to ovulation and the initiation of the first cycle. In the case of anovulatory follicles, it is probable that the oestradiol produced by the large antral follicles is insufficient to induce a preovulatory LH surge, and/or the responsiveness of the pituitary gland to GnRH is less in the early post-partum period(Garverick *et al.*, 1980; Eley *et al.*, 1981). Dufour and Roy(1985) also suggested that there is growth of small antral follicles into larger follicles from day 15 to 25 post-partum in dairy cows. The number of small follicles(3-5mm) and medium follicles(6-9mm) decreased when energy balance began returning towards zero, while numbers of large follicles(10-15mm) increased(Lucy *et al.*, 1990). Nevertheless, the rate of turnover of large antral follicles during the post-partum period is not known.

Kesler *et al.*(1979) showed that ovulation occurred approximately 2.4 days after the occurrence of the first follicle with a size of 10 to 20 mm, and corpora lutea of 15 mm in diameter were detected within 8 days. The interval to the first ovulation in those studies was about 19 days in dairy cows(Stevenson and Call, 1983; Stevenson and Britt, 1979; Marion and Gier, 1968).

Progesterone assays(Radioimmunoassay) in milk, plasma and serum have been extensively used to monitor post-partum ovarian activity in dairy cows (Eger *et al.*, 1988; Lamming, 1978; Lamming and Bulman, 1976; Henricks *et al.*, 1972; Manns *et al.*, 1983; Mather *et al.*, 1978). These studies used the first sustained rise of progesterone to indicate the post-partum re-establishment of cyclical ovarian activity after the first ovulation. Results obtained by Pope(1982), which included post-partum progesterone and oestradiol-17 β patterns, showed that there was a small rise in progesterone levels which was believed to be from luteinised follicles preceding the first ovulation(Triple *et al.*, 1973). Concurrent high oestradiol-17 β levels had also been found before the first progesterone rise had occurred. However, Castenson *et al.*(1976) observed that luteinisation had occurred in only one out of eight heifers.

Follicular Development during the Oestrous Cycle

The preovulatory follicle is the largest follicle present on either one of each pair of ovaries 3 days before oestrus (Dufour *et al.*, 1972). Results from Ireland and Roche (1983) showed that the growth and atresia of follicles occurred over at least 2 periods between days 3-13 of the oestrous cycle. One was during days 3-7 when a single O-A follicle (Oestrogen active), 6mm or more in diameter developed, and all other O-I follicles (Oestrogen inactive) regressed. The second was between days 7-13 when the O-A follicle from day 7 became an O-I follicle and regressed, and another O-A follicle developed. Recently, Sirois and Fortune (1988) studied the dynamics of the large follicles (> 5mm in diameter) throughout the oestrous cycle. They found that most heifers had three waves of follicular growth during the oestrous cycle, with the third wave resulting in ovulation.

Ovarian follicular population during the oestrous cycle

After ovulation, there are patterns of growth and regression of ovarian follicles in each category or stage of the oestrous cycle. A number of studies involving ultrasound examinations have shown the patterns of follicular populations of various categories during the oestrous cycle (Pierson and Ginther, 1984; Savio *et al.*, 1988). Small-sized follicles were found to be highest at the beginning of the oestrous cycle (day 3) than other stages (Matton *et al.*, 1981). The increase in number of small follicles after ovulation or oestrus may result from the effect of FSH (Schams *et al.*, 1977) which has a peak coincident with the preovulatory surge of LH (Kesner and Convey, 1982), and the second peak which is found just after ovulation (Baird and McNeilly, 1981).

The large number of medium-sized follicles after the increase in number of small follicles might have resulted from growth of small follicles present earlier in the cycle. In addition, the follicle that becomes dominant might inhibit the growth of small follicles (Matton *et al.*, 1981). Quirk and Fortune (1986) also found that bovine follicular fluid suppressed plasma concentrations of FSH, presumably due to the action of inhibin.

ULTRASONOGRAPHY

Diagnostic ultrasonography has been extensively used to study the reproductive tract in large animals (Pierson and Ginther, 1984, 1987; Reeves *et al.*, 1984). It allows dynamic structures to be visualised in the living animal when previously surgical techniques and/or removal of the structure for further investigation were necessary. It also allows monitoring of dynamic changes of reproductive structures, such as the ovarian follicular population during the oestrous cycle (Pierson and Ginther, 1987), during early pregnancy (Pierson and Ginther, 1986), and the interactions between the conceptus and the uterus (Kastelic *et al.*, 1988). Diagnostic ultrasonography has also been used in embryo transfer not only to evaluate follicular population and ovarian responses to superovulation regimens but also to evaluate the reproductive tract of recipients, including diagnosing pregnancy and embryonic loss (Curran *et al.*, 1986). The appearance of the bovine conceptus has been monitored ultrasonographically from the day an embryonic vesicle was first detected (day 11.7) through to day 60 (Curran *et al.*, 1986). The technology has been used to diagnose embryonic death or even detect pathologic conditions of the reproductive tract in animals (Curran *et al.*, 1986; Edmondson *et al.*, 1986; Fissore *et al.*, 1986; Ginther and Pierson, 1984).

Ultrasound Scanner

Ultrasound machines used for studying the reproductive tract of large animals are B-mode, real time and linear-array scanners.

The term "**B-mode**" refers to brightness modality, in which the ultrasound imaging is a two-dimensional display of dots.

The term "**real-time imaging**" refers to the "moving" display on the screen when the structures move in a manner in which the reflected echoes are recorded continuously; for example, the foetal heart beat and foetal movement.

The term "**linear-array**" refers to the examining field, and the two-dimensional image displayed on a screen which is rectangular in shape. The image represents a longitudinal sample of tissue with respect to the body, whereas the sector transducer refers to the pie-shaped display on the screen and the image represents a cross-sectional sample of tissue.

Ultrasound Waves

Ultrasound waves, like audible sound waves, are emitted from the original source (a transducer), travelling through tissue, reflected from tissue interface, received by the original source (the transducer) and processed into an image. Ultrasound waves, unlike the audible sound waves, are longitudinal waves that are emitted in one direction and consist of a wavelength, an amplitude, a frequency and speed (velocity).

The **wavelength** is the distance encompassed by an area of compression and rarefaction.

The **frequency** is the number of wavelengths or cycles that pass a given point in the

medium per second. It is measured in hertz(Hz) or megahertz(Mhz) units.

The amplitude is the strength or power of the ultrasound waves.

The speed or velocity is the time required for a wavelength to pass a given point and is determined by the characteristics of the medium. For example, in soft tissue, the speed for ultrasound waves is approximately 1540 metres per second. In other words, ultrasound is defined as any sound that has a frequency of at least 20,000 Hz.

Instrumental Components of a Ultrasound Scanner

An ultrasound scanner is composed of a transducer and a console.

The transducer contains the piezo-electric crystals that emit the ultrasound waves and receive the reflected echoes. It is connected by a cable to the console where the reflected echoes from the transducer are processed. Most of the transducers which have been used in the study of the reproductive tract in cattle and horses are designed for intrarectal manipulation.

The console contains components for providing electric signals to activate the piezo-electric crystals in the transducer(the pulser), processing the reflected signals from the transducer(the receiver), and displaying the resulting information on a viewing screen(the digital scan converter).

Production of Ultrasound Waves

When the ultrasound scanner is switched on, the pulser provides electric signals to vibrate the piezo-electric crystals in the transducer, resulting in acoustic ultrasound waves from the transducer. The ultrasound waves can be manually directed through the tissues by moving the transducer in various directions. Tissues have abilities to propagate or reflect the waves in various degrees. The reflected echoes from the tissues are received by the same piezo-electric crystals in the transducer and are processed by the receiver where the reflected signals are amplified. The processed signals are then converted into electric impulses by the digital scan converter and the resulting information displayed on the ultrasound screen.

Ultrasound Image on the Screen

The characteristics of tissues appearing on the ultrasound screen represent the echogenicity of the tissues by shades of grey, black and white.

Liquids such as follicular fluid which are non-echogenic, do not reflect ultrasound waves, so that the image on the screen appears black. Dense tissues, such as bone, reflect most of the ultrasound waves and appear white on the screen. Other tissues appear on the screen according to their echogenicity.

Attenuation

As ultrasound waves pass into tissues, they undergo modifications by tissue acoustic impedance and tissue interfaces. The interaction of ultrasound wave with tissue interfaces creates four phenomena.

1. **Reflection:** When ultrasound waves pass into tissues and cross an interface (a boundary between tissues that have different density), a proportion of the waves are reflected perpendicularly back to the transducer in relation to the tissue acoustic impedance, while the rest of the waves continue to deeper tissues to send back reflections at other tissue interfaces.

2. **Refraction:** It is a phenomenon that occurs when ultrasound waves cross tissues with different acoustic velocities, resulting in the bending of the ultrasound waves and decreasing the intensity of reflection. This commonly occurs when the waves pass from soft tissues into fluid-filled structure and appear as an artifact below the lateral edge of the structures.

3. **Scatter:** This phenomenon occurs when the ultrasound waves strike an irregular or small portion of tissue; only a small portion of the waves are reflected back to the transducer. The rest of the waves are reflected in different directions.

4. **Absorption:** This is a phenomenon that the ultrasound waves lose energy in the form of heat when they pass into tissues.

Resolution

Ultrasound resolution is the ability of an ultrasound pulse to produce distinctions between two closely spaced reflections.

1. **Axial resolution** is a measure of the ability to show two interfaces when they are slightly separated along the direction of the ultrasound beam. The shorter the axial resolution, the better the image. High-frequency transducers give better axial resolution because of the shorter pulse.

1. **Lateral resolution** is a measure of the ability to show two interfaces when they are slightly separated transversely to the direction of the ultrasound beam. Lateral resolution can be applied to either the width or thickness of the beam. The greater the space between the two reflections, the better the lateral resolution.

Interpretation of Images on the Ultrasound Screen

Interpretation of the ultrasound images on screen is an important skill for an ultrasonographer, apart from the correct ultrasound scanning technique. It requires not only knowledge of the relationships between tissues and echoes, but also the ability to distinguish true and artifactual images on the screen. Artifacts may lead to misinterpretations for either normal or pathological structures, especially during imaging of the reproductive tract, due to bowel gas, fluid-filled structures and pelvic bone. However, some artifacts such as specular and non-specular reflections can help obtain better interpretation. Other reflections such as reverberations may confuse the image.

Artifacts that are commonly found during imaging reproductive tract include:

1. **Specular reflections** occurring when a small portion of the pulse that strikes both upper and lower layers at the interfaces of a fluid-filled structure which is smooth and spherical, result in a highly echogenic reflection on the ultrasound screen. The specular reflections appear as bright and highly echogenic areas on the upper and

lower surfaces of the structure and are parallel to the surface of the transducer;

2. Non-specular reflections occurring when a pulse strikes a rough interface, or an interface that is narrower than the pulse. Examples are small interfaces between parenchymal cells and the surrounding small vessels. This phenomenon is also called "scatter"(as mentioned previously), resulting in grey-scale image on the screen. It may help to distinguish one tissue from another; for example, the corpus luteum can be identified from surrounding stromal tissue;

3. Acoustic shadow artifacts produced when ultrasound waves are blocked, decreased or deviated by either reflection or refraction at dense interfaces such as bones, soft tissues or gas-filled bowels. Shadows will appear underneath;

4. Enhancement or through-transmission artifacts arising when the ultrasound waves pass through fluid-filled structures such as follicles or embryonic vesicles, and the ultrasound waves are not attenuated while passing through the fluid compared to those passing through the surrounding tissues. The relatively greater strength of the ultrasound waves strikes the lower layer of the fluid-filled structure and creates a relatively brighter echoes underneath the structure.

5. Reverberation artifacts commonly found during the examination of a reproductive tract when there may be a gas-filled structure in the intestines. Large returning echoes from tissue(gas-filled structure) cause an echo to form at the transducer face, and then re-enter the tissue and cause the second echo to be displayed twice as far from the original acoustic interface and possibly repeated multiple times within the image(Herring and Bjornton, 1985). The three distinguishing features used to identify reverberation artifacts are that:

- (i) they are equidistant;
- (ii) they gradually diminish in intensity; and
- (iii) they are oriented parallel to the reflective interface.

Ultrasonic Morphology of the Ovary

Ultrasonography can be used as a diagnostic tool in detecting, monitoring and evaluating follicles and corpora lutea in large animals especially in cattle and mares(Ginther and Pierson, 1984). Ultrasound images of the ovary comprised ovarian stroma, follicles and corpora lutea.

Follicles

Follicles were non-echogenic, like other fluid-filled structures, and appeared as spherical black areas. Frequently, follicular images appeared as spherical black areas caused by compression either between adjacent follicles or a follicle and luteal tissue or stroma. Occasionally, the compression of the rectal probe against the follicular walls could distort the follicular shape. Some of the apposed walls of similar-sized adjacent follicles were straight. The apposed walls in groups of follicles, especially two or more medium or larger-sized follicles sometimes were too thin to detect, causing irregular shape of follicles.

The other non-echogenic areas such as the non-luteinised central portion of a corpus luteum or cross sections of blood vessels could be confused with follicles. However, follicles were usually distinguished by a well-defined, relatively smooth

outline. Follicles as small as 1 or 2 mm could be distinguished in the ultrasound images of the 5-MHz transducer.

Corpus luteum

The bovine corpus luteum has an echogenic texture differing from ovarian stroma (Pierson and Ginther, 1984). Ultrasonic images of corpora lutea with a well-defined border were visible approximately 3 days after ovulation. The newly formed corpus luteum is less echogenic, with more shades of dark grey than the later-staged corpus luteum. This is because the newly formed corpus luteum has relatively less tissue density.

Some corpora lutea contained fluid-filled areas ranging from 2-20mm in diameter. The fluid-filled areas were irregular in shape or multilobular in appearance. The presence of the central cavity occurred during the period of maximum size and did not significantly affect the length of the interovulatory interval (Pierson and Ginther, 1988).

MATERIALS AND METHODS

EXPERIMENTAL FARMS

This study was conducted using animals from two dairy farms(No1 Dairy and No4 Dairy) at Massey University, Palmerston North, New Zealand.

1. Massey University Dairy Farm No1

This farm had an autumn calving-town supply herd. It was situated near the Manawatu river, with a milking area of about 117.0 ha, and an effective area of about 113.0 ha. Soil types included Rangitikei loam sand, Manawatu silt loam, Manawatu sandy loam and Karapoti B. sandy loam. There were about 170 cows milked in this herd. The Planned Start of Calving(PSC) was the 10th of March, and the Planned Start of Mating(PSM) was the 1st of June.

2. Massey University Dairy Farm No4

This farm was a spring calving-seasonal supply herd. The milking area was about 137 ha, with an effective area of about 99 ha. Soil types included Tokomaru silt loam and Ohakea silt loam. There were 2 milking herds; Holstein Friesian cows in one herd and Jersey cows in the other herd. The Friesian herd comprised about 270 milking cows. The Planned Start of Calving(PSC) of this herd was the 1st of August, and the PSM date was the 23rd of October, 1989.

The study using the animals from the Massey Dairy Farm No1 started on the 30th of March, 1989 and finished on the 21st of May, 1989, while that in the Massey Dairy Farm No4 started on the 4th of September 1989 and ended on the 26th of October, 1989.

ANIMAL SAMPLES

Autumn Calving Cows

Twenty-five post-partum Friesian cows which had calved normally were divided into 5 groups based on calving date and age. Each group consisted of animals aged 2 years (first lactation), 3 years(2nd lactation) and more than 3 years (mature cows) which had either the same calving date or had calving dates spread over a few days. Coloured neck-bands were used to identify the cows in each of the study groups. Most cows calved between 11th of March and 3rd of April, 1989(Table 1.1).

Spring Calving Cows

Twenty post-partum Friesian cows were divided into 4 groups based on calving dates and age(The same as those of the autumn herd). Most cows calved between the 27th August and 31st August, 1989(Table 1.2).

PROCEDURES

The reproductive tract of each cow was examined by rectal palpation to detect any abnormality during the first week post-partum. Tail paint (Coopers Tailpaint, Wellington, New Zealand) was applied to each cow after examination. Each cow was condition scored at weekly intervals from calving until the end of the study period. Cows from the No4 herd were weighed fortnightly. Cows were observed for oestrous behaviour in the milking shed and the yards during the morning and afternoon milking. The study cows were also monitored by determining the extent to which tail paint was removed at each afternoon milking and during ultrasound examination. Groups of cows were drafted out after the afternoon milking and examined by rectal ultrasound probe from soon after calving, following the schedule shown in Table 1.1 and Table 1.2 and until each cow had ovulated at least once. Some cows were scanned until their second ovulations.

Milk Sample Collection

A milk sample (2 ml) was collected into a plastic vial on each day on which an ultrasound examination occurred, either after the afternoon milking or at the time of the ultrasound examination. Milk samples were frozen and stored at -10°C for subsequent milk progesterone (P_4) analysis by radioimmunoassay (RIA).

Farm insemination records were used to estimate date of ovulation weekly for animals that neither ovulated nor displayed oestrus during the study period. Milk samples were also collected from these animals for a month after the end of the main study period.

Ultrasound Examinations

A real time, B-mode, diagnostic ultrasound scanner (an Aloka Echo Camera, multicrystal scanner, Model SSD-210DX) equipped with an electronic linear-array, 5-MHz and 5.6cm length transducer designed for transrectal examinations in cattle and horses was used for ovarian examinations. A videotape recorder (National VHS, Model AG-6200-EN, Matsushita Electric Industries Co. Ltd, Japan) was connected to the scanner so that output from the ultrasound examinations was recorded on tape.

The uterus and ovaries were located after faecal material had been removed from the rectum. The transducer was then soaked with lubricant, inserted into the rectum and positioned directly dorsal to the ovary. The ovary then was scanned by moving the transducer in at least two planes; first in a medial-lateral direction and secondly in an anterior-posterior direction across the surface of the ovary to scan the entire ovary. Scanning the surface of the ovary did not always show visual images of all the follicles present in the ovary on the screen. At each scanning the number and location of follicles on each ovary found were recorded. Selected ovarian images of each ovary were frozen and recorded. The frozen images then were reviewed and photographed.

Each group of cows was scanned ultrasonographically on a schedule shown in Table 1.1 and Table 1.2. After each day of ultrasound examination, the videotape

of the ultrasound examinations was reviewed on a specific video cassette recorder (Panasonic AG-6200) monitored with a 14-16 inch screen television set. The numbers and locations of follicles on each ovary were recorded on an ovarian map. The size of each follicle was measured (based on the maximum diameter) and then classified as small (2-5mm), medium (6-9mm) or large follicles (>9mm). The measurements of follicular diameters were made at the interface between the follicular wall and follicular fluid and did not include the follicular wall. Diameters of follicles that were not spherical, were estimated by averaging the longest and shortest diameters. The length and width of corpora lutea and the ovaries were also measured and recorded. After each review of a day's results comparisons were made with those from the previous days. Then the numbers of follicles within each size category were counted and recorded.

VALIDATION OF ULTRASONIC MEASUREMENTS OF FOLLICULAR DIAMETERS

It has been shown that there is a linear relationship between the diameters of follicles measured by ultrasonography and the diameter of the same follicles measured after dissection from the ovaries (Quirk et al., 1986, Pierson and Ginther, 1987).

Because ovarian images appearing on the TV monitor screen while reviewing videotapes were not the same size as on the scanner screen, a conversion ruler was made by measuring the 1-cm scale along the edge of the monitor image and dividing it equally into 10 smaller scales so that one small unit equalled 1 mm. Thus equivalence was achieved between the monitor image and the original scaled scanner image.

CRITERIA FOR ESTIMATING THE DAY OF OVULATION

Milk progesterone concentrations were used to monitor ovarian function, and the evidence combined with follicular patterns to determine the day of ovulation.

1. Ovulation was considered to have occurred on the day following confirmed oestrus (when tailpaint had been removed), if the milk progesterone concentration was also at baseline (less than 1-2 ng/ml) on the day of oestrus and was followed by a sustained increase to more than 2 ng/ml.

2. When oestrus was not observed but tailpaint had been removed, ovulation was considered to have occurred on the day that a large follicle on one ovary had disappeared and the progesterone level had declined to less than 2 ng/ml.

3. When the animal was not detected in oestrus and did not show supplementary signs of oestrus at the first ovulation, ovulation was estimated to have occurred on the day that a large follicle on one ovary had disappeared when the progesterone level was less than 2 ng/ml but subsequently increased to more than 2 ng/ml.

4. When ovulation did not occur on the day of ultrasound examination, the progesterone levels at the two examinations between which ovulation had occurred were used in combination with follicular patterns during these days to estimate the day of ovulation.

Table 1.1. Schedule of ultrasound examinations of autumn calving cows from the Massey Dairy Herd No1.

Gr	Cows	Age	Calving date	Days post-partum for examination
1	Y2	2	18/3/89	7,14,16,18,20,28,35,37,39,41,49
	Y160	4	18/3/89	
	Y242	3	17/3/89	
	Y263	5	18/3/89	
	Y275	7	19/3/89	
2	R9	5	10/3/89	7,14,21,23,25,27,35,42,44,46,48,56,58,60,62
	R20	3	11/3/89	
	R31	2	10/3/89	
	R89	4	11/3/89	
	R121	4	11/3/89	
3	B22	3	13/3/89	7,14,21,28,30,32,34,42,44,46,48,56,58,60,62
	B54	2	14/3/89	
	B258	4	14/3/89	
	B273	5	13/3/89	
	B288	3	12/3/89	
4	M58	3	26/3/89	7,9,11,13,21,28,30,32,34,42,49
	M69	2	25/3/89	
	M156	14	25/3/89	
	M165	4	25/3/89	
	M227	5	25/3/89	
5	G3	2	27/3/89	7,14,21,23,25,27,35,37,39,41,51,53,55
	G59	5	28/3/89	
	G65	2	29/3/89	
	G138	5	27/3/89	
	G168	4	27/3/89	

Table 1.2. Schedule of ultrasound examinations of spring calving cows from the Massey Dairy Herd No4.

Gr	Cows	Age	Calving date	Days post-partum for examination
1	Y124	7	27/8/89	7,10,14,16,18,20,24,28,30,32,34,38,42, 44,46,48,52,56
	Y273	2	27/8/89	
	Y279	5	27/8/89	
	Y309	4	27/8/89	
	Y394	9	27/8/89	
2	G217	3	28/8/89	7,10,14,16,18,20,24,28,30,32,34,38,42, 44,46,48,52,56
	G383	5	28/8/89	
	G412	6	28/8/89	
	G429	2	28/8/89	
	G433	5	28/8/89	
3	M137	9	29/8/89	7,9,11,13,17,21,23,25,27,31,35,37,39, 41,45,49,51,53,55
	M205	3	29/8/89	
	M236	7	28/8/89	
	M380	2	29/8/89	
	M399	5	29/8/89	
4	B206	7	31/8/89	7,9,11,13,17,21,23,25,27,31,35,37,39, 41,45,49,51,53,55
	B308	6	31/8/89	
	B379	3	3/9/89	
	B401	8	30/8/89	
	B423	2	30/8/89	

MILK PROGESTERONE RADIOIMMUNOASSAYS

Whole milk samples were assayed for progesterone concentrations in duplicate by direct antibody radioimmunoassays(RIA) as described by Dobson et al.,(1975).

Procedures of Milk Progesterone Radioimmunoassays

1. Whole milk samples were thawed at room temperature and vortexed.
2. 20 μ l of milk samples and 20 μ l each of aliquots of standard progesterone concentrations(containing 0, 0.625, 1.25, 2.5, 5, 10, 20, 40 and 80ng/ml in buffers) were added to labelled plastic tubes in duplicate.
3. The aliquots of the standards were then dried down under air .
4. 20 μ l of a "zero" milk progesterone sample(from ovariectomised cows) was added to each of the standard tubes and blank for background.
5. A mixture of antisera(1:3000; courtesy by J.T.France, National Women's Hospital, Auckland), progesterone tracer working dilution(4000 CMP/100 μ l; The Radiochemical Centre, Amersham, U.K.) and PBSEG buffers(the ratio of antisera : tracer : buffer is 1:1:4, respectively) of 600 μ l/tube were added to each tube.
6. The tubes then were vortexed and incubated overnight at 4°C.
7. After incubation, 600 μ l of charcoal suspension in PBSEG buffer(2.5% W/V charcoal, Norit A; A.H. Thomas Co., Philadelphia, U.S.A.) was added rapidly at 4°C into the batches of incubated tubes , vortexed and incubated at 4°C within 12 minutes from commencing the additions.
8. The tubes were then centrifuged at 3000 rpm for 10 minutes at 4°C.
9. The supernatant containing protein-bound progesterone was then decanted into scintillation glass vials.
10. 6 ml of scintillation fluid(Toluene-triton mixture) was added and the mixture was placed in a scintillation counter(Beckman LS 7500) for 2 minutes.
11. Results from the counter were then used to calculate progesterone levels.
12. Pools of milk progesterone samples(P11, P100 and P269) were also located at the start and at the end of the aliquots of "unknown" milk samples of the aliquots.

Table 1.3 shows the amounts of solution in the aliquots.

Table 1.3. The aliquots of milk progesterone radioimmunoassays

Tubes	Milk Samples (μ l)	Antisera (μ l)	Tracer (μ l)	Buffer (μ l)	Charcoal (μ l)
Blanks	20(zero pool)	-	100	500	600
Totals	-	100	100	1000	-
Standards	20(zero pool)	100	100	400	600
Samples	20(unknown)	100	100	400	600
milk pool samples	20(P11, P100,P269)	100	100	400	600

Milk Progesterone Assay Determination

The mean assay sensitivity of milk samples from cows in the Massey University Dairy No1 was 0.43ng/ml(n = 18). The intra-assay coefficients of variation were 24.62%, 14.32% and 13.05%, while the inter-assay coefficients of variation were 22.9%, 13.8% and 19.82% for milk pool samples P11, P100 and P269, respectively. The mean assay sensitivity of milk samples from cows in the Massey University Dairy No4 was 0.40ng/ml(n = 13). The intra-assay coefficients of variation were 21.67%, 10.51% and 21.23% while the inter-assay coefficients of variation were 22.59%, 10.29% and 20.1% for milk pool samples P11, P100 and P269, respectively.

DATA ANALYSIS

Results of the reproductive indices of cows from the two herds were analysed by Panacea Database Program(Pan Livestock Inc., Reading, United Kingdom). One-way Analyses of Variance(ANOVA) were used to compare differences between the mean reproductive indices, the mean number of each follicle category between age groups and days examined in the week, and differences between the two herds. General Linear Models Procedure of SAS(Statistical Analysis System, SAS Institute Inc., 1985, 1986, 1987, Cary, NC 275 12-8000, USA) were used to analyse the mean number of each follicle category between cycling and non-cycling cows. The models included treatment (cycling and non-cycling cows), weeks post-partum, follicular sizes(SF, MF, LF and LF size) and treatment x week.

Ovarian maps from each cow's ovaries were drawn at each examination. The number of SF's, MF's, LF's, TF's and the size of largest follicle on the ovaries(LF size) were counted and compiled individually, concomitantly with the levels of milk progesterone. The presence or absence of a corpus luteum was also recorded. In calculating days before and after ovulation(Pre-and Post-OV), the day of ovulation of each animal was determined and then the dates of examinations before and after ovulation were used to calculate days Pre-and Post-OV for analysis of the mean

number of small follicles(SF), medium follicles(MF), largest follicles(LF), total follicles(TF), the mean size of the largest follicle(LF) and milk progesterone levels(P_4). Then data were converted from Panacea Database Program into Statgraphics(STSC Graphic Software System Version 2.13, Inc., Maryland, USA). Scattergrams from this Program were used to graph follicular patterns and progesterone levels during pre- and post-ovulation periods of cows in spring and autumn herds. Progesterone levels of individual cows that had a short first cycle post-partum from Massey Dairy No4 herd were also graphed. Bar graphs from Slidewrite Plus Version 3.10(Advanced Graphics Software, Inc., Suite 105 Sunnyvale, USA) were used to diagrammatically represent the post-partum interval to first ovulation for cows in both herds.

DEFINITIONS OF SOME TERMS USED IN THE TEXT

Planned Start of Calving(PSC) is the date when the calving period in a seasonal dairy herd is expected to commence and is 282 days after the first day of the seasonal breeding programme.

Planned Start of Mating(PSM) is the date when the mating process in a seasonal dairy herd is planned to commence. The cows are detected in heat and mated after the PSM date irrespective of their previous calving date.

Submission Rate(SR) is the proportion of cows that are submitted for a first service by a defined time from the PSM date. The most common periods used are either 21 days or 28 days after the PSM date.

A short cycle is an interval between the first post-partum ovulation and the second ovulation of from 7 to 12 days.

A shortened cycle is an interval between the first ovulation and the second ovulation post-partum within the range of 13 to 18 days.

A normal cycle is an interval between the first ovulation and the second ovulation post-partum within the range of 19 to 24 days.

Based on the number of days post-partum at which first ovulation occurred, the cows examined in each herd were divided into 3 groups:

1. **OV1 \leq 30 days pp** comprised cows which had a first ovulation within 30 days post-partum(Early post-partum ovulation).
2. **OV1 = 31-60 days pp** comprised cows which had a first ovulation from 31-60 days post-partum(Late post-partum period).
3. **OV1 > 60 days pp** comprised cows which had a first ovulation more than 60 days post-partum.

A cycling cow(CC) is one which had luteal tissue detected on one of its ovaries by ultrasonography, provides that this occurred after the largest follicle disappeared and was followed by a sustained rise in the milk progesterone levels.

A non-cycling cow(NC) is one in which luteal tissue was not detected by ultrasonography, and the milk progesterone levels were consistently below 2ng/ml.

P11, P100 and P269 are pools of known milk samples with average progesterone concentrations of 11.5, 42.4 and 18.0 ng/ml, respectively.

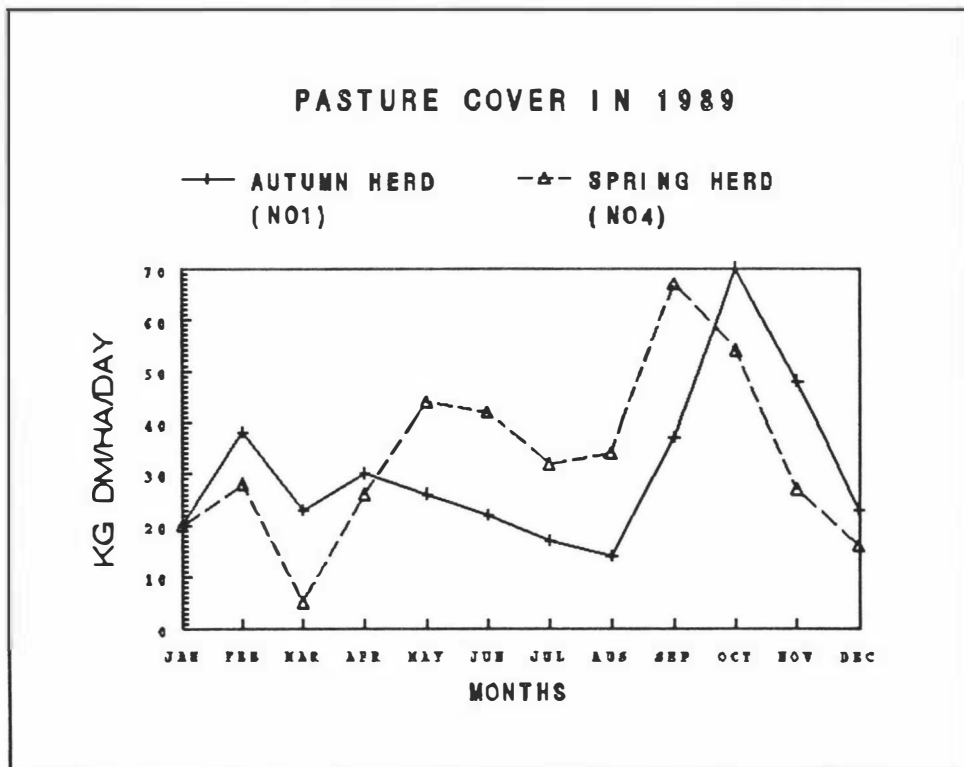


Figure 1.0. The estimated pasture production (kg DM/ha/day) in the autumn-(No1) and spring-calving(No4) herds in 1989.

RESULTS

MASSEY UNIVERSITY DAIRY HERD NO1(AUTUMN-CALVING HERD)

The percentage of cows included in the study represented 13.6% of the herd (25 out of 184). The mean age of these cows was $3.8(\pm 0.3)$ years (\pm S.E.), ranging from 2 to 7 years, while that of the main herd was 4.8 ± 0.2 years, ranging from 2 to 13 years.

POST-PARTUM REPRODUCTIVE INDICES

1. Interval from Calving to Estimated First Post-partum Ovulation

The mean calving to estimated first post-partum ovulation interval for 22 of the 25 examined cows was 23.7 ± 2.4 days, ranging from 10 to 45 days (Table 1.4). The mean for cows which ovulated <30 day post-partum was 18.4 days, while that for cows which ovulated from 31-60 days post-partum was 41.8 days (Table 1.5, $p < 0.0001$).

The mean intervals for each age group were 23.4 ± 5.1 , 32.8 ± 6.2 and 20.0 ± 2.4 days for the 2 year, 3 year and mature cows, respectively (Table 1.6, $p = 0.09$). There was a significant difference in the mean intervals between cows that ovulated with and without being detected in oestrus at the first ovulation (35.9 and 20.1 days, respectively, $p < 0.05$). The percentage of cows that showed oestrus at the first ovulation was 45.4% (10 out of 22 cows, Figure 1.1). The mean inter-ovulatory interval from first ovulation post-partum was 18.2 ± 1.0 days, ranging from 12 to 30 days (Table 1.4). Unlike the spring-calving cows, autumn-calving cows ovulating within 30 days post-partum had the lowest percentage of short cycles (10%, 2 cows), compared with 25% or 40% (5 and 8 cows, respectively) with a shortened or normal cycle, respectively (Figure 1.2 and Table 1.7). Most autumn-calving cows ovulated within 30 days (80%, 16 cows). There was one cow which ovulated within 30 days post-partum that had a first cycle of more than 24 days. There were 2 cows (10%) from the examined groups which had a short first cycle, and there were 6 cows (30%) which had a shortened cycle, compared with 55% (11 cows) which had normal cycles (Table 1.7).

Cows which had body condition scores at first ovulation of 4 or more (≥ 4) tended to have a shorter interval from calving to first ovulation than those that had body condition scores of less than 4 (< 4) [21.9 ± 2.7 and 34.6 ± 8.7 days, $p = 0.06$, respectively]. There were no differences between cows that had body condition score at calving of 4 or more and less than 4 [24.7 ± 3.1 days (16 cows) and 20.8 ± 3.2 days (6 cows), respectively]. When the intervals from calving to first ovulation of the two herds (No1 and No4) were pooled, the mean interval to first ovulation of cows that had a body condition score of 4 or more at calving was 28.4 ± 2.8 days (27 cows), compared with 32.0 ± 4.9 days (14 cows) for cows that had a body condition score of less than 4 ($p = 0.5$).

No equivalent data from the main herd were analysed.

2. Interval from Calving to First Post-partum Oestrus

The mean interval from calving to first oestrus in the examined cows was 41.6 ± 3.4 days (Table 1.4).

The mean interval from calving to first oestrus for each of the 5 groups of examined cows was 33.8 ± 4.3 , 52.0 ± 4.5 , 45.4 ± 11.4 , 40.4 ± 6.7 and 33.0 ± 9.7 days for group 1,2,3,4 and 5, respectively. The mean intervals for each age group were 46.4 ± 5.1 , 29.7 ± 5.2 and 43.3 ± 4.9 days for 2 year old, 3 year old and mature cows (Table 1.6), respectively ($p = 0.27$).

3. Submission Rate(SR)

The 3-week submission rate for the examined cows was 87.0%, compared with 72.0% for the main herd. The comparable 4-week submission rates were 87.0% and 77.0%, respectively.

4. Interval from Calving to First Service Postpartum

The mean interval from calving to first service for the examined cows was 84.4 ± 2.4 days, while that of the main herd was 79.4 ± 2.4 days (Table 1.4, $p < 0.01$).

The mean intervals for each age group of the examined cows were 83.3 ± 8.5 , 95.5 ± 7.6 and 81.5 ± 2.1 days for the two, three year and mature cows, respectively ($p = 0.08$), while those for the main herd were 73.6 ± 5.9 , 88.7 ± 10.2 and 78.9 ± 2.3 days ($p = 0.24$).

5. Interval from PSM to First Service(PSM = 1/6/89)

The mean interval from PSM to first service for the examined cows was 10.9 ± 1.9 days, compared with 20.5 ± 1.9 days of the main herd ($p = 0.08$). The mean intervals for each age group among the examined cows were 16.0 ± 3.8 , 15.7 ± 8.8 and 8.1 ± 1.3 days for the two, three year and mature cows, respectively (Table 1.8, $p = 0.15$).

6. Interval from PSM to Conception

The mean interval from PSM to conception for the examined cows was 24.0 ± 5.3 days, compared with 36.5 ± 2.9 days in the main herd ($p < 0.05$). The mean intervals for each age group among the examined cows were 25.0 ± 7.5 , 16.0 ± 9.0 and 26.1 ± 7.5 for the two, three year and mature cows, respectively (Table 1.8).

7. Interval from First Service to Conception

The mean interval from first service to conception for the examined cows was 12.0 ± 5.4 days, compared with 18.5 ± 2.6 days in the main herd ($p = 0.1$). The mean intervals for each age group among the examined cows were 0, 0.2 ± 0.2 and 17.9 ± 7.7 days for the two, three year and mature cows, respectively ($p = 0.3$).

8. Interval from Calving to Conception

The mean intervals from calving to conception were 97.8 ± 5.1 and 97.9 ± 3.2 days

for the examined cows and the main herd, respectively. There were no differences in the mean interval for each age group of the examined cows.

9. First Service Conception Rate

The first service conception rate among the cows in the examined groups was 71.4% while that for the main herd was 50.7% (Table 1.4, $p=0.5$).

10. Services per Conception

Examined cows had a mean number of services per conception of 1.57 ± 0.2 , compared with 1.89 ± 0.1 in the main herd.

There were two cows (No.3 and No.59) in the examined groups that had uterine discharge after calving. They could not be excluded from the study because there were no other cows which calved at the same time.

One cow (No.69, 2 year old) did not ovulate during the period for which cows were examined, and remained anoestrus for a further three months thereafter even though she was treated with a CIDR (Control Intravaginal Drug Release) device for 7 days and had 400 I.U. of PMSG (Pregnant Mare Serum Gonadotropin) injected at the time of CIDR device removal. This cow had a body condition score of 3.5 at calving. No large follicles ($> 10\text{mm}$) developed on either ovary, and only medium (6-9mm) or small sized follicles (2-5mm) were identified during the examination period.

Cystic ovaries developed in 3 cows (12%, Nos.22, 89 and 273). Cow No.22 developed cysts on both ovaries at approximately Day 28 post-partum, but then came into oestrus and ovulated on Day 44 post-partum followed by normal corpus luteum formation. Cow No.89 developed cysts on both ovaries at approximately Day 46 post-partum which was after the second ovulation post-partum. In this latter case, the cysts were luteinised spontaneously, and the animal came into oestrus on Day 66 post-partum. Cow No.273 developed cysts on Day 28 post-partum. These did not ovulate during the examination period and the animal was not detected in oestrus. The cysts eventually luteinised spontaneously and the animal was in oestrus and inseminated on Day 87 post-partum.

Two cows (No.156 and No.273) were excluded from the study. Cow No.156 had very poor body condition (body condition score of 2.5) because of facial eczema (Sporidesmin intoxication) and was slaughtered. However, this cow had a body condition score of 3.5 after calving, and significant follicular activity was detected during the first week post-partum when 5 to 6 medium-sized follicles and 16 to 21 small-sized follicles were observed at each examination. The consequence of facial eczema produced the decline in body condition score to less than 3.0, and follicular activity stopped with no medium-sized follicles. Cow 273 was excluded because of cystic ovarian disease as described above.

Table 1.4. Mean intervals of post-partum(pp) reproductive indices for examined cows and for cows in the main herds at the Massey University No1(autumn cows) and No4(spring cows) Dairy Herds.

Reproductive indices	No1 ^A		No4 ^B	
	Examined cows	Main herd	Examined cows	Main herd
1. Interval from calv-1 st ovulation pp(days)	23.7 ^b (10-45)	-	36.6 ^b (16-68)	-
2. Interval from calv-1 st Oest. pp(days)	41.6 (20-75)	-	40.7 (20-72)	-
3. Interval from 1 st inter-ovul. pp(days)	18.2 (12-30)	-	14.5 (7-22)	-
4. Interval from PSM to 1 st service (days)	10.9 (0-95)	20.5 ^b (0-121)	12.4 (3-26)	15.0 ^b (1-81)
5. Interval from 1 st service to conception	12.0 (0-85)	18.5 ^c (0-114)	8.4 (0-41)	13.9 ^c (0-76)
6. Interval from PSM to conception pp(days)	24.0 ^a (0-95)	36.5 ^{a,b} (0-121)	20.1 (3-55)	28.3 ^b (0-81)
7. Interval from calving to 1 st service pp(days)	84.4 ^{b,d} (68-118)	79.4 ^b (16-183)	66.2 ^d (55-82)	75.3 (19-170)
8. Interval from calving to conception pp(days)	97.8 ^c (68-160)	97.9 ^{c1} (33-189)	73.4 ^{c,a} (55-108)	88.9 ^{a,c1} (30-170)
9. Services per conception	1.57	1.89 ^c	1.68	1.59 ^c
10. 1 st service conception rate(%)	71.4	55.2	56.4	56.4

() = range of mean(days)

^A = autumn calving herd ^B = late winter calving herd

^{a,b,c,d} Mean values within rows with the same superscripts(a=p<0.05, b=p<0.01, c=p<0.001, d=p<0.0001)

Table 1.5. Mean days from calving to first post-partum ovulation of the examined cows from the autumn-(No1) and spring-calving herds(No4).

Herds	Mean OV1 < 30 days pp	Mean OV1 31-60 days pp	All cows(days)
Autumn-calving cows	18.3 ± 1.3(17) ^{a,d1}	41.8 ± 1.6(5) ^{d1}	23.7 ± 2.4(22) ^b
Spring-calving cows	23.3 ± 1.5(10) ^{a,d}	44.0 ± 4.9(6) ^d	36.6 ± 4.1(19) ^{b,*}
Mean of all cows(2 herds)	20.2 ± 1.1(27) ^d	43.0 ± 2.7(11) ^d	29.6 ± 2.5(41)

() = Numbers of cows

* = There were 3 cows in the spring herd that ovulated after 60 days pp and were included in the analysis.
 Superscription **a** = $p < 0.05$, **b** = $p < 0.01$, **c** = $p < 0.005$, **d** = $p < 0.0001$

Table 1.6. The mean interval from calving to estimated first ovulation and oestrus post-partum of the examined cows of differing ages in autumn(No1) and spring(No4) calving herds

Herds	Age (yrs)	Calving to estimated 1 st ovulation(days)	Calving to estimated 1 st oestrus(days)
Autumn cows	2	23.4 ± 5.0(4)	46.4 ± 5.1(4)
	3	32.8 ± 6.2(4)	29.7 ± 5.2(4)
	Mature cows	20.0 ± 2.4(12)	43.3 ± 4.9(12)
Age effects		p = 0.09	p = 0.27
All autumn cows		23.7 ± 2.4	41.6 ± 3.4
Spring cows	2	26.0 ± 2.1(3)	25.0 ± 2.1(3)
	3	28.7 ± 5.2(3)	34.0 ± 4.0(3)
	Mature cows	40.8 ± 5.5(13)	45.9 ± 4.9(13)
Age effects		p = 0.36	p = 0.11
All spring cows		36.6 ± 4.1	40.7 ± 3.9
Spring and autumn cows	2	24.4 ± 3.1(7)	38.4 ± 5.0(7)
	3	31.2 ± 4.2(7)	31.6 ± 3.3(7)
	Mature cows	30.8 ± 3.7(25)	44.5 ± 3.4(25)
Mean all cows		29.65 ± 2.46	41.21 ± 2.54
Age effects(p)		p = 0.58	p = 0.15

Mean ± Std error(numbers of cows)

Table 1.7. Numbers of monitored of autumn calving(No1 Herd) and spring-calving cows(No4 Herd) which ovulated < 30 days or > 30 days post-partum that had short, shortened or normal cycles post-partum(pp).

	OV1 < 30 days	OV1 = 31-60 days	OV1 > 60 days	All cows
Spring herd				
Short cycle	6(33.3%)	2(11.1%)	-	8(44.4%)
Shortened cycle	1(5.6%)	-	1(5.6%)	2(11.1%)
Normal cycle	3(16.7%)	4(22.2%)	1(5.6%)	8(44.4%)
Spring cows	10(55.6%)	6(33.3%)	2(11.1%)	18
Autumn herd				
Short cycle	2(10%)	-	-	2(10%)
Shortened cycle	5(25%)	1(5%)	-	6(30%)
Normal cycle	8(40%)	3(15%)	-	11(55%)
> 24 days cycle	1(5%)	-	-	1(5%)
Autumn cows	16(80%)	4(20%)	-	20
All cows	26(68.4%)	10(26.3%)	2(5.3%)	38

() = percentage of all spring or autumn calving cows

Short cycle = 6-12 days

Shortened cycle = 13-18 days

Normal cycle = 19-24 days

Table 1.8. Interval from PSM to 1st service and conception compared each age group of both examined groups and the main herd of Massey Dairy No1(Autumn calving cows).

Cows	Age	PSM to 1 st service	1 st service to conception	PSM to conception
Examined cows	2	16.0 ± 3.8 (4)	0(3)	25.0 ± 7.5 (3)
	3	15.7 ± 8.8 (4)	0.2 ± 0.2 (4)	16.0 ± 9.0 (4)
	Mature cows	8.1 ± 1.3 (14)	17.9 ± 7.7 (14)	26.1 ± 7.5 (14)
Age effects		p = 0.15	p = 0.2	p = 0.2
All examined cows		10.9 ± 1.9	12.0 ± 5.4	24.0 ± 5.3
Main herd	2	30.0 ± 4.5 (36)	19.1 ± 4.3 (28)	46.7 ± 5.6 (28)
	3	30.8 ± 9.9 (15)	14.8 ± 8.7 (12)	40.6 ± 11.6 (12)
	Mature cows	15.4 ± 1.6 (98)	18.9 ± 3.3 (83)	32.4 ± 3.4 (83)
Age effects		p = 0.008	p = 0.8	p = 0.11
All main herd		20.5 ± 1.9	18.5 ± 2.6	36.5 ± 2.9

() = Numbers of cows

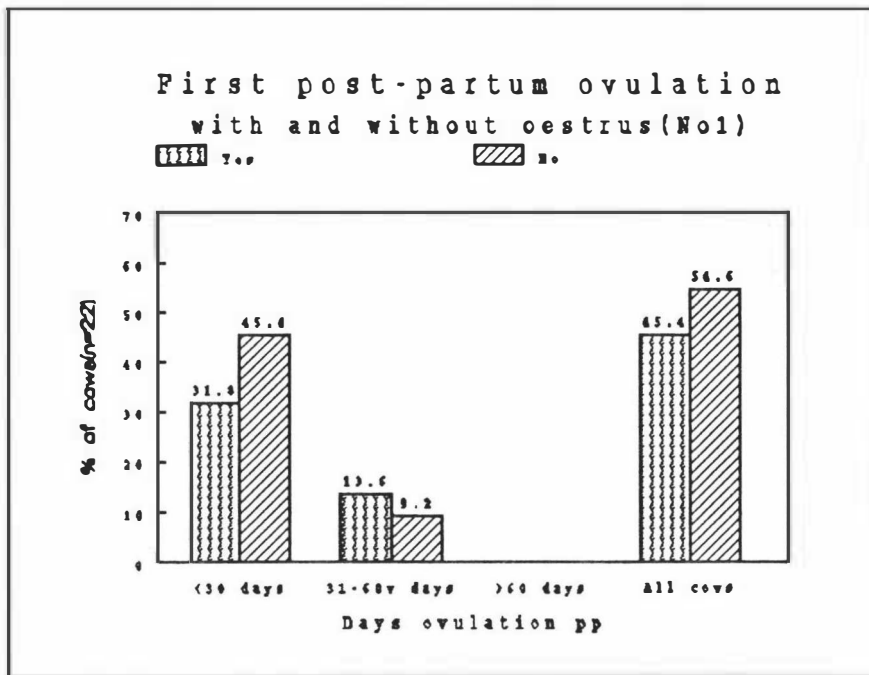


Figure 1.1. The percentage of the autumn-calving cows which ovulated with and without oestrus at first ovulation.

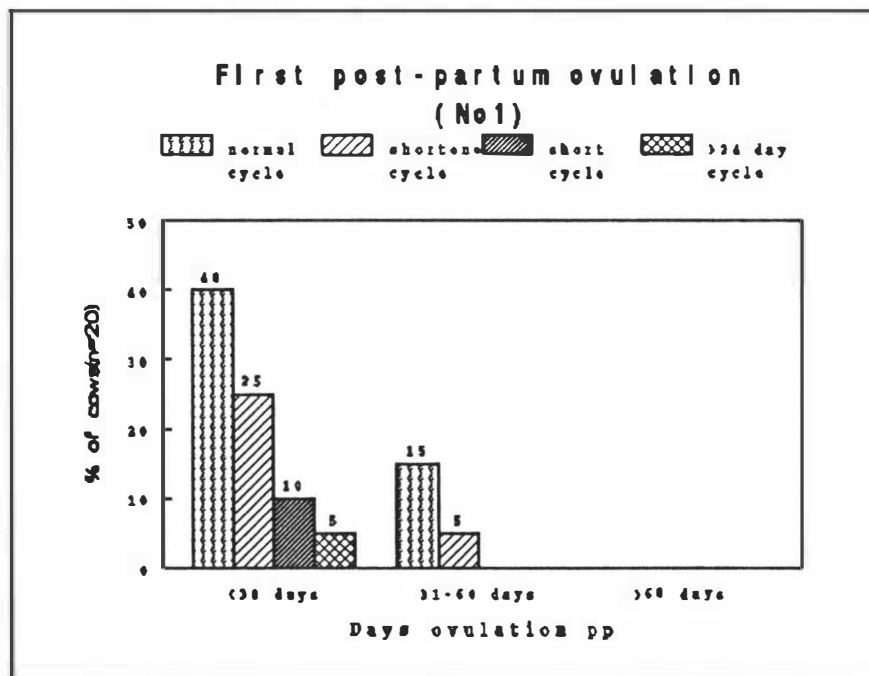


Figure 1.2. The percentage of the autumn-calving cows (No1) which had normal, shortened and short first cycles after first ovulation post-partum.

MASSEY UNIVERSITY DAIRY HERD NO4(SPRING-CALVING HERD)

The percentage of cows included in the study represented 9.3% of cows in the main herd(25 out of 270). These mean age of was $5.0(\pm 0.5)$ years(S.E.), ranging from 2 to 10 years, whereas that of the main herd was 4.6 ± 0.2 years, ranging from 2 to 13 years. The mean weight for the examined cows during the study period was 392 kilograms.

POST-PARTUM REPRODUCTIVE INDICES

1. Interval from Calving to Estimated First Post-partum Ovulation

The mean calving to estimated first postpartum ovulation interval for 19 of the 20 cows was 36.6 ± 4.1 days (mean \pm S.E.), ranging from 16 to 68 days(Table 1.4). This interval for cows which ovulated <30 days post-partum was 23.3 ± 1.5 days, while that for cows which ovulated from 31-60days post-partum was 44.0 ± 4.9 days(Table 1.5, $p < 0.01$). The mean intervals were not significantly different between the 4 groups of examined cows(39.2 ± 9.2 , 37.4 ± 8.3 , 33.2 ± 7.0 and 36.5 ± 11.2 days for group 1,2,3 and 4, respectively).

The mean intervals to first ovulation in relation to age were 26.0 ± 2.1 , 28.7 ± 5.5 and 40.8 ± 5.5 days for the 2 year, 3 year olds and mature cows, respectively(Table 1.6, $p = 0.36$). There was a trend that the mean interval of cows which ovulated with oestrus at the first ovulation was longer than that of cows which ovulated without oestrus(42.3 and 26.7 days for ovulation with and without oestrus, respectively, $p = 0.06$). The percentage of cows which showed oestrus at the first ovulation was 63.2%(12 cows out of 19 cows, Figure 1.3). The mean inter-ovulatory interval postpartum was 14.5 ± 1.2 days, ranging from 7 to 22 days(Table 1.4). It can be seen from Figure 1.4 and Table 1.7 that spring-calving cows which ovulated within 30 days post-partum had a higher incidence of short cycle(33.3%) than those which ovulated more than 30 days post-partum(11.1%). Table 1.7 also showed that there were 8 cows(44.44%) which had a short cycle(7-12 days) after the first post-partum ovulation, compared with 44.4 %(8 cows) that had normal cycles(19-24 days). The remaining 2 cows(11.1%) had shortened first cycle of 13-18 days.

There were no differences in this interval for cows which had body condition scores at first ovulation of 4 or more(≥ 4), or less than 4(< 4)(35.1 ± 4.8 days and 39.8 ± 7.9 days, respectively). Cows that had body condition scores at calving of 4 or more did not have a shorter average interval than cows that had body condition scores of less than 4(33.8 ± 4.9 days(11 cows) and 40.4 ± 7.1 days(8 cows)($p = 0.44$).

There were two 2 year old cows(No273 and No429) which had a uterine discharge during the first 2 weeks postpartum. They had a mean interval to first ovulation of 24.0 ± 1.0 days, compared with 38.1 ± 4.4 days of cows without a detected uterine discharge, respectively($p = 0.3$).

There were no records for the interval to first ovulation and to first oestrus for other cows in the main herd.

2. Interval from Calving to Estimated First Post-partum Oestrus

The mean interval from calving to estimated first oestrus in the examined cows was 40.7 ± 3.9 days (Table 1.4).

The mean intervals from calving to first oestrus for the 4 groups of examined cows were 43.6 ± 7.0 , 38.8 ± 7.5 , 36.4 ± 8.9 and 45.0 days for group 1,2,3 and 4, respectively ($p = 0.88$). The intervals between groups of cows that were examined on the same day in the week were not different (41.2 ± 4.9 days and 40.2 ± 6.5 days for group 1 + 2 and 3 + 4, respectively, $p = 0.9$).

The intervals to first oestrus for each age group of the examined cows were 25.0 ± 2.1 , 34.0 ± 4.0 and 45.9 ± 5.0 days for two year old, three year old and mature cows, respectively (Table 1.6, $p = 0.11$).

Cows in the main herd (No4) were not routinely observed for Premating Heats (PMH), simply relying on the extent to which tailpaint had been rubbed off during the three weeks before Planned Start of Mating (PSM) and/or that some cows showed oestrus before the oestrus-observation period started. Data for analysing the intervals of cows in the main herd were not available.

3. Submission Rate (SR): This is the proportion of cows that have been submitted for the first insemination during the first 4 weeks after PSM.

The 3-week submission rate of the examined cows was 90%, compared with 81% for the main herd, while the 4-week SRs for the examined cows and the main herd were 95% and 89%, respectively.

4. Interval from Calving to First Service

The mean interval from calving to first service for the examined cows was 66.2 ± 1.8 days, while that of the main herd was 75.3 ± 1.5 days (Table 1.4).

The mean intervals for each age group among the examined cows were 61.3 ± 4.9 , 58.3 ± 0.3 and 69.1 ± 2.0 days for the two, three year old and mature cows, respectively ($p < 0.05$), while the equivalent intervals in the main herd were 80.7 ± 3.4 , 79.7 ± 4.4 and 72.5 ± 1.7 days ($p < 0.05$).

5. Interval from PSM (Planned Start of Mating) to First Service (PSM = 21/10/89)

The mean interval from PSM to first service for the examined cows was 12.4 ± 1.6 days, compared with 15.0 ± 0.9 days in the main herd (Table 1.4). The mean intervals for each age group among the examined cows were 7.0 ± 3.5 , 6.3 ± 2.4 and 15.1 ± 1.7 days for the two, three year and mature cows, respectively (Table 1.9, $p < 0.05$).

6. Interval from PSM to Conception

The mean interval for cows in the examined groups was 20.1 ± 4.1 days compared with 28.3 ± 1.5 days in the main herd (Table 1.4). The mean intervals for each age group of the examined cows were 3.5 ± 0.5 , 6.7 ± 2.3 and 26.8 ± 4.8 days for the two, three year and mature cows, respectively (Table 1.9, $p < 0.05$).

7. Interval from First Service to Conception

The mean interval from first service to conception for the examined cows was 8.4 ± 3.5 days, compared with 13.9 ± 1.3 days for the remaining cows in the herd (Table 1.4). The mean intervals for each age group were 0, 0.3 ± 0.3 and 12.2 ± 4.8 days for the two, three year and mature cows, respectively (Table 1.9, $p = 0.3$).

8. Interval from Calving to Conception

The mean interval for the examined cows was 73.4 ± 4.3 days, compared with 88.9 ± 1.8 days in the main herd (Table 1.4, $p < 0.05$). The mean intervals for each age group were 56.5 ± 1.5 , 58.7 ± 0.3 and 80.4 ± 5.0 days for the two, three year and mature cows, respectively ($p < 0.05$).

9. First Service Conception Rate

According to the artificial insemination record from the herd, the percentage of first service conceptions for the examined cows was 56.4, while that in the main herd was 58.4 (Table 1.4).

10. Services per Conception

Examined cows had mean number of services per conception of 1.68 ± 0.2 , compared with 1.59 ± 0.1 of the main herd (Table 1.4).

One cow from the examined group (No.380, 2 year old) failed to ovulate and showed no signs of oestrus during the examination period or during the three month breeding programme, even though she was treated with a CIDR device (Control Intravaginal Drug Release) for 7 days, and with 400 I.U. of PMSG (Pregnant Mare Serum Gonadotropin) at CIDR removal. The body condition score of this cow was between 3.0-3.5 during the examination period. The ovaries of this cow were very small (inactive ovaries). The follicular pattern of this cow showed ovarian activity with a large follicle (12.5 mm in diameter on the right ovary) on day 11 postpartum, but thereafter only a small number of medium-sized and small-sized follicles were found.

Cow No.394 had its first post-partum oestrus (at which time it was inseminated) after the examination period. Ovulation date was presumed to be one day after insemination.

Cow No.236 developed follicular cysts on the left ovary after the first post-partum ovulation. Ovarian activity on the other ovary continued with a normal follicle ovulating to form a normal CL. The interovulatory interval for this sequence in this cow was 22 days.

Table 1.9. Interval from Planned Start of Mating(PSM) to first service and conception compared each age group of both examined cows and the main herd from Massey Dairy No4(Spring calving herd).

Cows	Age	PSM to 1 st service	1 st service to conception	PSM to conception
Examined cows	2	7.0 ± 3.5(3)	0(2)	3.5 ± 0.5(2)
	3	6.3 ± 2.4(3)	0.3 ± 0.3(3)	6.5 ± 2.3(3)
	Mature cows	15.1 ± 1.7 (13)	12.2 ± 4.8 (11)	26.8 ± 4.8 (11)
Age effects		p = 0.03	p = 0.2	p = 0.04
All examined cows		12.4 ± 1.6	8.4 ± 3.5	20.1 ± 4.1
Main herd	2	16.7 ± 2.3 (56)	18.4 ± 3.3 (43)	32.9 ± 3.4 (43)
	3	20.3 ± 3.3 (31)	14.3 ± 3.6 (30)	35.2 ± 4.5 (30)
	Mature cows	13.3 ± 0.9 (150)	12.4 ± 1.5 (141)	25.4 ± 1.7 (141)
Age effects		p = 0.02	p = 0.2	p = 0.02
All main herd		15.0 ± 0.9	13.9 ± 1.3	28.3 ± 1.5

() = Number of cows

Table 1.10. Number of spring(No4 Dairy) and autumn(No1 Dairy) calving cows between age groups at first ovulation post-partum(pp).

Herd	Age(yrs)	OV1 ≤ 30 days pp	OV1 = 31-60 days pp	OV1 > 60 days pp	Row totals
Spring herd	2	3(15.8%)	0	0	3(15.8%)
	3	2(10.5%)	1(5.3%)	0	3(15.8%)
	Mature cows	5(26.3%)	5(26.3%)	3(15.8%)	13(68.4%)
Spring cows		10(52.6%)	6(31.6%)	3(15.8%)	19
Autumn herd	2	4(18.2%)	1(4.5%)	0	5(22.7%)
	3	2(9.1%)	3(13.6%)	0	5(22.7%)
	Mature cows	11(50%)	1(4.5%)	0	12(54.5%)
Autumn cows		17(77.3%)	5(22.7%)	0	22
All spring and autumn cows		27(65.8%)	11(26.8%)	3(7.3%)	41

() = Percentage of cows

Table 1.11. Number of cows by age groups from spring- and autumn-calving herds that had a short, shortened or normal cycle post-partum(pp).

Herds	First cycle pp	2 year old	3 year old	Mature cows	Row totals
Spring herd	short ^a	2(11.1%)	1(5.6%)	5(27.8%)	8(44.4%)
	shortened ^b	1(5.6%)	0	1(5.6%)	2(11.1%)
	normal ^c	0	2(11.1%)	6(33.3%)	8(44.4%)
Autumn herd	short	0	0	2(10%)	2(10%)
	shortened	2(10%)	1(5%)	3(15%)	6(30%)
	normal	3(15%)	3(15%)	5(25%)	11(55%)
	>24 days	0	0	1(5%)	1(5%)

^a= 6-12 days interval, ^b= 13-18 days interval, ^c= 19-24 days interval

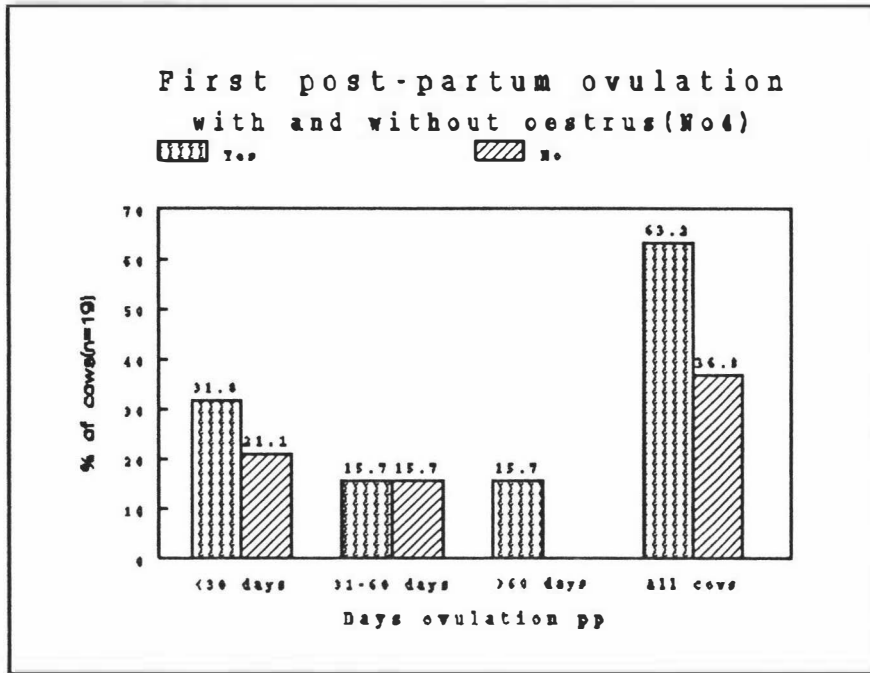


Figure 1.3. The percentage of the spring-calving cows which ovulated with and without oestrus at first ovulation post-partum.

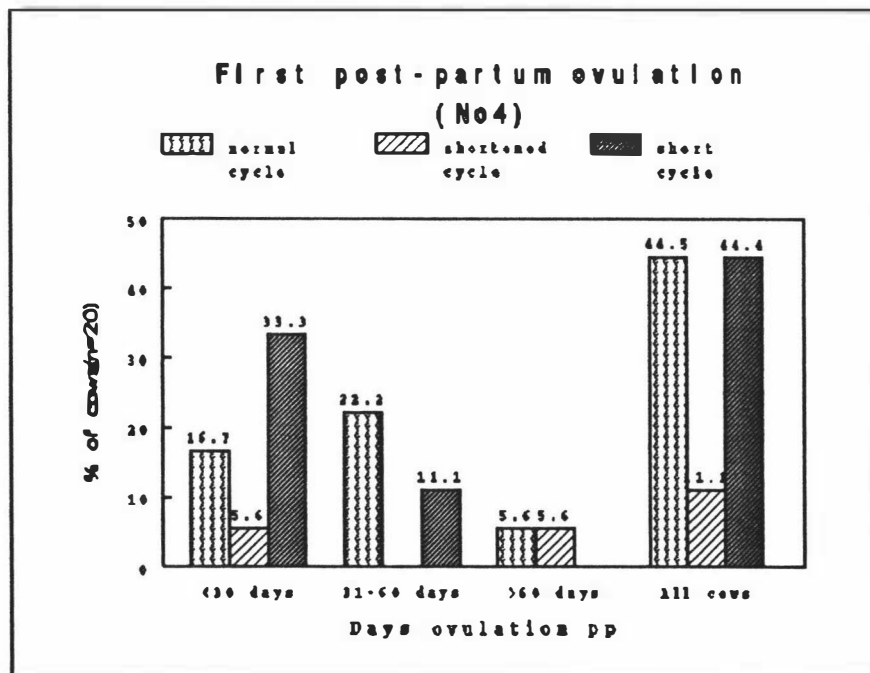


Figure 1.4. The percentage of the spring-calving cows (No4) which had normal, shortened and short first cycles after first ovulation post-partum.

POST-PARTUM REPRODUCTIVE INDICES BETWEEN AUTUMN- AND SPRING-CALVING COWS

The interval from calving to first post-partum ovulation for the examined cows in the autumn-calving herd was significantly shorter than that in the spring-calving herd (23.7 vs 36.6 days, Table 1.4, $p < 0.01$). It was 20.0 ± 2.4 days in the mature cows examined in the autumn, compared with 40.8 ± 5.5 days in the spring cows ($p < 0.005$). There were no differences in the interval from calving to first oestrus for the examined cows between the two herds (41.6 vs 40.7 days, Table 1.4).

The percentage of the spring-calving cows which showed oestrus at their first post-partum ovulation was higher than that of the autumn-calving cows (62.9% vs 45.4%, respectively, $p = 0.5$, Figure 1.3 and 1.1). The percentage of the autumn- and spring-calving cows which showed oestrus at the first post-partum ovulation was higher in cows which ovulated within 30 days pp (31.7%, compared with 14.6% in cows which ovulated from 31-60 days pp, Figure 1.5). Figure 1.6 showed that the percentage of cows which had a short first cycle was higher in cows which ovulated within 30 days pp (22.5%), compared with 5% in cows which ovulated from 31-60 days pp. The percentage of cows which ovulated within 30 days pp and then had short first cycles was 22.5%, compared with 27.5% of the ovulators which had a normal first cycle. Spring-calving cows which ovulated within 30 days pp had a higher percentage of short first cycles (35%) than those in autumn-calving cows (10%), while spring-calving cows had a lower percentage of normal first cycles (15%) than autumn-calving cows (40%) [Figure 1.4 and 1.2]. The interval from calving to first ovulation in cystic autumn-calving cows was 56 days, compared with 29.1 days for cows which did not develop an ovarian cyst. Table 1.10 shows the percentage of each age group of the autumn and spring cows which ovulated within 30 days, from 31-60 days pp or > 60 days pp. Table 1.11 shows the percentage of each age group of autumn and spring cows which had a short, shortened or normal cycle pp.

The interval from PSM to first service for the examined cows in the autumn and spring herds was not different ($p = 0.08$). There was a significant difference in the mean interval from PSM to first service of cows in the main herd between the autumn and spring herds (20.5 days for the autumn herd, compared with 15.0 days for the spring herd, $p < 0.01$). The intervals from PSM to conception and first service to conception for the main herd were also significantly shorter in the spring cows than those in the autumn cows (28.3 and 13.9 days vs 36.5 and 18.5 days, respectively, $p < 0.001$).

The interval from calving to first service for the examined cows was significantly shorter in spring cows than in autumn cows (66.2 days vs 84.4 days, respectively, $p < 0.0001$). The intervals from calving to conception for the examined cows and the main herd were also significantly shorter in the spring herd (73.4 and 88.9 days for the spring herd vs 97.8 and 97.9 days for the autumn herd, respectively, $p < 0.001$). Spring cows in the main herd needed fewer services per conception than that the autumn-calving cows (1.59 in spring cows, compared to 1.89 in the autumn cows, $p < 0.001$).

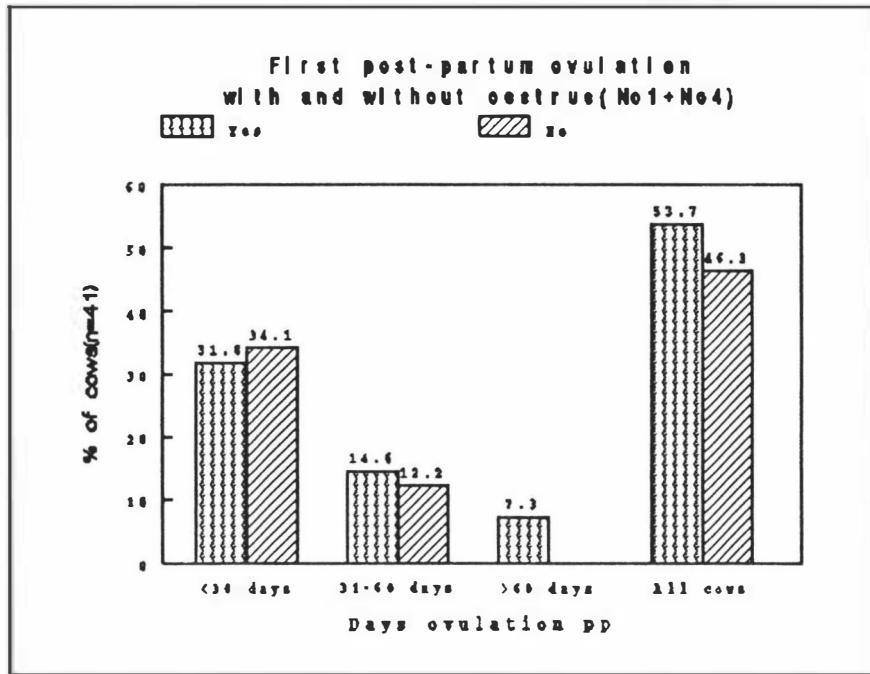


Figure 1.5. The percentage of cows from both herds which ovulated with and without oestrus at first ovulation post-partum.

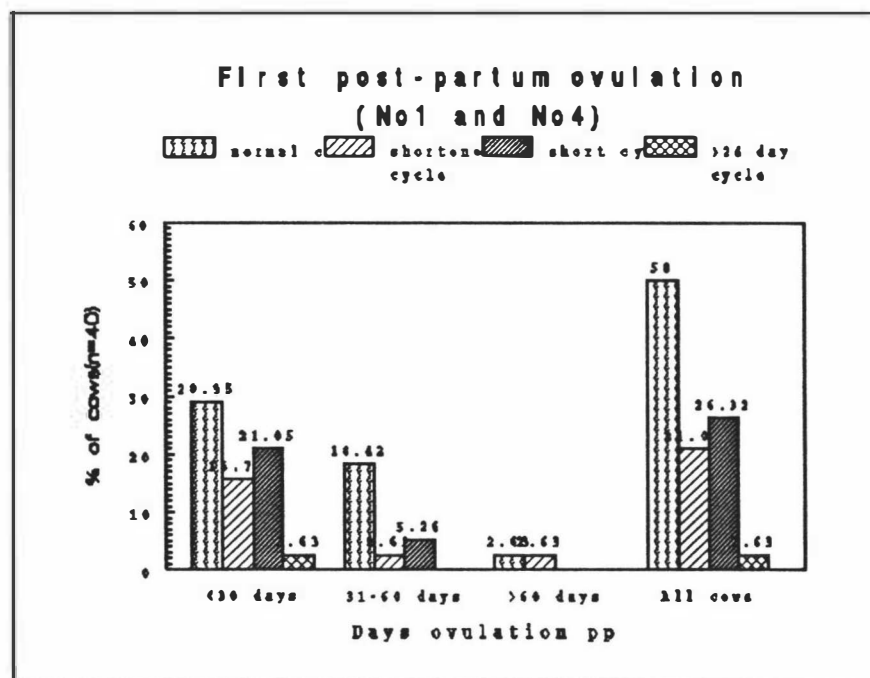


Figure 1.6. The percentage of cows from both herds which had normal, shortened and short first cycles after first ovulation post-partum.

OVARIAN FOLLICULAR DISTRIBUTION POST-PARTUM

1. FOLLICULAR NUMBERS IN CYCLING(CC) AND NON-CYCLING COWS(NC) POST-PARTUM

Within each group of cows in the autumn- and spring-calving herds which was examined on the schedules shown in Table 1.1 and 1.2, the mean number of each follicle category was compared between cycling(CC) and non-cycling cows(NC) examined at the same period post-partum.

MASSEY DAIRY NO1(AUTUMN-CALVING HERD)

Because an ultrasound examination had not been made in the autumn-calving cows which ovulated during the first two weeks post-partum, no comparison for these early intervals could be made.

Table 1.12 shows the mean number of each follicle category and the size of the largest follicle(LF size) from Week 2 to Week 7 post-partum. The mean number of SF's and TF's in cycling cows(CC) was significantly higher than that in non-cycling cows(NC; 19.0 and 22.8, compared with 16.3 and 19.3, respectively, $p < 0.0001$). The mean number of each follicle category was also significantly different between weeks post-partum(Week 2 to Week 7 pp, $p < 0.01$). There were no differences in the mean size of the largest follicle(LF size) in CC and NC between weeks pp. There were also no Group x Week interactions for the mean number of each follicle category and the mean size of LF's.

Table 1.13 shows the mean number of each follicle category and the mean size of LF's in CC and NC, compared within weeks post-partum. The mean number of SF's was significantly higher in the CC than in the NC in Weeks 5,6 and 7 post-partum($p < 0.05$). The mean number of TF's was also higher in the CC than in the NC in Weeks 5 and 6($p < 0.05$). Only the mean size of LF's in the CC was significantly higher in Week 6 than in NC($p < 0.05$).

Table 1.14 and Figure 1.7 show the distribution of the mean number of follicles in each category from Week 2(Days 7-13) to Week 7(Days 42-48) in the autumn-calving cows.

MASSEY DAIRY NO4(SPRING-CALVING HERD)

One examined cows in the spring -calving herd ovulated within 2 weeks post-partum(Day 13 pp), but no previous ultrasound examination had been made in this cow.

Table 1.15 shows the mean number of each follicle category and the size of LF's in the CC and NC. There were significant differences in the mean number of follicles in all categories between CC and NC($p < 0.05$). CC had a higher mean number of SF's and TF's than in the NC(21.1 vs 19.3 and 24.7 vs 23.7, respectively, $p < 0.05$). Unlike those in the autumn-calving herd, the NC in the spring-calving herd

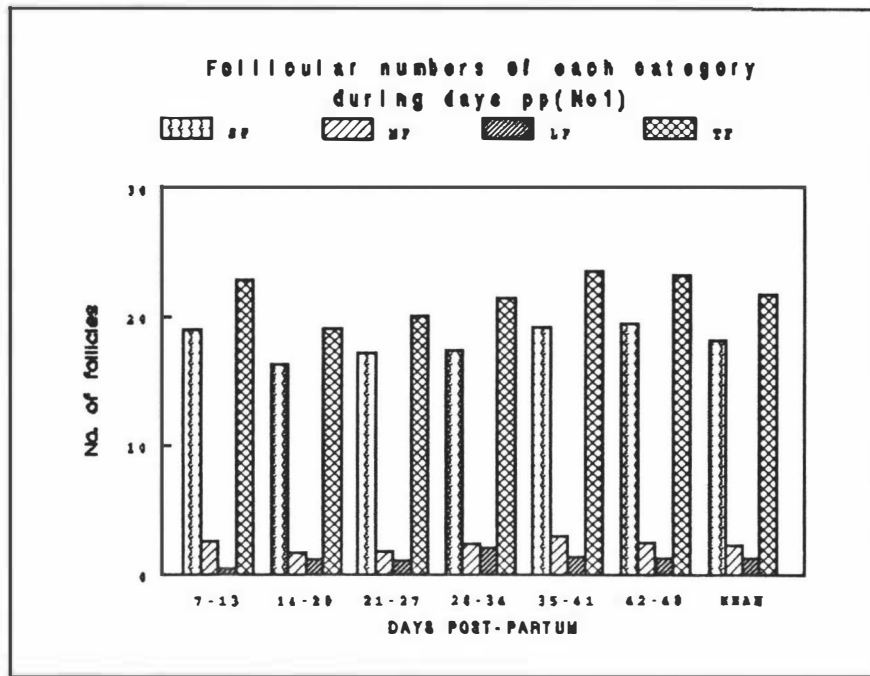


Figure 1.7. The mean numbers of each follicle category in the autumn-calving cows(cycling and non-cycling cows) during days post-partum.

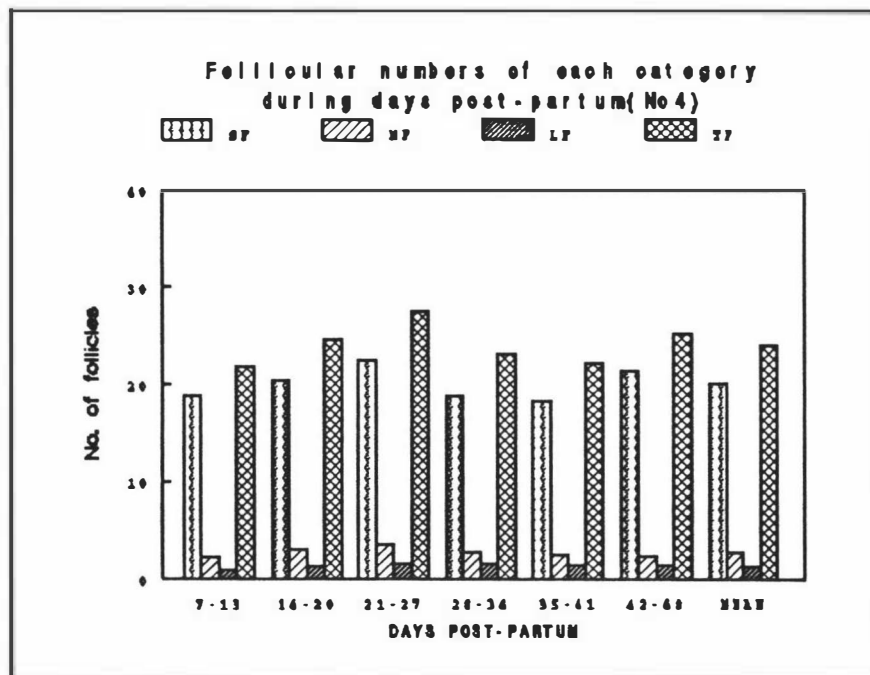


Figure 1.8. The mean numbers of each follicle category in the spring-calving cows(cycling and non-cycling cows) during days post-partum.

Table 1.12. The mean number of each follicle category(SF, MF, LF and TF) and the mean size of the largest follicle(LF size) from Week 2 to Week 7 post-partum in cycling(CC) and non-cycling cows(NC) in the autumn-calving herd(No1).

Follicles	Group		SEM	Significant levels	
	Cycling cows (CC)	Non-cycling cows (NC)		Group (CC vs NC)	Week
SF	19.0 ^a	16.3 [°]	0.9	***	*
MF	2.4 ^a	2.1 [°]	0.2	NS	*
LF	1.3 ^a	1.0 [°]	0.0	NS	**
TF	22.8 ^a	19.3 [°]	0.9	***	*
LF size(mm)	15.1 ^b	15.8 ^d	0.5	NS	NS

Total mean(Superscripts = Number of observations, ^a= 139, ^b= 117, [°]= 73 and ^d= 58)

Significant levels(* = $p < 0.01$, ** = $p < 0.0005$, *** = $p < 0.0001$, NS = Not significant).

Table 1.13. Follicular numbers between cycling(CC) and non-cycling cows(NC) in the autumn-calving herd(No1).

Week	Cycling cows(CC)					Non-cycling cows(NC)					Significance levels(C vs NC)				
	SF	MF	LF	TF	LF size	SF	MF	LF	TF	LF size	SF	MF	LF	TF	LF size
2	-	-	-	-	-	19.0 ± 1.4 (25)	2.6 ± 0.3 (25)	0.5 ± 0.1 (25)	22.1 ± 1.5 (25)	14.5 ± 1.0 (12)	-	-	-	-	-
3	17.2 ± 1.1 (20)	1.7 ± 0.3 (20)	1.2 ± 0.2 (20)	20.1 ± 1.1 (20)	14.7 ± 0.9 (17)	12.8 ± 1.8 (5)	1.2 ± 0.6 (5)	1 (5)	15.0 ± 2.3 (5)	14.5 ± 1.0 (5)	NS	NS	NS	NS	NS
4	18.3 ± 1.5 (22)	2.0 ± 0.3 (22)	1.2 ± 0.2 (22)	21.5 ± 1.5 (22)	16.0 ± 1.2 (17)	16.2 ± 1.1 (25)	1.5 ± 0.3 (25)	1.1 ± 0.1 (25)	18.8 ± 1.2 (25)	15.7 ± 0.8 (24)	NS	NS	NS	NS	NS
5	18.4 ± 1.5 (27)	2.4 ± 0.4 (27)	2.2 ± 0.8 (27)	23.0 ± 1.7 (27)	15.2 ± 0.6 (23)	10.3 ± 1.2 (6)	1.8 ± 0.4 (6)	2.0 ± 0.4 (6)	14.2 ± 1.4 (6)	17.3 ± 0.7 (6)	**	NS	NS	*	NS
6	19.9 ± 0.7 (38)	3.0 ± 0.2 (38)	1.4 ± 0.1 (38)	24.3 ± 0.8 (38)	14.8 ± 0.5 (35)	15.4 ± 2.4 (7)	2.6 ± 0.7 (7)	1.3 ± 0.3 (7)	19.3 ± 2.7 (7)	17.8 ± 1.3 (6)	*	NS	NS	*	*
7	20.1 ± 0.9 (32)	2.4 ± 0.3 (32)	1.3 ± 0.1 (32)	23.8 ± 0.9 (32)	15.1 ± 0.8 (25)	15.2 ± 1.9 (5)	2.8 ± 0.7 (5)	1.4 ± 0.2 (5)	19.4 ± 2.1 (5)	16.2 ± 0.7 (5)	*	NS	NS	NS	NS
Mean	19.0	2.4	1.5	22.8	15.1	16.3	2.1	1.0	19.3	15.8					
Total	(139)	(139)	(139)	(139)	(117)	(73)	(73)	(73)	(73)	(58)					

() = Numbers of observations, Significant levels(* = $p < 0.05$, ** = $p < 0.01$, NS = Not significant)

Table 1.14. Mean numbers of each follicle category between weeks post-partum(pp) in cycling and non-cycling cows in the autumn-calving herd.

Weeks	Days pp	SF	MF	LF	Total follicles	LF size
2	7-13	19.0 ±1.4 (25)	2.6 ±0.3 (25)	0.5 ±0.1 (25)	22.8 ±1.5 (25)	14.6 ±1.0 (12)
3	14-20	16.3 ±1.0 (25)	1.6 ±0.2 (25)	1.2 ±0.1 (25)	19.1 ±1.1 (25)	14.7 ±0.7 (22)
4	21-27	17.2 ±0.9 (47)	1.7 ±0.2 (47)	1.1 ±0.1 (47)	20.1 ±0.9 (47)	15.9 ±0.6 (41)
5	28-34	16.9 ±1.4 (33)	2.3 ±0.3 (33)	2.1 ±0.7 (33)	21.4 ±1.5 (33)	15.6 ±0.5 (29)
6	35-41	19.2 ±0.7 (45)	2.9 ±0.2 (45)	1.4 ±0.1 (45)	23.5 ±0.8 (45)	15.3 ±0.5 (41)
7	42-48	19.4 ±0.9 (37)	2.5 ±0.3 (37)	1.3 ±0.1 (37)	23.2 ±0.9 (37)	15.3 ±0.6 (30)
Mean total		18.1 (212)	2.3 (212)	1.3 (212)	21.7 (212)	15.3 (175)

() = Numbers of observations
Mean ± SEM

had significantly higher mean numbers of MF's and LF's than in the CC (3.0 vs 2.3 and 1.4 vs 1.3, respectively, $p < 0.005$). The mean number of follicles in all categories and the size of LF's were also significantly different between weeks post-partum (Week 2 to Week 7). There were significant Group x Weeks post-partum interactions in the mean number of SF's and TF's ($p < 0.05$).

The mean number in each follicle category and the size of LF's were compared within weeks post-partum between the CC and NC in the spring-calving herd (Table 1.16). The CC had higher mean numbers of SF's and TF's in Week 3, compared with those in the NC (36.0 vs 18.9 and 39.7 vs 23.3, respectively, $p < 0.0001$). In contrast, NC had more mean numbers of LF's in Weeks 5 and 6 ($p < 0.05$). The NC also had more number of MF's during Weeks 6 and 7 ($p < 0.05$). Only the mean size of LF's in CC in the Week 6 was significantly higher than in the NC ($p < 0.005$).

Table 1.17 and Figure 1.8 show the distribution of the mean number of each follicle category in the spring-calving cows from Week 2 to Week 7 post-partum.

The means numbers of follicles in each category per cow in cycling and non-cycling animals during the post-partum period among cows in the No1 and No4 herds are shown in Figures 1.22 to 1.29.

2. OVARIAN FOLLICULAR DISTRIBUTION BEFORE THE FIRST OVULATION POST-PARTUM (PP)

2.1. Ovarian Follicular Patterns before the First Ovulation in Cows which Ovulated within 30 days Post-partum

MASSEY DAIRY NO1 (AUTUMN-CALVING HERD)

The distribution of follicular patterns 11 days before the first ovulation (Pre-OV1) in 10 autumn-calving cows which ovulated within 30 days are shown in Figure 1.9. The mean number of SF's varied during the last 15 days Pre-OV1, from 22 on Day 15 Pre-OV1 to 6 on Day 5 from when the mean number increased to 16 before declining slightly to 14 one day before Pre-OV1. In other words, there was possibly a decline in the peak of the mean number of SF's between Days 4 and 6 Pre-OV1.

The mean number of LF's remained static at 1 from Day 8 Pre-OV1 through the first ovulation. The mean size of LF's 11 days before Pre-OV1 was 15.8mm, and increased to 19mm one day before Pre-OV1 (Figure 1.9).

MASSEY DAIRY NO4 (SPRING-CALVING HERD)

The distribution of follicular patterns in 10 spring-calving cows 11 days before the first ovulation (Pre-OV1, less than 30 days pp) are shown in Figure 1.10. The frequency distribution of the mean number of SF's varied between 14 on Day 11 Pre-OV1, then 25 approximately 5 days Pre-OV1, and declining to 16 one day Pre-OV1. Similar trends were seen in the mean number of MF's. The mean number of LF's varied between 1 and 1.5 from 11 days Pre-OV1 declining to 1 at one day Pre-OV1.

Table 1.15. The mean number of each follicle category(SF, MF, LF and TF) and the mean size of the largest follicle(LF size) from Week 2 to Week 7 post-partum in cycling(CC) and non-cycling cows(NC) in the spring-calving herd(No4).

Follicles	Group		SEM	Significance levels		
	Cycling cows (CC)	Non-cycling cows (NC)		Group (CC vs NC)	Week	Group&Week
SF	21.1 ^a	19.3 ^c	1.0	**	**	*
MF	2.3 ^a	3.0 ^c	0.2	**	*	NS
LF	1.3 ^a	1.4 ^c	0.0	***	***	NS
TF	24.7 ^a	23.7 ^c	1.1	*	**	*
LF size	15.8 ^b	14.7 ^d	0.4	NS	***	NS(0.07)

Mean(Superscripts = Number of observations, ^a = 111, ^b = 96, ^c = 190 and ^d = 175)

Significant levels(* = $p < 0.05$, ** = $p < 0.005$, *** = $p < 0.0001$, NS = Not significant)

Table 1.16. Follicular numbers between cycling and non-cycling cows in the spring-calving herd(No4)

Week	Cycling cows(CC)					Non-cycling cows(NC)					Significance levels between CC and NC				
	SF	MF	LF	TF	LF size	SF	MF	LF	TF	LF size	SF	MF	LF	TF	LF size
2	-	-	-	-	-	18.8 ±1.0 (57)	2.2 ±0.2 (57)	0.8 ±0.0 (57)	21.8 ±1.1 (57)	12.8 ±0.3 (43)	-	-	-	-	-
3	36.0 ±1.3 (4)	3.0 ±0.7 (4)	0.7 ±0.5 (4)	39.7 ±1.7 (4)	12.5 ±1.5 (4)	18.9 ±1.1 (46)	3.0 ±0.3 (46)	1.4 ±0.5 (46)	23.3 ±1.3 (46)	15.0 0.5 (46)	***	NS	NS	***	NS
4	21.8 ±2.4 (16)	3.1 ±0.6 (16)	1.3 ±0.2 (16)	26.1 ±2.5 (16)	15.9 ±1.0 (13)	22.7 ±1.7 (32)	3.8 ±0.4 (32)	1.6 ±0.1 (32)	28.2 ±1.9 (32)	15.9 ±0.6 (32)	NS	NS	NS	NS	NS
5	20.4 ±1.6 (25)	2.6 ±0.4 (25)	1.2 ±0.1 (25)	24.2 ±1.8 (25)	15.3 ±1.0 (21)	17.1 ±1.5 (25)	3.0 ±0.4 (25)	1.8 ±0.1 (25)	22.0 ±1.6 (25)	16.5 ±0.6 (25)	NS	NS	**	NS	NS
6	19.0 ±1.3 (31)	2.0 ±0.2 (31)	1.2 ±0.1 (31)	22.2 ±1.4 (31)	15.5 ±0.6 (28)	16.8 ±2.5 (15)	3.6 ±0.9 (15)	1.7 ±0.1 (15)	22.2 ±3.0 (15)	13.1 ±0.7 (15)	NS	*	*	NS	**
7	21.6 ±1.5 (35)	2.0 ±0.3 (35)	1.4 ±0.1 (35)	25.0 ±1.7 (35)	16.5 ±0.6 (32)	20.8 ±1.9 (15)	3.3 ±0.5 (15)	1.5 ±0.2 (15)	25.5 ±2.0 (15)	15.3 ±0.6 (15)	NS	*	NS	NS	NS
Mean	21.1	2.3	1.3	24.7	15.8	19.3	3.0	1.3	23.6	14.7					
Total	(111)	(111)	(111)	(111)	(96)	(190)	(190)	(190)	(190)	(175)					

Means ± S.E.M.(Numbers of observations)

Significant levels(* = p<0.05, ** = p<0.005, *** = p<0.0001, NS = Not significant)

Table 1.17. Mean number of follicles in each category between weeks post-partum(pp) in the spring-calving cows(No4) from both cycling and non-cycling cows.

Weeks	Days pp	SF	MF	LF	TF	LF size
2	7-13	18.8 ±1.0 (57)	2.2 ±0.2 (57)	0.8 ±0.0 (57)	21.8 ±1.1 (57)	12.8 ±0.3 (43)
3	14-20	20.3 ±1.2 (50)	3.0 ±0.3 (50)	1.3 ±0.1 (50)	24.6 ±1.4 (50)	14.9 ±0.5 (47)
4	21-27	22.4 ±1.4 (48)	3.6 ±0.3 (48)	1.5 ±0.1 (48)	27.5 ±1.5 (48)	15.9 ±0.5 (45)
5	28-34	18.8 ±1.1 (50)	2.8 ±0.3 (50)	1.5 ±0.1 (50)	23.1 ±1.2 (50)	16.0 ±0.6 (46)
6	35-41	18.3 ±1.2 (46)	2.5 ±0.3 (46)	1.4 ±0.1 (46)	22.2 ±1.3 (46)	14.7 ±0.4 (43)
7	42-48	21.4 ±1.2 (50)	2.4 ±0.3 (50)	1.4 ±0.1 (50)	25.2 ±1.3 (50)	16.1 ±0.4 (47)
Total mean		20.0 (301)	2.7 (301)	1.3 (301)	24.0 (301)	15.1 (277)

() = Numbers of observations
Mean ± SEM

There was also growth and turnover of LF's from calving to the first ovulation. From individual recording maps, three cows (Cows. 124, 205, 401) out of 18 had only one large follicle develop and grow to ovulation. In fact, these three animals ovulated within 20 days post-partum. However, in other cows, there was growth and regression of more than one LF Pre-OV1.

The mean size of the largest follicle (LF size) in ovaries of spring-calving cows steadily increased from 14.5 mm on Day 11 Pre-OV1 and reached the mean diameter of 17 mm one day before the first ovulation (the mean size of LF 11 days Pre-OV1 to OV1 = 16.07mm, [Figure 1.10](#)).

2.2. Follicular Patterns before the First Ovulation (Pre-OV1) in both Autumn- and Spring-calving Cows which Ovulated within 30 days Post-partum (pp)

The follicular patterns of the mean number of SF's, MF's, LF's and the mean diameter of LF's in 20 cows from both herds were shown in [Figure 1.10](#). It can be seen that the patterns of the mean size of LF's gradually increased from a diameter of 12.5mm at Day 13 Pre-OV1 to 19mm one day before the first ovulation. The patterns for each follicle category were not different for autumn- or spring-calving cows ([Figure 1.9](#) and [1.10](#)).

2.3. Follicular Patterns before the First Ovulation (Pre-OV1) in Cows which Ovulated from 31-60 days Post-partum.

The frequency distribution of the mean number of SF's, MF's, LF's, TF's and the mean diameter of LF of spring-calving and autumn-calving cows which ovulated from 31-60 days pp were similar and were therefore combined ([Figure 1.12](#)). The mean number of SF's on approximately Day 10 Pre-OV1 was about 8, then increased to approximately 21.5 on Day 9 and finally decreased to about 11 on Day 6 Pre-OV1. The mean number of SF's increased to 16.0 approximately on Day 4 and then the mean number declined to 15 one day Pre-OV1. It is clear from [Figure 1.12](#) that there were two peaks in LF size during 2 weeks Pre-OV1. The first peak was about Day 10 Pre-OV1 with the mean diameter of 19mm. Then the mean diameter declined to 16mm on Day 6 Pre-OV1, and then increased to 20mm (the second peak) one day before the first ovulation.

2.4. Average Follicular Numbers before the First Ovulation

The mean number of follicles from Day 11 Pre-OV1 to OV1 in cows which ovulated either within 30 days pp or from 31-60 days pp from both herds are shown in [Table 1.18](#). It can be seen from [Table 1.18](#) that the mean number of SF's, MF's, LF's and TF's 11 days Pre-OV1 were significantly higher in the spring-calving cows than those in the autumn-calving cows ($p < 0.001$, $p < 0.05$, $p < 0.001$ and $p < 0.0001$ for SF's, MF's, LF's and TF's, respectively).

The mean number of SF's in the spring-calving cows which ovulated within 30 days pp was significantly higher than in those which ovulated from 31-60 days pp (21.0 vs 16.5, $p < 0.05$). The mean number of SF's, LF's and TF's in the spring-calving cows which ovulated within 30 days pp were significantly higher than those

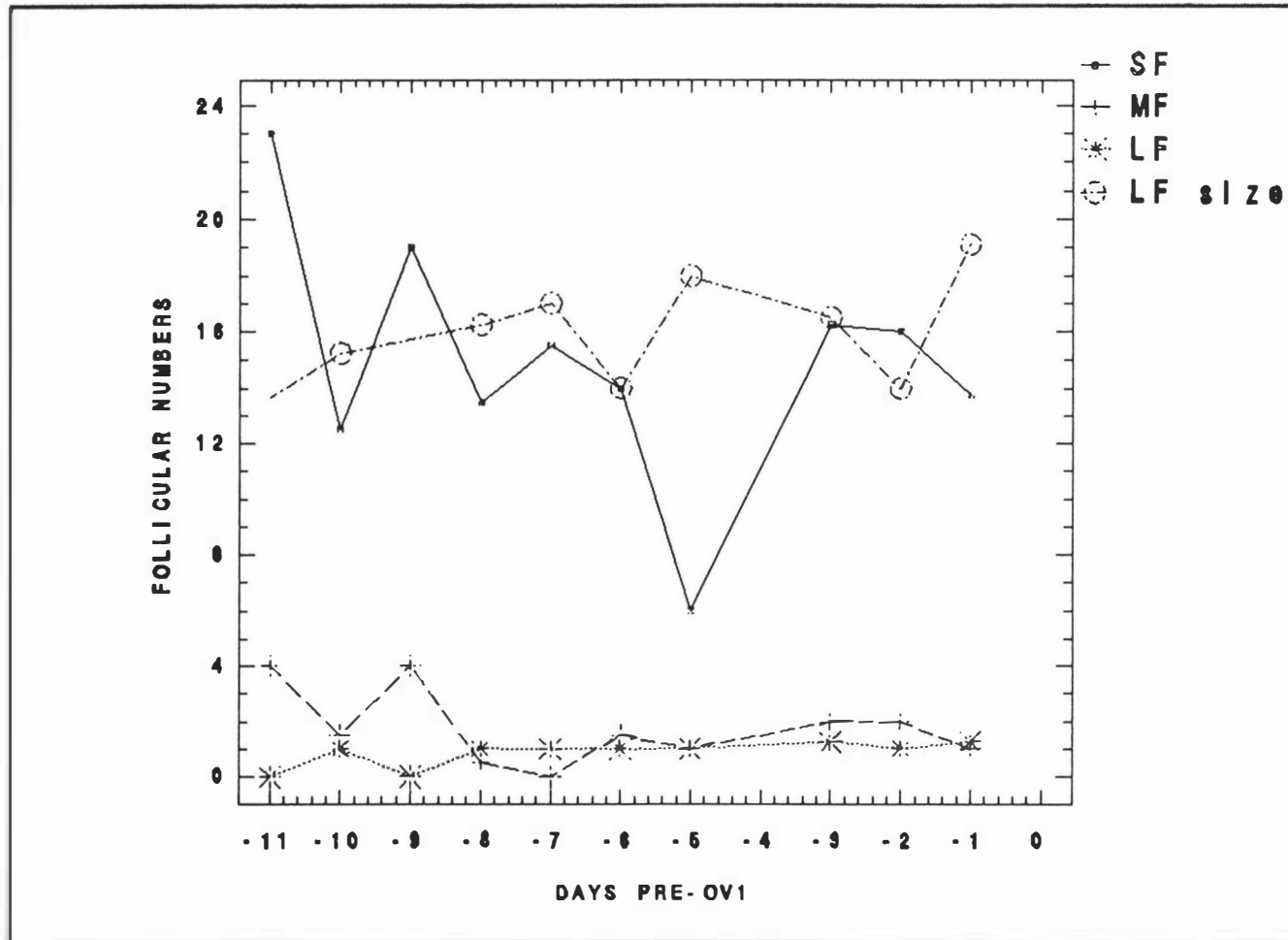


Figure 1.9. Follicular patterns Pre-OV1 in 10 autumn-calving cows which ovulated within 30 days pp.
 (Mean 11 days Pre-OV1 of SF= 15.7 ± 1.3 , MF= 2.0 ± 0.3 , LF= 0.9 ± 0.1 and LF size= 15.8 ± 0.8 mm).

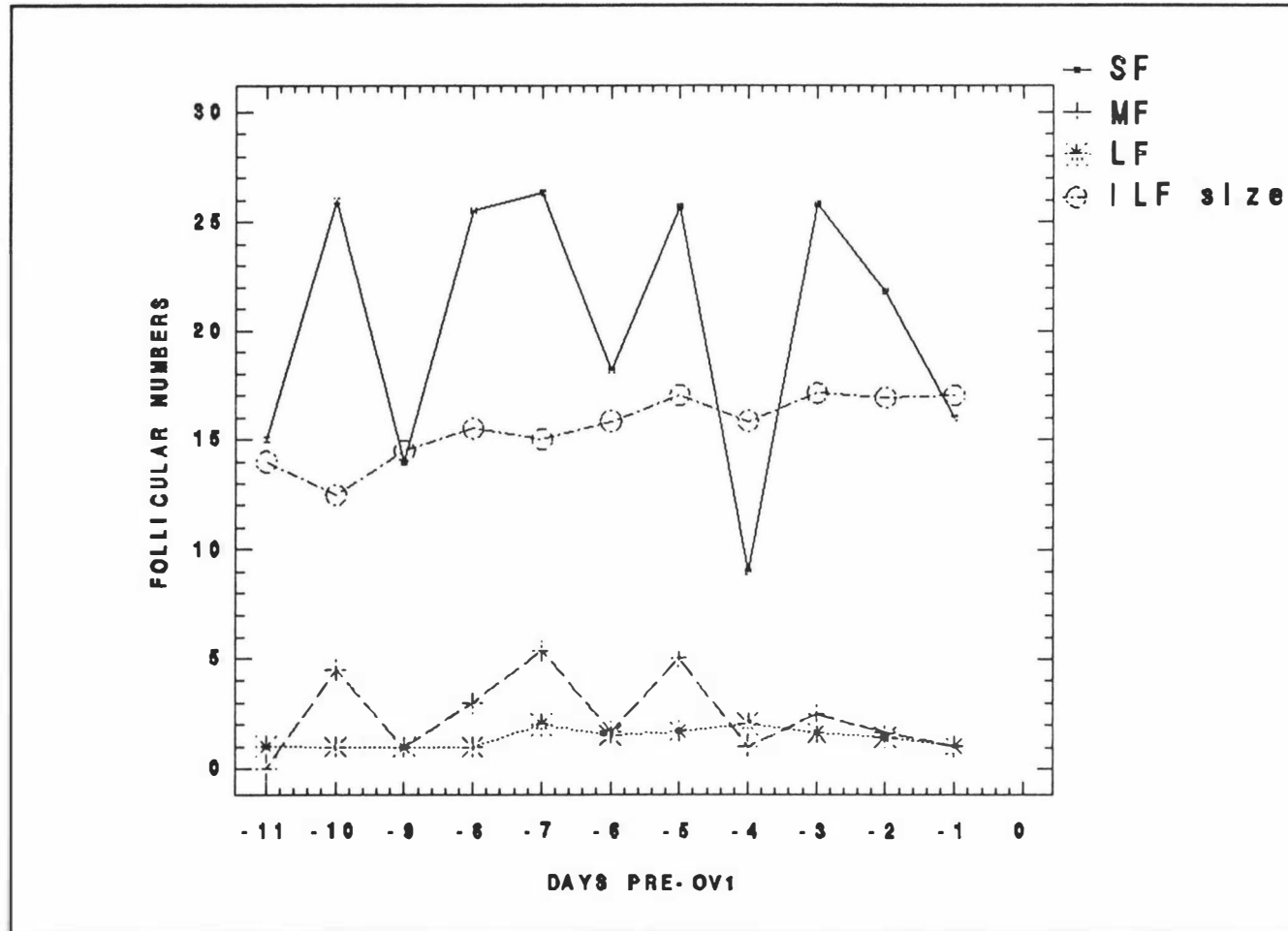


Figure 1.10. Follicular patterns Pre-OV1 in 10 spring-calving cows which ovulated within 30 days pp. (Mean 11 days Pre-OV1 of SF = 20.2 ± 2.1 , MF = 2.4 ± 0.6 , LF = 1.5 ± 0.1 and mean LF size = 16.1 ± 0.3 mm).

in the autumn-calving cows ($p < 0.005$). However, the mean size of LF's in the spring-calving cows which ovulated within 30 days pp tended to be smaller than that of cows which ovulated from 31-60 days pp (16.2 mm vs 17.6 mm, $p = 0.1$).

The mean number of LF's in the spring-calving cows which ovulated from 31-60 days pp was significantly higher than that in the autumn-calving cows (1.8 vs 1.2, Table 1.18, $p < 0.05$). The mean number of MF's and TF's in the spring-calving cows which ovulated from 31-60 days pp tended to be higher than those in the autumn-calving cows ($p > 0.2$).

3. FOLLICULAR DISTRIBUTION AFTER THE FIRST OVULATION POST-PARTUM

There appeared to be two peaks in the mean number of SF's during the first two weeks Post-OV1 (Figure 1.13). The mean number of SF's was high (22-25) during the first 4 days after the first ovulation, then decreased to 14 on Day 8 Post-OV1, before increasing to about 20 between Days 11 to 12 Post-OV1 and then finally declining. The MF's followed a similar pattern. The mean number was approximately 3.5 one day Post-OV1 and gradually declined to about 1.5 on Day 7 Post-OV1 and then increased to 3.5 on Days 11 to 12 Post-OV1. It can be seen from Figure 1.13 that the mean size of the LF was 11.3 mm diameter on Day 1 Post-OV1 and steadily increased and reached the first peak of 17 mm between Days 8 and 9 Post-OV1, then started to regress to 11.5 mm between Days 10 and 11 Post-OV1. Subsequently, the mean size increased towards a second peak.

3.1. Follicular Patterns after the First Ovulation (Post-OV1) in Cows which had a Short First Cycle (6-12 days)

After the first ovulation (Figure 1.14), cows which had a short cycle pp seemed to have only one peak in the mean number of SF's, starting from 26 on Day 1 Post-OV1 and then tending to decline to 15 on Days 8 and 9 Post-OV1.

The follicular pattern in the mean number of MF's Post-OV1 was similar to the SF's. The mean number of LF's was between 1 and 1.7 up to Day 6 Post-OV1, then remained static at 1 throughout the rest of the period to Day 9 (Figure 1.14).

The mean size of LF's increased steadily from 10.5 mm on Day 1 Post-OV1 to about 19 mm diameter between Days 8 and 9 Post-OV1 (Figure 1.14). It appeared that there was only one peak in the mean size of LF's in these cows. In addition, when the size of the LF's of individual cows in the spring herd was observed from ovarian maps during the short first cycle pp, there was only one large follicle which developed after the first ovulation and subsequently ovulated within 6-12 days Post-OV1 with CL formation (5 out of 8 cows).

3.2. Follicular Patterns after the First Ovulation (Post-OV1) in Cows which had a Shortened First Cycle Length of 13-18 days

The pattern of the mean number of SF's appeared to have 2 peaks. The first peak

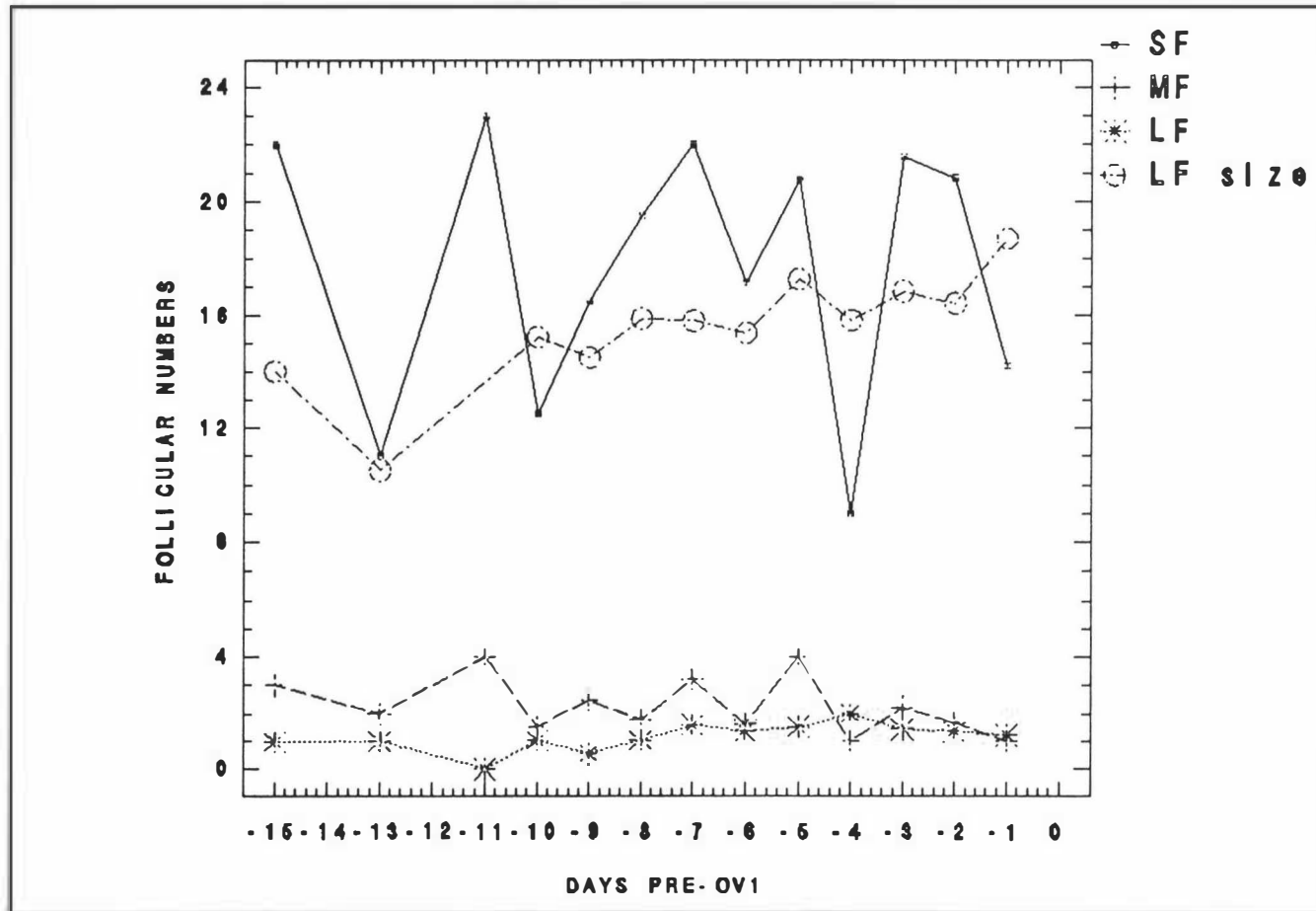


Figure 1.11. Follicular patterns Pre-OV1 in 20 cows from both herds which ovulated within 30 days pp. (Mean 11 days Pre-OV1 of SF = 18.0 ± 1.2 , MF = 2.3 ± 0.3 , LF = 1.1 ± 0.1 and LF size = 15.8 ± 0.6 mm).

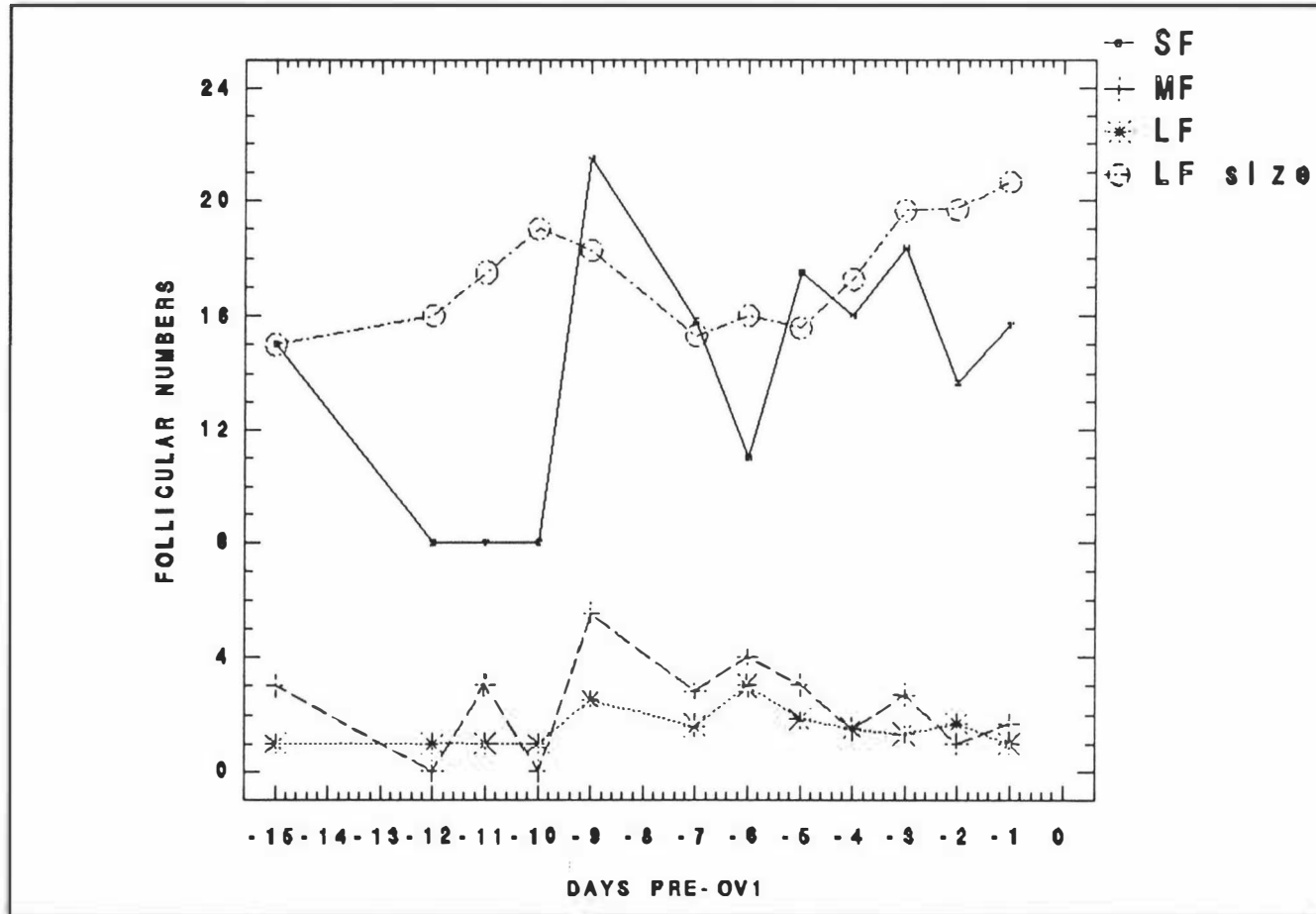


Figure 1.12. Follicular patterns Pre-OV1 in 10 cows from both herds which from ovulated 31-60 days pp. (Mean 11 days Pre-OV1 of SF= 14.6 ± 1.3 , MF= 2.2 ± 0.5 , LF= 1.5 ± 0.2 and LF size= 17.3 ± 0.5 mm).

Table 1.18. Mean numbers of follicles in each category from 11 days Pre-OV1 to first ovulation post-partum in the autumn(A) and spring-calving cows(S)

Herd	OV1 < 30 days pp					OV1 = 31-60 days pp					All animals*				
	SF	MF	LF	Total F	LF size	SF	MF	LF	Total F	LF size	SF	MF	LF	Total F	LF size
A	15.2 ^d ±1.0 (23)	1.6 ±0.2 (23)	1.0 ^d ±0.1 (23)	17.9 ^d ±1.7 (23)	16.3 ±0.8 (21)	14.6 ±1.7 (12)	1.9 ±0.5 (12)	1.2 ^a ±0.1 (12)	17.7 ±2.0 (12)	16.9 ±0.7 (12)	15.0 ^o ±0.8	1.8 ^a ±0.2	1.1 ^o ±0.1	17.9 ^o ±0.9	16.4 ±0.5
S	21. ^{a,d} ±1.5 (29)	2.5 ±0.4 (29)	1.5 ^d ±0.1 (29)	25.1 ^d ±1.7 (29)	16.2 ±0.5 (29)	16.5 ^a ±1.5 (18)	2.7 ±0.4 (18)	1.8 ^a ±0.2 (18)	21.1 ±1.7 (18)	17.6 ±0.9 (18)	20.2 ^o ±0.9	2.8 ^a ±0.2	1.5 ^o ±0.2	24.6 ^o ±1.0	16.3 ±0.3
All A and S	18.4	2.1	1.3	21.9	16.3	15.8	2.5	1.6	19.7	17.3	18.3	2.4	1.4	22.1	16.3

() = Numbers of observations

* = including cows which ovulated > 60 days pp

^{a,b,c,d,e} = Mean values within the same row with the same head column or within the same column in the same superscripts (^a=p<0.05, ^b=p<0.01, ^c=p<0.001, ^d=p<0.005, ^e=p<0.0001)

of SF's declined to 12-14 between Days 7 and 9 Post-OV1, then a second peak with an increase to 29 on Day 10 and declined to 17 on Day 12 Post-OV1(Figure 1.15).

The patterns for the mean number of MF's and LF's were the same as for SF's. The mean number of MF's peaked at 3 and 7 on Days 3 and 10 Post-OV1, respectively, while that of LF's had two peaks on Days 3 and 10 Post-OV1, respectively.

The pattern for the mean size of LF's of cows in this cycle appeared to have at least two peaks, starting from 12mm in diameter on Day 1 Post-OV1, and increasing to peak at 19mm in diameter on Day 9 Post-OV1, and then regressing on Days 10 and 11. The mean size then started to increase to 21.5mm on Day 14 Post-OV1(the second peak) and possibly ovulated at the second peak.

3.3. Follicular Patterns after the First Ovulation(Post-OV1) in Cows which had a First Cycle Length of 19-24 days

There were at least two peaks in the mean number of SF's, MF's and LF's in cows that had the first cycle post-partum which was of normal length(Figure 1.16). The mean number of SF's was 25 on Days 1 and 2 Post-OV1, declining to 14 between Days 7 and 9, then starting to a second peak. Similarly, the mean number of MF's started at 3.5 on Day 1, then declined to 0.7 on Days 7 and 9 before increasing to a second peak. The mean number of LF's increased from 0 on Day 1 to the first peak of 2 on Day 6, then declining to 1 between Days 9 and 11 before increasing to the second peak thereafter.

The mean size of the largest follicle(LF) was 10mm in diameter on Days 1 and 2, increasing to the first peak at about 15.5mm on Days 6 and 7, and then declining to 10mm on Day 10 before starting the second peak.

4. Follicular Patterns in Autumn- and Spring-calving Cows which had a Normal First Cycle Post-partum before the Second Ovulation(Pre-OV2).

The patterns of the mean number of SF's, MF's, LF's and the mean size of LF's are shown in Figure 1.16. It appeared that there were two peaks of the mean size of LF's during two weeks Pre-OV2. The first peak was approximately on Day 9 Pre-OV2 with the mean diameter of 17mm. The second peak was 18mm in diameter on Day 1 Pre-OV2 and resulted in ovulation.

The mean number of SF's appeared to have only one peak during the 12 days Pre-OV2, starting at 10 on Day 12 Pre-OV2. The number then steadily increased to peak at 32 on Day 4 Pre-OV2 and declined to 3 on Day 3 Pre-OV2. The mean number of MF's followed a similar pattern. The mean number of LF's was between 1 and 1.5 during 12 days Pre-OV2.

5. Follicular Distribution during the Normal First Cycle Post-partum

The data for numbers of SF's, MF's, LF's and the mean size of LF's in cows which had a normal first cycle Post-OV1 were pooled together with those of Pre-OV2(Figure 1.16 and Figure 1.17). The combined patterns of the mean numbers of SF's, MF's,

LF's and the mean size of LF's during the normal first cycle pp are shown in [Figure 1.18](#).

The mean number of SF's had two peaks. The first peak of 25 was on Days 3 and 4 Post-OV1 and declined to 12 on Days 8 and 9. The second peak was 23 on Day 13 Post-OV1 and then declined before the second ovulation. The mean number of MF's followed a similar pattern.

The mean number of LF's followed a contrasting pattern. It increased from 0 after the first ovulation to a first peak of two on Day 6 Post-OV1. The second peak was on Day 12 Post-OV1, and the third peak was on Day 17 before it declined to 1 before the second ovulation.

The mean size of the LF increased after the first ovulation from 10mm in diameter on Day 2 Post-OV1 to the first peak of 15.5mm approximately on Days 6 and 9, then declining to 13mm between Days 10 and 11. The second peak appeared between Days 13 and 14 Post-OV1 when the diameter was 16mm. Lastly, the mean size of the LF which was to ovulate was 11.5mm in diameter on Day 15 and then increased to about 18mm on Day 20 Post-OV1 (one day before the second ovulation).

Milk Progesterone Levels(P₄)

The changes in the mean milk P₄ in the autumn- and spring-calving cows during the first normal cycle post-partum are shown in [Figure 1.19](#). The mean milk P₄ during this first cycle was not significantly higher in the spring-calving cows than in the autumn-calving cows ($13.1 \pm 2.5\text{ng/ml}$, compared with $9.9 \pm 1.2\text{ng/ml}$, $p = 0.25$). The mean milk P₄ during the dioestrous phase (Day 7-16 of the normal first cycle) was $23.3 \pm 1.7\text{ng/ml}$ in 4 spring-calving cows, compared with $14.1 \pm 0.5\text{ng/ml}$ in 5 autumn-calving cows ($p < 0.0005$).

There were no comparisons for the mean milk P₄ between the autumn- and spring-calving cows which had short or shortened first cycles because there were small numbers of autumn-calving cows which had short first cycles and spring-calving cows which had shortened first cycles. The mean milk P₄ pattern after the first ovulation in cows which had short and shortened first cycles post-partum are shown in [Figure 1.20](#) and [Figure 1.21](#). Because the length of short first cycle ranged 6 to 12 days, the levels of milk P₄ dropped on Days 6 and 8 ([Figure 1.20](#)).

ULTRASOUND IMAGES

Ultrasound images of follicles in each category and a corpus luteum in the ovaries of examined cows are shown in [Figures 1.31](#).

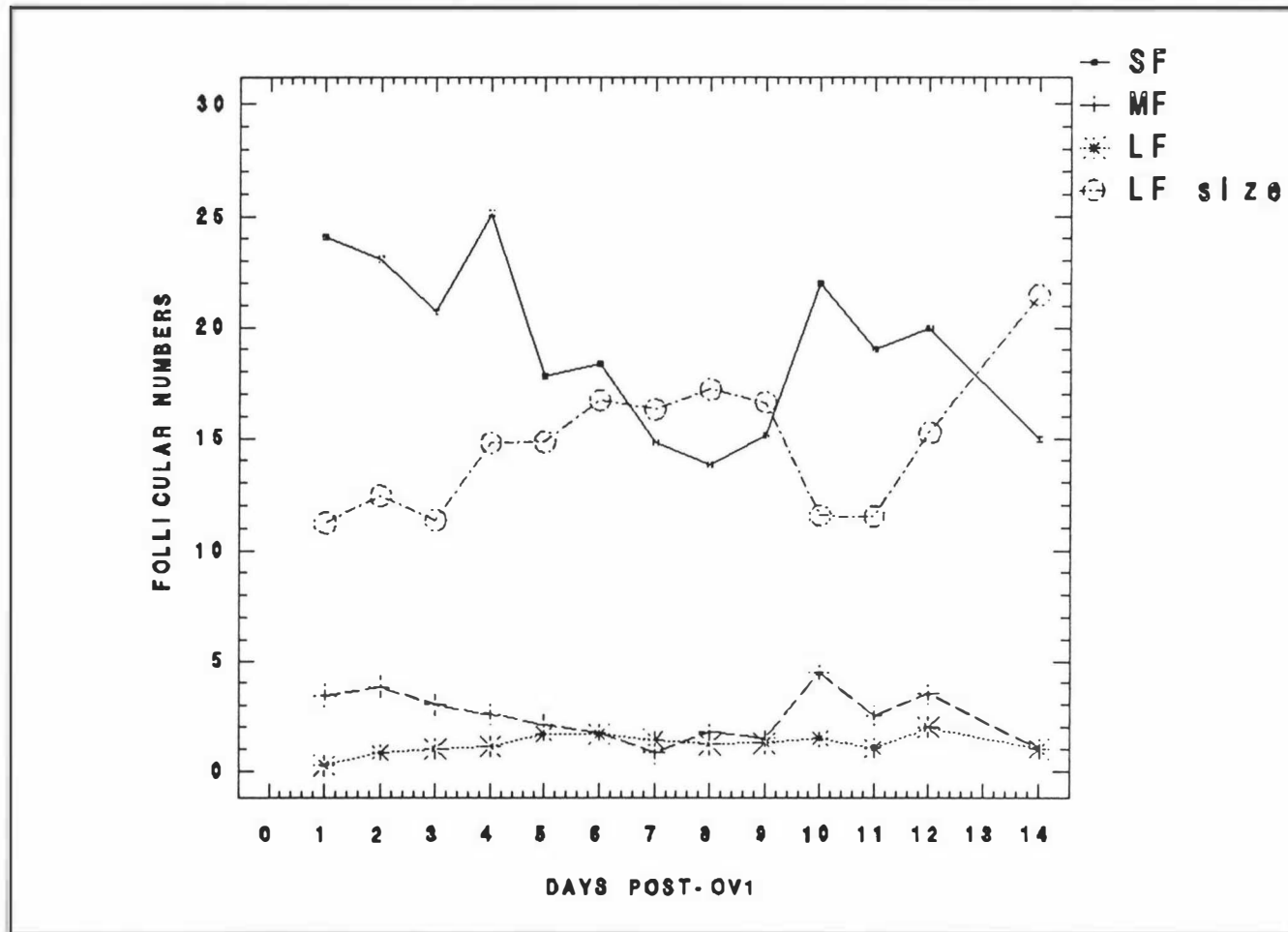


Figure 1.13. Follicular patterns after first ovulation(Post-OV1) pp in 36 cows from both herds.
 (Mean SF= 19.1 ± 1.0 , MF= 2.5 ± 0.3 , LF= 1.2 ± 0.1 and LF size= 14.7 ± 0.8 mm).

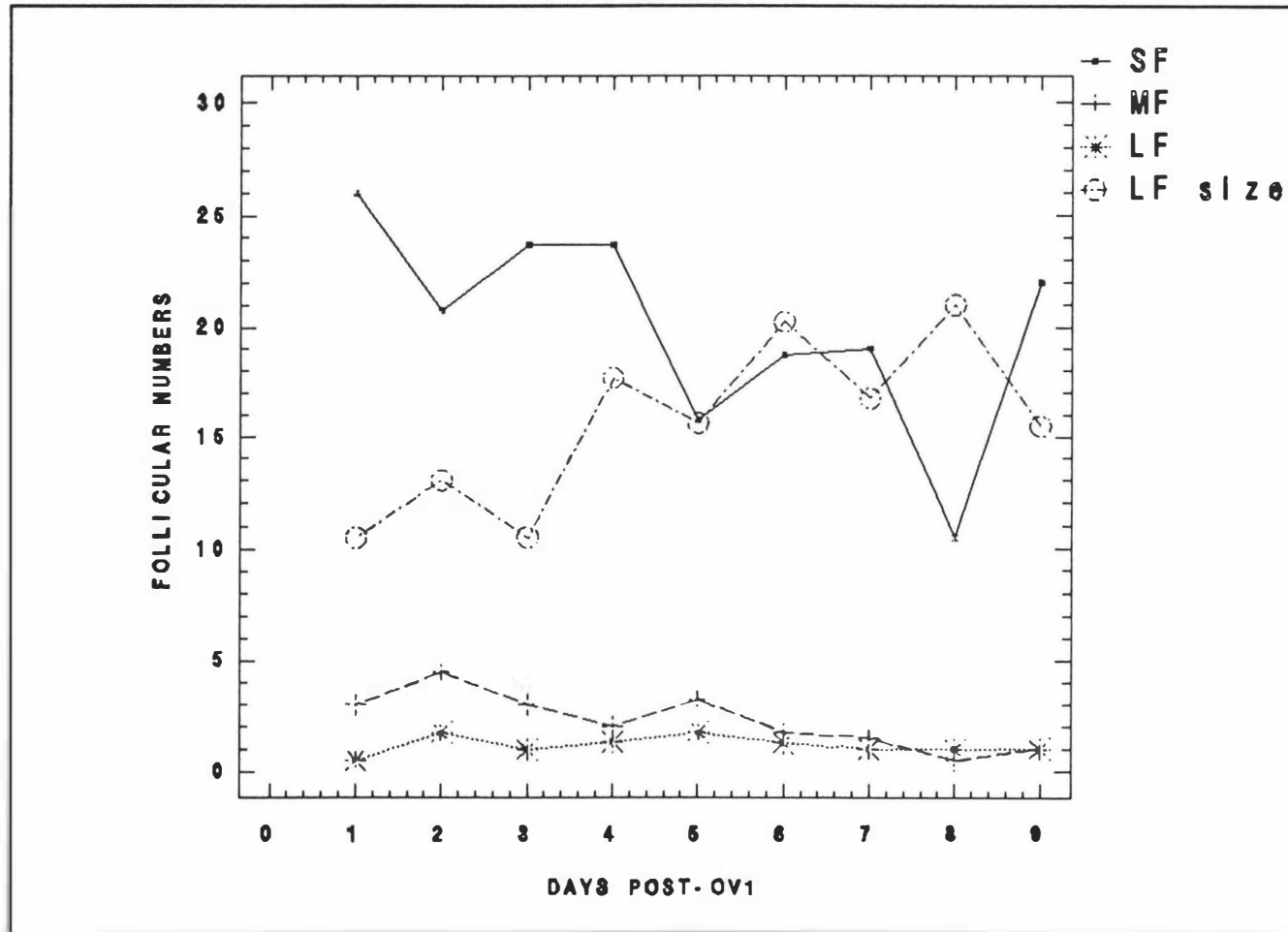


Figure 1.14. Follicular patterns after first ovulation(Post-OV1) in 10 cows which had a short first cycle pp.
 (Mean SF = 20.0 ± 1.6 , MF = 2.3 ± 0.4 , LF = 1.2 ± 0.1 and LF size = 15.6 ± 1.3 mm).

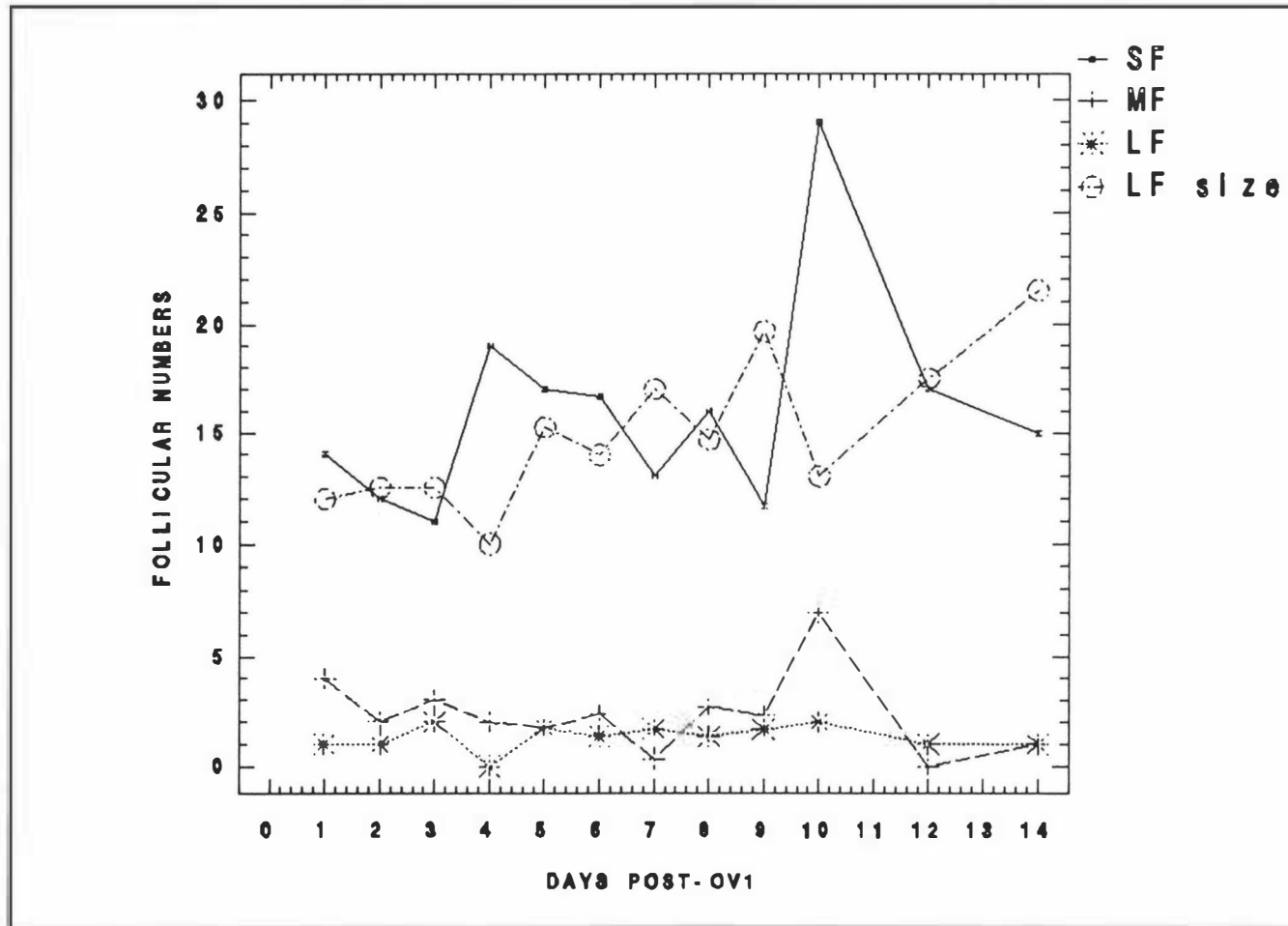


Figure 1.15. Follicular patterns Post-OV1 in 8 cows which had a shortened first cycle pp.
 (Mean SF = 15.9 ± 1.4 , MF = 2.4 ± 0.5 , LF = 1.3 ± 0.2 and LF size = 15.0 ± 1.0 mm).

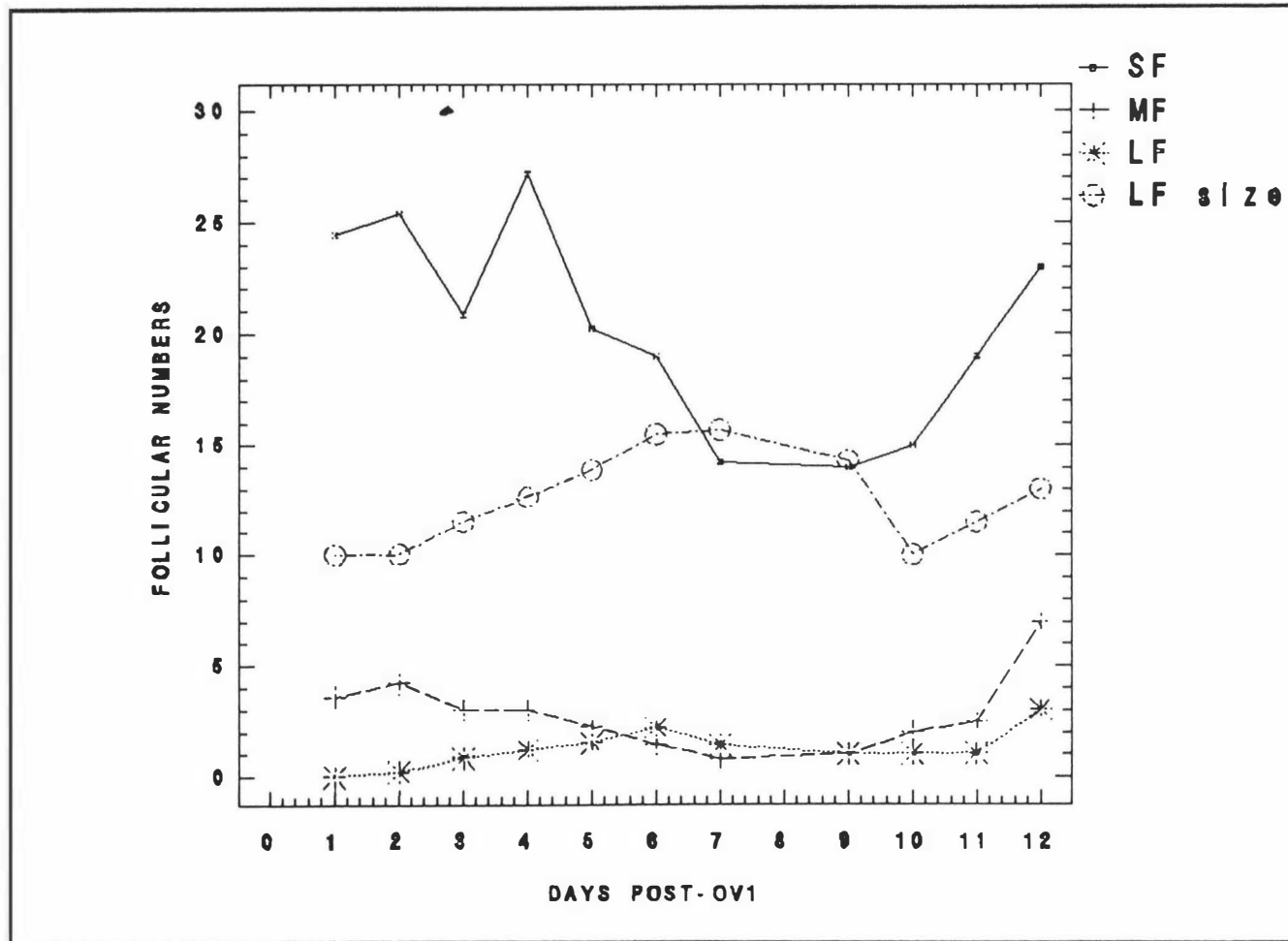


Figure 1.16. Follicular patterns Post-OV1 in 16 cows which had a normal first cycle pp.
 (Mean SF = 20.2 ± 1.4 , MF = 2.8 ± 0.5 , LF = 1.2 ± 0.2 and LF size = 12.5 ± 0.6 mm).

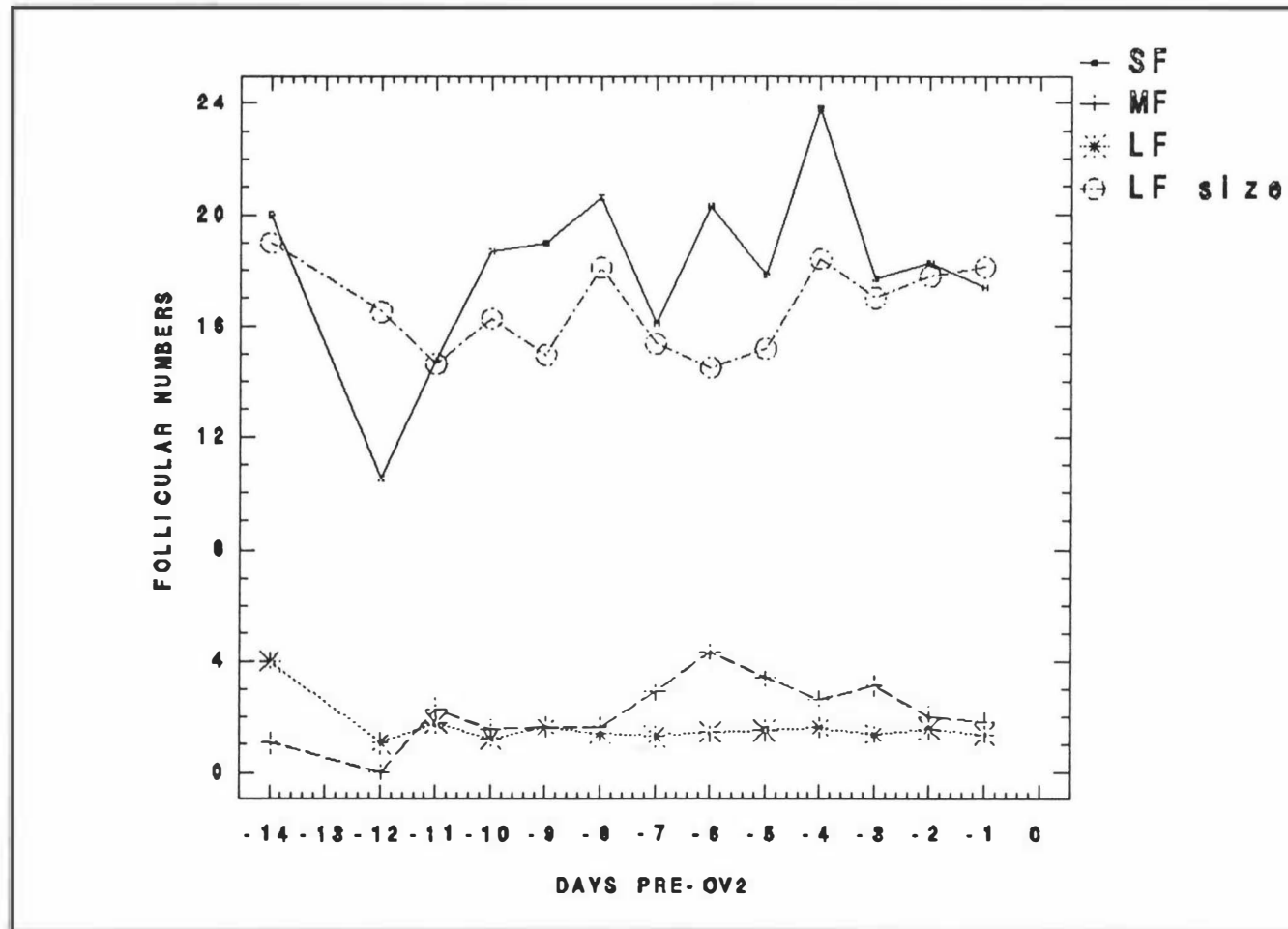


Figure 1.17. Follicular patterns before second ovulation(Pre-OV2) in 16 cows which had a normal first cycle pp. (Mean SF = 19.5 ± 1.4 , MF = 2.5 ± 0.5 , LF = 1.6 ± 0.2 and LF size = 15.7 ± 0.4 mm).

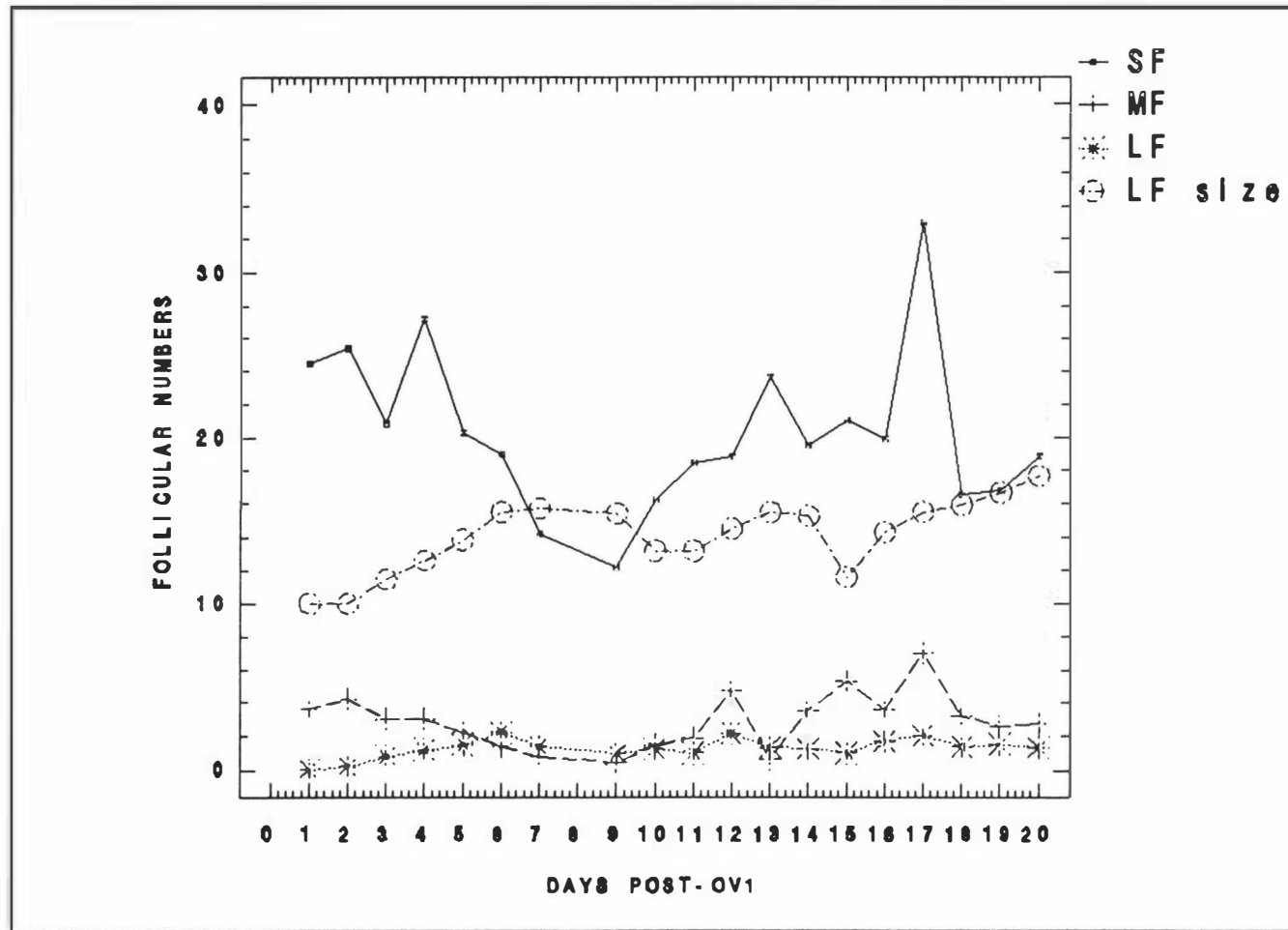


Figure 1.18. Follicular patterns in 16 cows during a normal first cycle pp(0 = Day of first ovulation).
 (Mean SF = 20.2 ± 1.0 , MF = 2.9 ± 0.4 , LF = 1.3 ± 0.1 and LF size = 14.3 ± 0.5 mm).

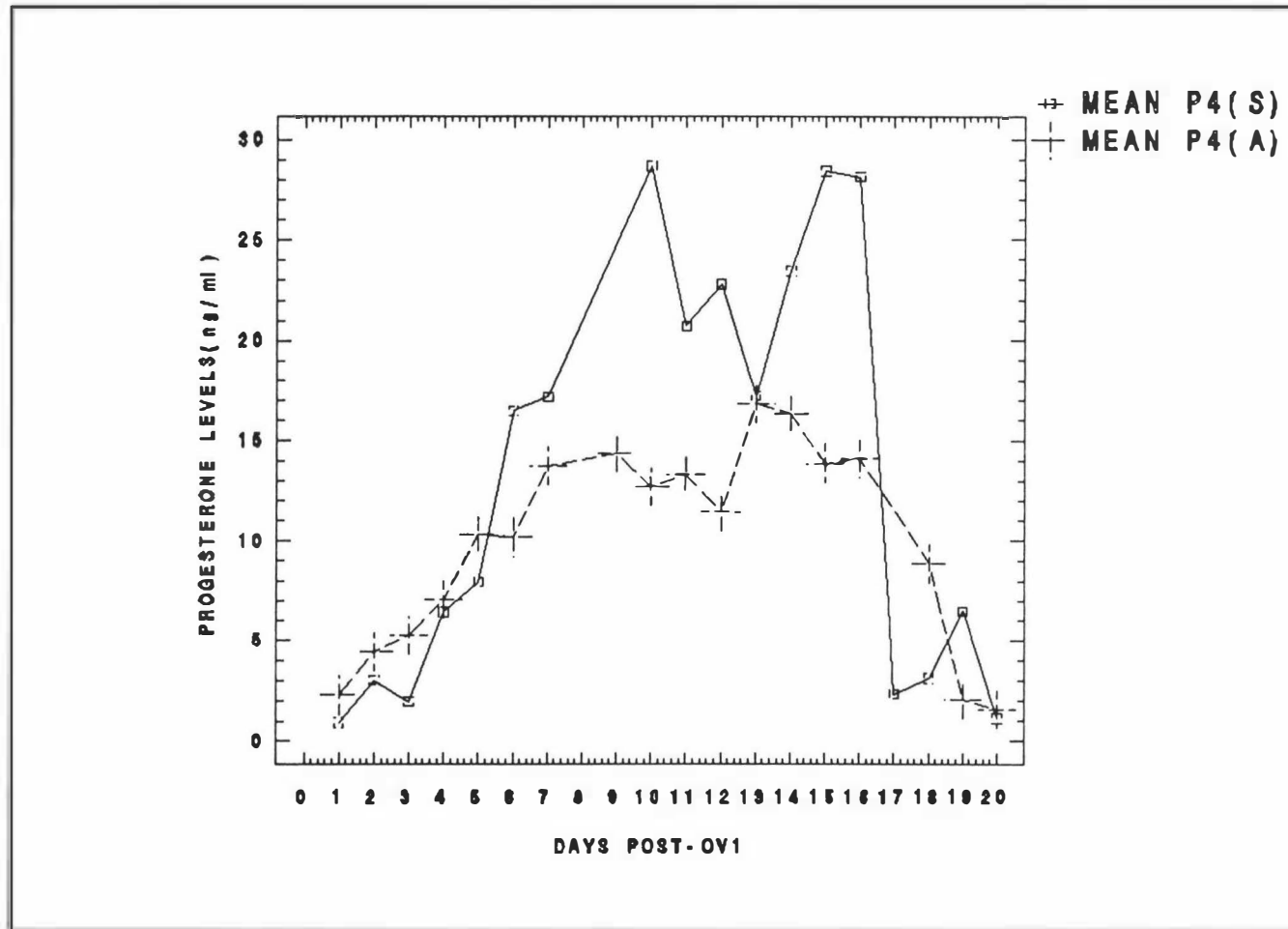


Figure 1.19. Mean milk progesterone(P₄) in 11 autumn(A) and 5 spring(S) cows during a normal cycle pp.
 [A = 9.9 ± 1.2, S = 13.1 ± 2.5 ng/ml].

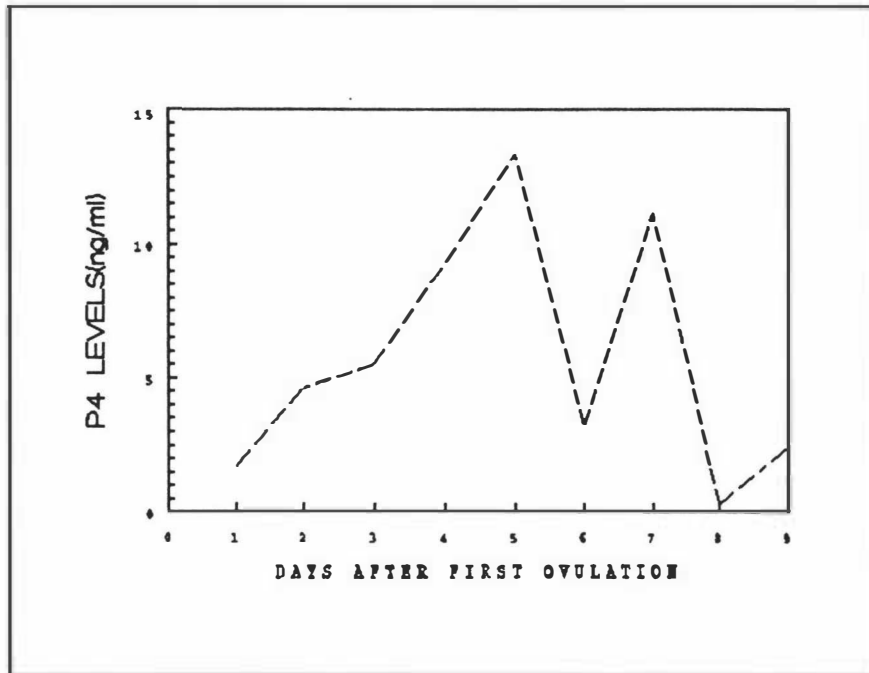


Figure 1.20. Mean milk progesterone levels(P_4) after first ovulation in cows which had a short first cycle pp.

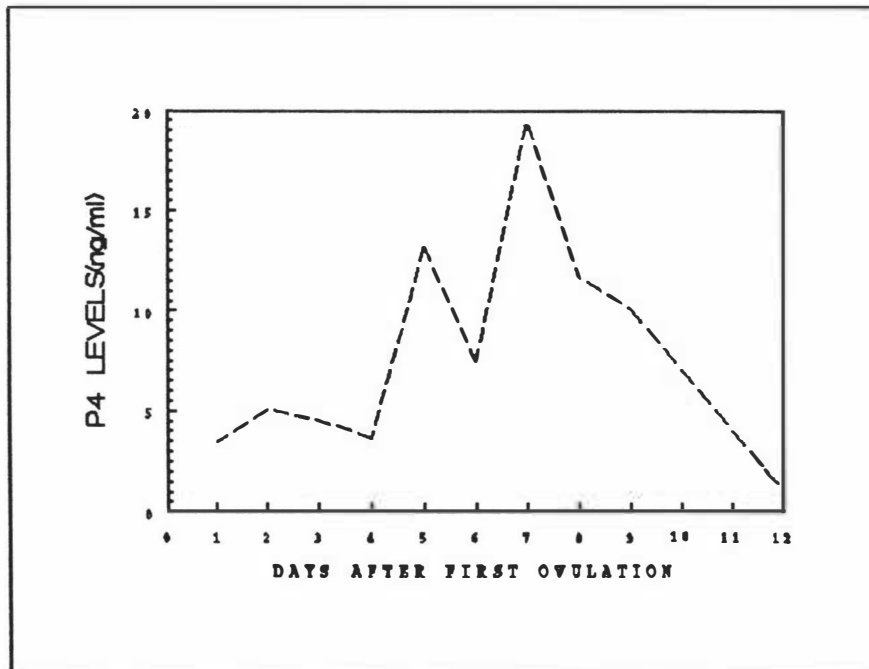


Figure 1.21.. Mean milk progesterone levels(P_4) after first ovulation in cows which had a shortened first cycle pp.

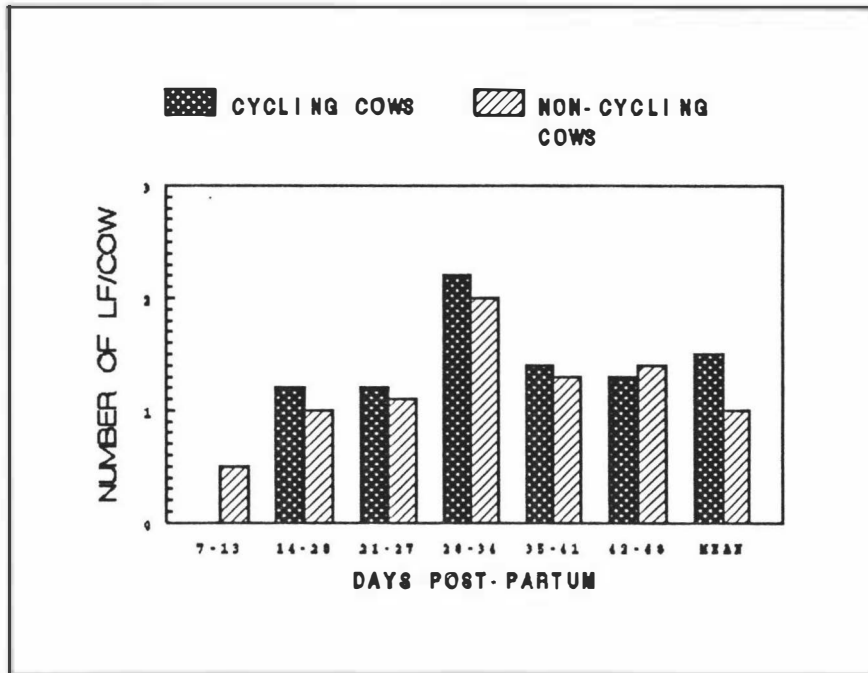


Figure 1.22. Mean numbers of the largest follicle(LF) per cow in cycling and non-cycling animals during the post-partum period among cows in the No1 herd.

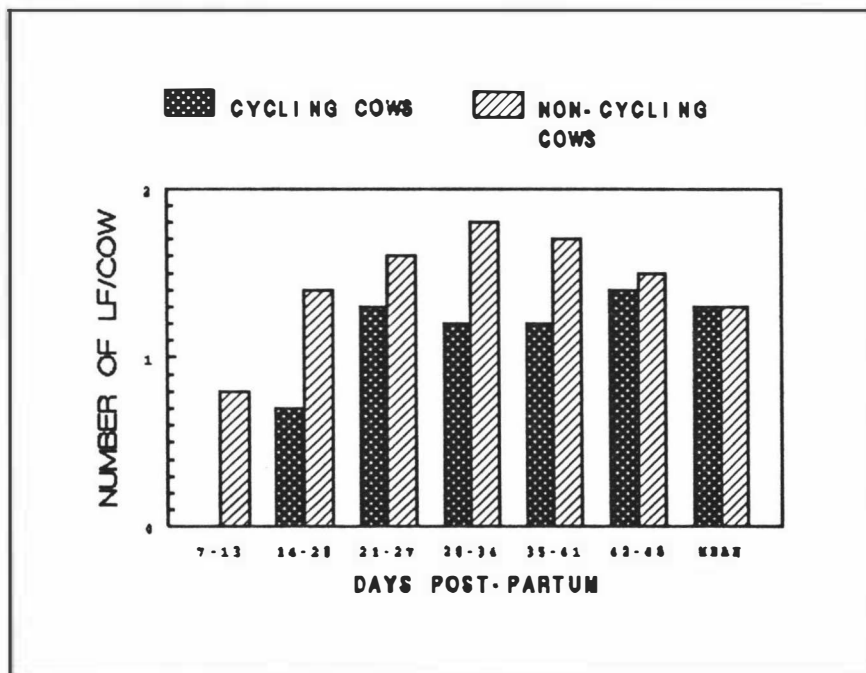


Figure 1.23. Mean numbers of the largest follicle(LF) per cow in cycling and non-cycling animals during the post-partum period among cows in the No4 herd.

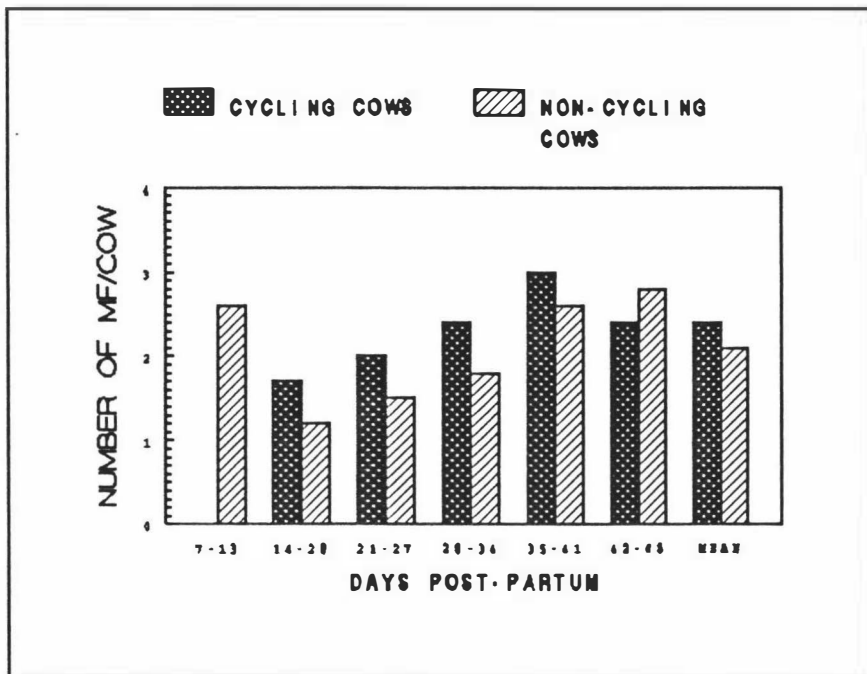


Figure 1.24. Mean numbers of medium follicle(MF) per cow in cycling and non-cycling animals during the post-partum period among cows in the No1 herd.

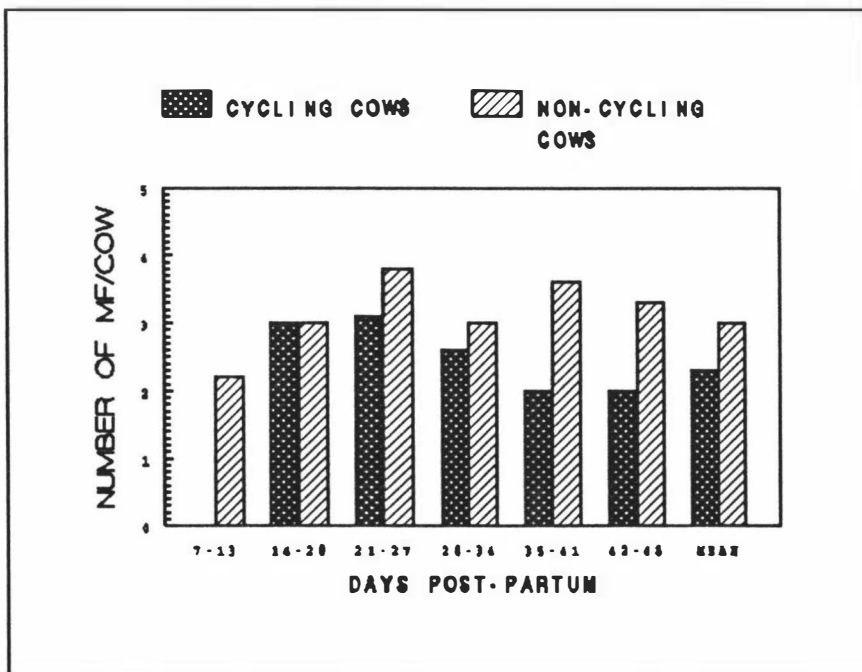


Figure 1.25. Mean numbers of medium follicle(MF) per cow in cycling and non-cycling animals during the post-partum period among cows in the No4 herd.

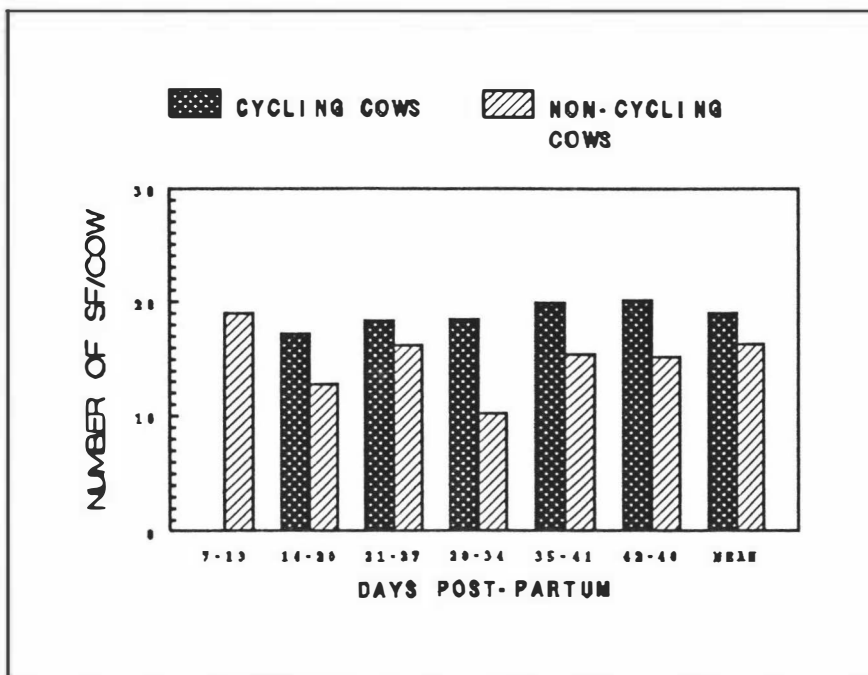


Figure 1.26. Mean numbers of small follicle(SF) per cow in cycling and non-cycling animals during the post-partum period among cows in the No1 herd.

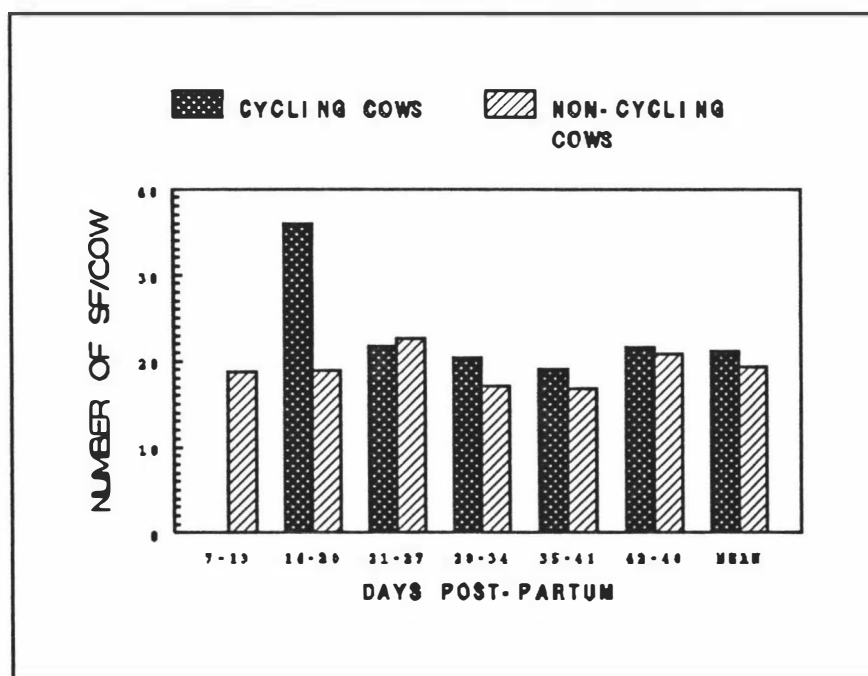


Figure 1.27. Mean numbers of small follicle(SF) per cow in cycling and non-cycling animals during the post-partum period among cows in the No4 herd.

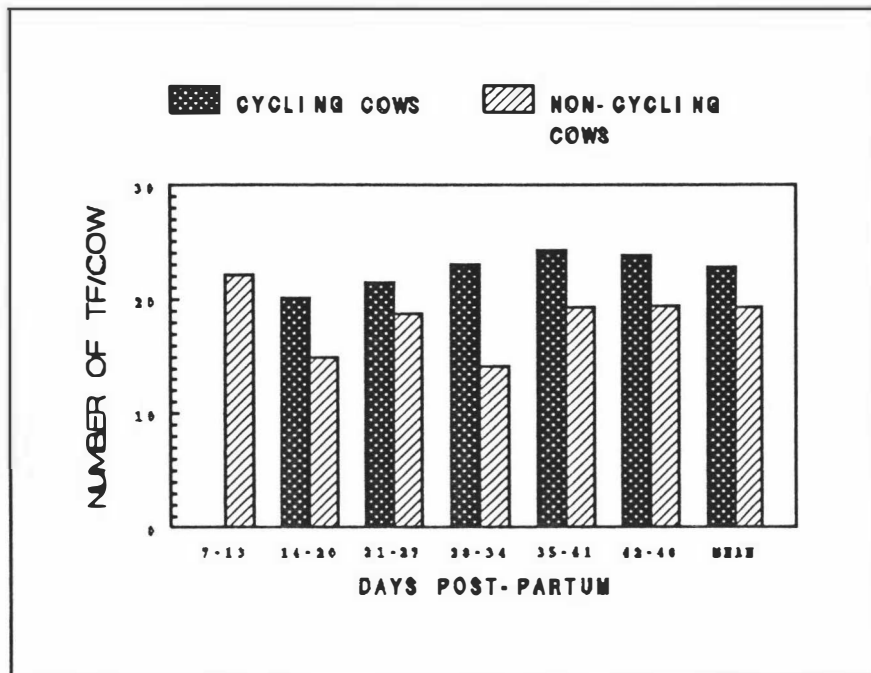


Figure 1.28. Mean numbers of total follicle(TF) per cow in cycling and non-cycling animals during the post-partum period among cows in the No1 herd.

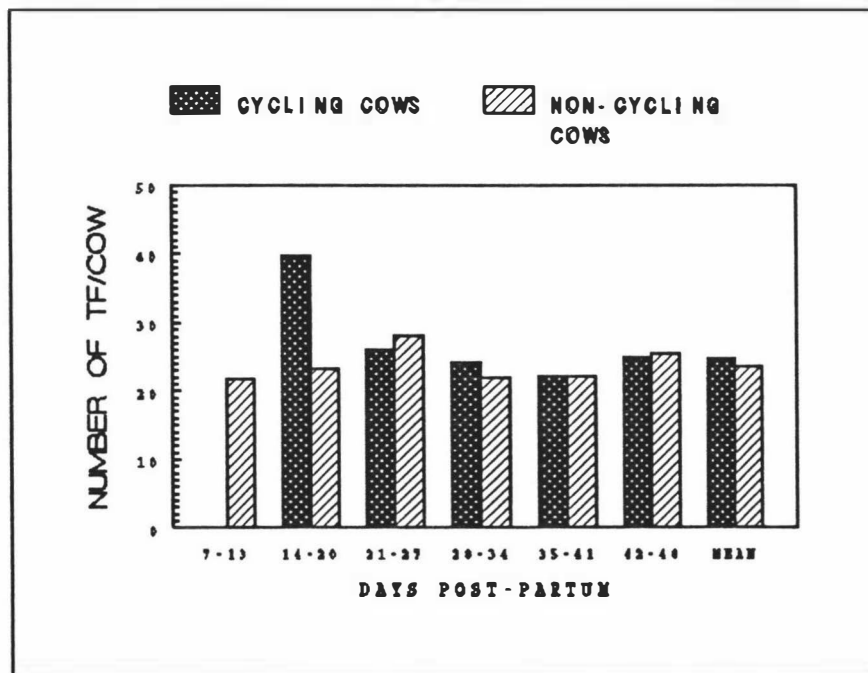


Figure 1.29. Mean numbers of total follicle(TF) per cow in cycling and non-cycling animals during the post-partum period among cows in the No4 herd.



Figure 1.30. A real time, B-mode ultrasound scanner(a, an Aloka Echo Camera) equipped with a 5 MMz rectal probe(b) and an videotape recorder(c) used for ovarian examinations.

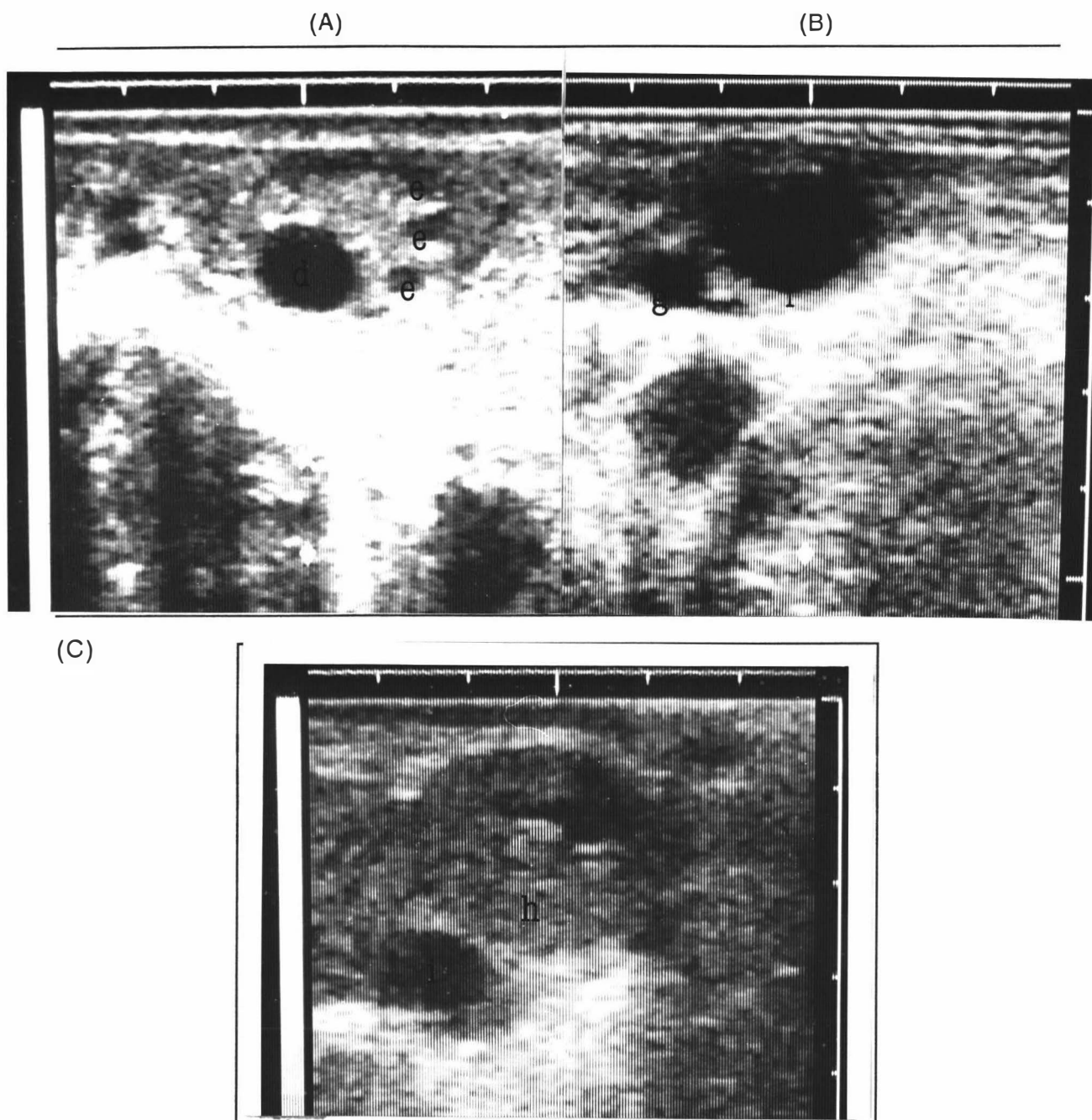


Figure 1.31 (A) One large follicle (d, 10mm diameter) with 3 small follicles (e, 4 mm) detected in one post-partum dairy cow (Cow 412)

(B) One large follicle (f, 20 mm diameter) and a medium-sized follicle (g, 6mm) 5 days before the first post-partum ovulation (Cow 423)

(C) A corpus luteum containing fluid-filled cavity (h) and a large follicle (i, 13 mm diameter) developed after the first post-partum ovulation

DISCUSSION

1. POST-PARTUM REPRODUCTIVE INDICES

1.1 The Interval from Calving to First Ovulation

The mean interval from calving to estimated first post-partum ovulation of the examined cows from the spring-calving herd in the present study was longer than that in the autumn-calving herd (36.57 days, compared with 23.68 days, $p < 0.01$). This result may be contrary to expectations, because spring pasture grows more rapidly and allows higher production per cow than autumn or winter pasture.

The results in this present study are in accordance with those of Peters and Riley (1982), King and Macleod (1984) and Montgomery (1984). Peters and Riley (1982) have reported that beef cows calving in spring had a longer period of acyclicity post-partum than those calving during autumn/winter months (83.0 days in spring-calving cows, compared with 44.0 days in autumn/winter-calving cows). They also showed a significant negative correlation between the length of acyclic period and post-partum body weight. Cows with a higher body weight at calving had a shorter period of post-partum acyclicity. King and Macleod (1984) found that the average interval to first post-partum ovulation was shorter in autumn than in spring-calving beef cows in Canada (32 days vs 59 days). In the present study, the examined cows from both spring- and autumn-calving herds had mean body condition scores at calving of between 3.75 and 4, and there were no significant differences in the mean intervals from calving to first post-partum ovulation between cows which had body condition scores at calving of ≥ 4 and less than 4.

Some authors (Hansen and Hauser, 1983; Baker, 1968) have reported that post-partum anoestrus is shorter for cows calving in spring and summer, while others (Bulman and Lamming, 1978; Peters and Riley, 1982; King and Macleod, 1984) found that cows calving in the spring produced longer intervals from calving to first ovulation. Savio *et al.* (1990b) found that the interval from calving to first ovulation in cows with normal dominant follicles in an autumn-calving herd tended to be shorter than in a spring-calving herd (12.0 days vs 27.3 days, respectively). King and Macleod (1984) proposed that photoperiod, either alone or interacting with temperature, might be a major cause in delaying ovarian activity in spring-calving beef cows. All the cows in their study were confined and fed with balanced rations of stored feed throughout the year, so that nutritional factors could be eliminated. However, under New Zealand conditions, dairy cows graze pasture, and the effect of season can be influenced by pasture supply both before and after calving. It can be seen from Figure 1.0 that pasture offered at the time of calving of the examined cows in the autumn-calving herd was low (23 kg/DM/ha/day), but this was higher than that in July and August, 1989 (mating period). During the spring months, photoperiod is increasing as well as pasture growth, and spring-calving cows usually have better feeding after calving than autumn-calving cows. This can affect the fertility of the herd by producing higher conception rates at first service in the main herd (the spring-calving herd) than in the autumn-calving herd. In addition, it is likely that the spring-calving cows may experience feed shortages during the dry period (in late winter and/or early spring, between July and August) when pasture growth is low (Figure

1.0). A feed shortage during the dry period and/or the early lactation in the spring-calving cows may affect reproduction by prolonging the post-partum interval to first ovulation (Terqui *et al.*, 1982), but probably not affecting the fertility of the herd. In contrast, the autumn-calving cows calved during a period when pasture growth is still significant (March and April, compared with July and August), and is sufficient for producing milk and maintaining ovarian function during the early lactation period. The poor feeding after calving and/or before mating in the autumn-calving cows may then affect reproduction by reducing the fertility of the herd, resulting in a lower conception rate and a prolonged 1st service to conception interval (Table 1.4).

The interval from calving to first ovulation is influenced by the post-partum period required to resume normal pulsatile LH secretion (Lamming *et al.*, 1981). Critser *et al.* (1983) found that LH concentrations in ovariectomised heifers were highest during the winter and lowest during the summer months. This suggests that seasonal difference in endocrine patterns, irrespective of nutritional factors, may contribute to the shorter period of post-partum interval to first ovulation in autumn-calving cows than in spring-calving cows.

McNatty *et al.* (1984a) found that LH pulse frequency was higher during spring than during autumn-months. They suggested that the difference might be due to a higher level of oestrogen biosynthesis initiated in healthy follicles of a smaller diameter in October than in May or June. However, underfed cows may be an exception, since Terqui *et al.* (1982) found that LH concentration was low in post-partum underfed cows. Imakawa *et al.* (1987) observed that the pulse frequency of LH was reduced with dietary energy restrictions in ovariectomised heifers.

The mean intervals to first ovulation in each age group of the examined cows in the spring-calving herd were 26.0, 28.7 and 40.8 days, while those in the autumn-calving cows were 23.4, 32.8 and 20.0 days for 2 year, 3 year old and mature cows, respectively. The results from the spring-calving cows in the present study were in contrast to the finding of Moller (1970) that the 2 year and 3 year old cows had longer post-partum intervals to first ovulation than the older cows in the herd. It is well-documented that cows in good body condition before and after calving have short intervals to first ovulation (Butler *et al.*, 1981; Grainger *et al.*, 1978). In the present study, the 3 two year old cows of the examined cows in the spring-calving herd were in good body condition, except for one cow (No380) which did not ovulate during the study period and for three months thereafter. Unlike that of the spring-calving herd, the mean interval of mature cows from the autumn-calving herd was shorter than that for the younger ones. This is consistent with results reported by Moller (1970).

In two first-calving heifers (Nos. 273 and 429) in the spring-calving herd, a uterine discharge was detected during the first 2 weeks post-partum. These cows were treated with antibiotics. Once the uterus became normal without any abnormal discharge, the two animals regained ovarian cyclicity within one week. Cows with uterine infections post-partum have a longer duration of elevated levels of PGF_{2α} (Fredriksson *et al.*, 1985; Lindell *et al.*, 1982) and ovulations occur after PGF_{2α} levels return to or near basal levels (Kindahl *et al.*, 1982; Kindahl *et al.*, 1984). In these cases, uterine involution should be completed once uterine infections were treated. In the present study, cows that were treated during the first 2 weeks post-partum, had a shorter mean interval from calving to first ovulation than "normal" cows (24.0 days, compared with 38.1 days, respectively).

Silent oestrus is common at first ovulation during the early post-partum

period(Morrow *et al.*, 1966; Marion and Gier, 1968; Fonseca *et al.*, 1983; Moller, 1970; Stevenson and Call, 1983) and oestrous detection rates increase with the number of post-partum ovulations. The percentage of the spring-calving cows that showed oestrus at the first ovulation was higher than that in the autumn-calving cows(63.2% compared with 45.4%, respectively). The interval from calving to first ovulation in the autumn-calving cows which showed oestrus at first ovulation was significantly longer than those which ovulated without oestrus. The reasons for this are that the longer the interval from calving to first ovulation, the more likely they are to show oestrus. In addition, Stahringer *et al.*(1990) and Plasse *et al.*(1968) showed that oestrous activity in beef heifers is depressed during the winter. They suggested that this effect could be related to the reduction in daylength during that period.

1.2. The Interval from Calving to First Detected Oestrus

The mean intervals from calving to first oestrus of the examined cows from the spring- and autumn-calving herds were 40.7 and 41.6 days, respectively. This reproductive index is consistent with the results reported by the author(Chapter 4) that the mean post-partum interval to first oestrus in New Zealand dairy cows(Ruakura Dairy Herds No1 and No2) is 43.7 days. In fact, the mean intervals for each age group were 51.6, 47.8 and 39.6 days for 2 year, 3 year and mature cows, respectively. Macmillan *et al.*(1985) reported the interval to first oestrus of normally calving cows was 48.5 days, with the means of each age group of 60.5, 48.3 and 44.7 days, respectively. In addition, there was a higher incidence of anoestrus in the first and second calvers, compared with mature cows in New Zealand dairy herds(Fielden *et al.*, 1973). The mean intervals of each age group of the examined cows from the spring-calving herd were 25.0, 34.0 and 45.9 days, while those in the autumn-calving herd were 46.4, 29.7 and 43.2 days, for 2 year, 3 year and mature cows, respectively. As mentioned earlier, the two year old cows in the spring-calving herd had good condition scores which may have produced the shorter intervals to first ovulation and oestrus than in the older animals.

The technique of tailpainting as an oestrus detection aid(Macmillan and Curnow, 1977) in the present study combined with oestrus observations in the yards by the author twice a day during the milking and the ultrasound examinations were sufficient to accurately detect oestrus and to monitor oestrous activity during the post-partum period in the examined cows in both herds.

1.3. The Interval from PSM to First Service and Conception

The intervals from PSM to first service in the examined cows from the spring- and autumn-calving herds were not different because the intervals from calving to first oestrus in the examined cows from the two herds were not different. In contrast, the mean intervals in the autumn-calving cows from the main herd were significantly longer than those in the spring-calving herd. The reason for this, as mentioned earlier, is that the seasonal influence on lower pasture supply in the autumn-calving cows during the lactation and before mating resulted in the longer interval from calving to first oestrus in the autumn-calving herd. This leads to the longer interval from PSM to first service.

The intervals from PSM to conception and from first service to conception were not different between the examined cows in the two herds. The reason might

be that the examined cows were closely observed after calving until oestrus and insemination. Any abnormalities during the post-partum period in the examined cows such as a uterine discharge could be detected and treated. Cows in the main herd might or might not be detected a uterine discharge until they were in oestrus. This may produce the shorter intervals in the examined cows. Metritic cows were shown to have long intervals from calving to first oestrus, to first service and to conception (Bosu *et al.*, 1984; Eley *et al.*, 1981; Kindahl *et al.*, 1983).

The intervals from PSM to conception and from first service to conception were significantly longer in the autumn-calving cows in the main herd than those in the spring-calving herd. Pasture production during the examination period in the two herds might have affected the intervals. The autumn-calving herd had pasture production gradually decreased after calving until the end of the mating period, while the spring-calving herd had pasture production at low levels during the period of calving and increased thereafter. Unlike the spring-calving cows, the gradual decrease in the feed intake in the autumn-calving cows before and during mating may have resulted in the low conception rates and extended the intervals from PSM to conception and first service to conception. This means that spring-calving cows were mated when gaining weight, while autumn-calving cows were losing, or at best maintaining weight. This resulted in the longer interval to conception. The autumn-calving cows also needed more services to conceive than the spring-calving cows.

The interval from PSM to conception was longer in the younger ones. This is the result of the longer interval from PSM to first service (Moller, 1970; Fielden *et al.*, 1973; Macmillan and Clayton, 1980).

2. OVARIAN FOLLICULAR DISTRIBUTION POST-PARTUM

2.1 Follicular Distribution before the First Ovulation (Pre-OV1)

The follicular patterns Pre-OV1 were similar in the spring- and autumn-calving cows which ovulated within 30 days pp. There was growth and regression of the largest follicles during the post-partum period before the first ovulation (Dufour and Roy, 1985; Lucy *et al.*, 1990a). This pattern of growth and turnover of the largest follicles Pre-OV1 occurred in most cows in the present study. The largest follicle (> 10mm in diameter) appeared on one ovary as early as Day 7 post-partum, which is consistent with observations by Spicer *et al.* (1986). The number of small follicles (SF) decreased when the size of the largest follicle increased and vice versa. The number of MF's increased after the number of SF's had increased. This may be due to a movement of SF's into larger-size follicles (MF), leading to the follicular selection process. The dominant follicle then develops, resulting in oestradiol production (Ireland and Roche, 1987) to initiate first ovulation.

In the present study, there were two peaks of the mean size of LF's during the two weeks before the first ovulation. This pattern was seen in cows which ovulated from 31-60 days pp. However, the pattern in cows which ovulated within 30 days pp involved only one peak. This difference, as observed in the present study, was that there was only one large follicle which developed in cows which ovulated within 20 days pp, while those which ovulated from 31-60 days pp had their first dominant follicles during two weeks Pre-OV1 regress, and it was the second dominant follicles which resulted in ovulation. The first dominant follicle may have produced insufficient oestradiol to induce preovulatory LH surges (Beck and Convey, 1977; Ireland and

Roche, 1987). However, other components or factors such as body condition and nutrition after calving may be contributing factors influencing the initiation of first post-partum ovulation.

2.11 Seasonal Difference in the Mean Number of Each Follicle Category before the First Ovulation

The mean numbers of follicles in each follicle category 11 days Pre-OV1 in the spring-calving cows were significantly higher than those in the autumn-calving cows. The mean number of SF's, LF,s and TF's were also significantly higher in the spring-calving cows which ovulated within 30 days pp than in the autumn-calving cows. The reason for this is unknown. It is possible that firstly, the autumn-calving cows may experience negative energy balance after calving. Lucy *et al.*(1989) and Lucy *et al.*(1990a) suggested that energy balance influences the average number of follicles per cow for the first 25 days pp and that energy balance after calving may be one important factor which can affect follicular numbers. Secondly, it may be the seasonal difference in endocrine hormone secretion in the control of follicular development before the first ovulation. The differences in follicular numbers before the first ovulation between the two herds in the present study support the hypothesis that there is a form of seasonality which could modulate some reproductive patterns in cattle(Tucker, 1982; Critser *et al.*, 1983; Critser *et al.*, 1987; McNatty *et al.*, 1984; Stanisiewski *et al.*, 1988).

2.2. Follicular Distribution after the First Ovulation(Post-OV1)

After the first ovulation, there were patterns of growth and regression of each follicle category in concert with the growth of the normal corpus luteum which secreted progesterone. There is usually one large dominant follicle present on the ovary at all times(Ireland *et al.*, 1979, Matton *et al.*, 1981) which is ready to ovulate.

2.21 Follicular Patterns during the Normal First Cycle

Pierson and Ginther(1984) have shown follicular patterns of the mean numbers of follicles in each follicle category, and the mean size of the first and second largest follicles during the oestrous cycle. The increase in the mean number of small follicles(SF) may be due to the rise in the levels of FSH and LH during the follicular phase of the oestrous cycle prior to ovulation(Ireland and Roche, 1987). This is associated with the appearance of a large pool of small antral follicles during the post-ovulatory and the early luteal phase(Matton *et al.*, 1981; Skyer *et al.*, 1987). The mean number of MF's increased after the mean number of SF's had increased. This is probably because the MF(antral follicles 5 to 8mm in diameter) grow from the pool of small follicles and be selected to dominant follicles for oestradiol production and to maintain the cycle(Ireland and Roche, 1987). It has been suggested that a follicle destined to ovulate may inhibit growth of other follicles(Matton *et al.*, 1981; Staigmiller and England, 1982; Goodman and Hodgen, 1983) due to follicular inhibition which is shown to decrease FSH secretion in ovariectomised heifers(Miller *et al.*, 1979; Ireland *et al.*, 1983; Quirk and Fortune, 1986). This results in a decrease in the mean number of SF's when the mean size of LF's has increased and vice versa.

In the present study, there were three waves in the mean size of the largest

follicle during the normal first cycle (even though the second wave was not apparently distinguished). This is in agreement with the results of Savio *et al.* (1990b) who reported that in 54% of animals, the oestrous cycle in the early post-partum cow had 3 dominant follicles, whereas 2 dominant follicles were observed in the remaining cycles. Ireland and Roche (1987) also showed that there were three cycles of development in follicle dominance of dominant follicle during a bovine oestrous cycle.

2.22 Follicular Distribution during the Shortened First Cycle

The patterns of the mean number of each follicle category and the mean size of the largest follicle in cows which had a shortened first cycle were similar to those seen in the first two stages of a normal first cycle. The dominant follicle which resulted in ovulation, was usually the second dominant follicle (i.e. the second wave).

2.23 Follicular Distribution during the Short First Cycle

The follicular patterns in cows which had a short first cycle post-partum were the same patterns as those in the first stage of an oestrous cycle. The first dominant follicle which grew and reached a peak, did not regress, but ovulated, resulting in a corpus luteum formation. There may be some spontaneous causes which induced early luteolysis (at least 5-6 days after the first ovulation), resulting in a short or shortened cycle. Oestradiol-17 β which would peak 5-6 days Post-OV1 might induce PGF_{2 α} production and produce early luteolysis (Pope, 1982). Kindahl *et al.* (1982) proposed that uterine infections during early post-partum period released PGF_{2 α} and that these infections were enhanced by progesterone influence, resulting in early luteolysis. In addition, Duby *et al.* (1985) reported that the corpora lutea from the first post-partum ovulation were smaller and contained fewer cells than those obtained after subsequent ovulations.

2.24 Follicular Distribution in Cycling (CC) and Non-cycling Cows (NC)

There were no Group x Week interactions for the mean numbers in each follicle category and the mean size of LF's between the CC and NC in the autumn-calving cows in the present study. This suggests that follicular numbers in each category in the CC and NC were independent. In cycling cows after the first post-partum ovulation, as observed in the present study, there were patterns of increase and decline in the mean number of each follicular category, as well as the mean size of LF's. This was also found in the non-cycling cows after calving until their first ovulation. Rajakoski (1960) showed that there was great variation in the mean number of follicles < 5mm in diameter.

There were no Group x Week pp interactions in the mean number of MF's and LF's in the spring-calving herd. This indicated that the mean number of MF's and LF's were independent since it has been shown in cycling cows that there were 2 to 4 follicles of 4 to 8mm in diameter found with a large follicle and that these follicles remained static throughout an oestrous cycle (Rajakoski, 1960; Dufour *et al.*, 1972; Ireland *et al.*, 1979; Matton *et al.*, 1981; Ireland and Roche, 1982) and in post-partum cows (Lucy *et al.*, 1990a). In contrast to the mean number of MF's and LF's, there were Group x Week interactions in the mean number of SF's and TF's in the spring-calving cows. The mean numbers of SF's and TF's in the CC and NC changed

as weeks pp increased. During Week 3 pp, the mean number of SF's and TF's in the CC were also significantly different than in the NC. This is because there was only one cow(CC) which ovulated on Day 13 pp. Then the ultrasound examinations were done on Days 14, 16, 18 and 20 pp (starting one day after ovulation) during which high number of small follicles were observed. After Week 3, the mean number of SF's significantly decreased. The pattern of the mean numbers of TF's was similar to that of SF's.

In the spring-calving herd, there were significant differences between the CC and NC in the mean number of each follicle category. Significant differences were also observed between weeks pp. The mean number of MF's and LF's were higher in the NC than in the CC in the spring-calving herd. This suggests that the higher number of these larger follicles in the NC may have been physiologically inactive. One of the MF would normally be expected to be selected to become a dominant follicle, resulting in further oestradiol production, and to suppress development of other follicles by the action of inhibin.

The mean size of LF's was not significantly different between the CC and NC in the two herds, but they were significantly different between weeks pp. There were also no Treatment x Week pp interactions. This could suggest that the mean size of LF's in the CC and NC had similar patterns of growth and regression (Lucy *et al.*, 1990a).

3. FIRST POST-PARTUM CYCLES

The first post-partum cycles in the present study were divided, according to the inter-ovulatory period, into short, shortened and normal cycles. The percentage of short first cycles pp was higher in the spring-calving cows (33.3%) than in the autumn-calving cows (10%, [Table 1.7](#)). This result is in agreement with that of Peters and Riley (1982); namely 37.5% of spring-calving cows (beef cows) in UK had short first cycles pp. In contrast to the above findings, no cows studied by King and Macleod (1984) experienced a short cycle after the first ovulation as shown by individual progesterone profiles. Doby *et al.* (1985) found that short cycles occurred when cows ovulated within 25 days pp. In contrast, short cycles observed after the first ovulation were from dominant follicles detected after Day 20 pp (Savio *et al.*, 1990b), who also showed that the long cycles were commonly found during the early post-partum period. In the present study, 8 cows out of 10 examined cows from the two herds which had a short first cycle, ovulated after Day 20 pp. Only one cow from the autumn-calving herd had a long cycle of 30 days. The shortened cycles were more frequent in the autumn-calving cows than in the spring-calving cows (25% vs 5.6%, [Figure 1.2](#), [Figure 1.4](#) and [Table 1.7](#)).

4. MILK PROGESTERONE LEVELS

Because of a small number of the autumn-calving cows which had short first cycles pp, and because the spring-calving cows had a shortened first cycle pp, there were no comparisons for milk progesterone levels between the two herds. The mean milk progesterone concentrations during the dioestrous phase in the spring-calving cows which had normal first cycle, were significantly higher than those for cows in the autumn-calving herd. The difference in the mean milk progesterone concentrations in the two herds supports the hypothesis that there is a form of seasonality in

cattle(Tucker, 1982; Critser *et al.*, 1983; Critser *et al.*, 1987; McNatty *et al.*, 1984; Stanisiewski *et al.*, 1988). Rosenberg *et al.*(1977) reported that progesterone concentrations on Days 4-15 of the oestrous cycle were significantly lower during summer(29-32°C) than in winter(18-26°C) in dairy cows in Israel. Stahringer *et al.*(1990) reported that serum progesterone concentrations were lowest in November which is the transitional period to the shortest daylength, while the concentrations were highest in the longest daylength(October and March).

5. CYSTIC OVARIES

There were a single spring-calving cow(5%) and 3 autumn-calving cows(12%) which developed cystic ovaries post-partum. This incidence is similar to results reported by Savio *et al.*(1990a); namely 26.6% of autumn-calving cows developed cysts. Whitmore *et al.*(1974) reported that 71% of ovarian cysts developed before the first ovulation within 45 days pp. In the present study, there were 3 cows that developed cysts before the first ovulation. One cow developed cysts on Day 28 pp, and the cyst ovulated on Day 44 post-partum followed by formation of a normal corpus luteum. Another cow developed cysts on Day 28 pp and did not ovulate. The cysts spontaneously luteinised, and the animal came to oestrus and was inseminated on Day 87 pp. In the third cow, cysts developed on one ovary before the first ovulation, but ovarian activity on the other ovary continued. The ovulatory follicle on this latter ovary ovulated with formation of a normal corpus luteum. One cow from the autumn-calving herd developed cysts on both ovaries on approximately Day 46 post-partum. This was after the second ovulation. The cysts were luteinised spontaneously and the animal came to oestrus on Day 66 pp. "Cystic" autumn-calvers had a longer interval to first ovulation than cows which did not develop cystic ovaries(Savio *et al.*, 1990a). In the present study, the interval to first ovulation in the cystic autumn-calving cows was 56 days, compared to 29.1 days for cows which did not develop an ovarian cyst.

CONCLUSION

The present study showed that seasonality does occur in dairy cows in New Zealand and does influence aspects of their reproduction. The effect of season (day length or ambient temperature, inclement weather) may directly or indirectly influence pasture production and/or nutrition of cows in the herd. This is, in turn, responsible for body condition and/or energy balance before and after calving, and before and during mating period. It was found that the effect of season of calving altered the reproductive performance of the two herds that the post-partum interval from calving to first ovulation was shorter in the autumn-calving herd. However, other reproductive indices were lower in the autumn-calving herd. In addition, the seasonal difference may have created a difference in the hormones which control reproductive patterns in cattle. The mean milk progesterone concentrations during the dioestrous phase of the post-partum oestrous cycle were greater in the spring-calving cows. This may result in the higher mean numbers of follicles in each category in the spring-calving cows, compared with those in the autumn-calving herd. Also, the distribution of first cycle lengths (short, shortened and normal cycles) differed between the two herds.

The ovarian follicular distribution before and after the first ovulation are shown. There were patterns of growth and regression in the numbers in each follicle category, and the size of the largest follicle after calving until the first ovulation and during the first cycle post-partum. The normal first cycle had three waves of in the mean size of the largest follicle, while the short and shortened cycles showed one and two waves, respectively.

Data on the cycling and non-cycling cows ([Table 1.12](#) and [Table 1.15](#)) showed that numbers in each follicle category and the mean size of the largest follicle were independent of weeks post-partum, but the mean numbers of the follicles did vary between weeks post-partum.

In the present study, only milk progesterone concentrations were measured. More research is warranted to clarify the relationships between follicular distribution after calving until the first ovulation and possibly during the first cycle, and endocrine patterns such as LH, FSH, oestradiol and $\text{PGF}_{2\alpha}$ on the return of ovarian activity post-partum. Body condition, nutrient intake and energy balance after calving concurrently with the above suggestions should also be assessed.

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CHAPTER 2

GONADOTROPHIN RELEASING HORMONE

IN POST-PARTUM ANOESTROUS DAIRY COWS

ABSTRACT

Eight Holstein-Friesian cows which had no significant luteal activity as determined by ultrasound examination, and which were from 18 to 23 days post-partum, were randomly divided into two groups. Each of the four cows in one group was given a single intramuscular injection of 10 μ g busserelin, a potent analogue of gonadotrophin releasing hormone(GnRH). The four cows in the control group each received a placebo injection. Blood samples for luteinising hormone(LH) determination were taken from a coccygeal vein at 0 min(before injection), 30 min, 2hr, 4hr and 24hr post-GnRH injection. Ultrasound examinations of the ovaries in both treated and control cows were completed after the morning milking on Days 0, 2, 4, 6 and 8 after a GnRH injection and twice a week thereafter(0 = Day of treatment). The number and location of every ovarian follicle was recorded on an ovarian map and the size of each follicle was measured based on the maximum diameter. The follicles then were classified as small(SF, 2-5mm), medium(MF, 6-9mm) or large follicle(LF, \geq 10mm), including total follicles(TF = SF + MF + LF). Milk samples were collected after the morning milking on each day that ultrasound examinations occurred, and analysed for progesterone concentration by radioimmunoassay.

The GnRH treatment increased plasma LH concentrations in each of the treated animals. The mean number of SF's, MF's, LF's and TF's tended to increase after GnRH treatment. The mean number of MF's of treated cows increased from 2.3 ± 0.7 on Day 0 to 5.7 ± 2.1 on Day 2 post-injection, compared with those in control cows(1.8 ± 0.6 to 2.2 ± 1.6 , $p = 0.22$). The mean number of SF's of treated cows also increased from 16.3 ± 4.4 on Day 0 to 26.2 ± 7.2 on Day 2 post-injection, compared with those in control cows(11.5 ± 3.6 to 17.5 ± 2.7 , $p = 0.3$). The mean number of LF's of treated cows decreased from 1.7 ± 0.2 on Day 0 to 1.0 ± 0.4 on Day 2 post-injection, compared with those in control cows(1.3 ± 0.6 to 1.0 ± 0.4 , $p = 0.22$). Thus, the study showed that the GnRH-induced release of LH was associated with an increase in the average number of MF's and a decrease in LF's in the ovaries of treated animals.

Treated cows had a significant increase in the mean milk progesterone levels from Day 0 to Days 2-9 post-injection(0.1ng/ml on Day 0 to 3.6ng/ml on Days 2-9), compared with control cows(0.1ng/ml on Day 0 to 0.8ng/ml on Days 2-9, $P < 0.01$).

Treated cows ovulated in 4.7 ± 2.6 days, ranging from 2 to 12 days post-injection, while only one control cow ovulated- on the equivalent of Day 5 post-injection. Two of four treated cows showed oestrus at the first post-treatment ovulation.

The average intervals from calving to first oestrus, calving to first service, calving to conception, and first service to conception of treated cows were shorter than control cows, but these differences were not significant.

INTRODUCTION

An important goal in dairy farming is to have most cows cycle by 30 days after calving. They have only 80 to 100 days after calving to conceive so as to maintain a 365-day herd calving interval. Many attempts have been made to initiate cyclical ovarian activity in the early post-partum period in dairy cattle. Hormonal treatments such as GnRH alone or in combination with other hormones (prostaglandin $F_{2\alpha}$ and oestradiol- 17β) have been extensively used to induce earlier post-partum ovulation (Britt *et al.*, 1974; Garverick *et al.*, 1978; Fernandes *et al.*, 1978 (Abstr); Richardson *et al.*, 1983; Zaied *et al.*, 1980), to improve reproductive performance (Britt *et al.*, 1977; Langley and O'Farrell, 1979), to reduce abnormal ovarian activity such as the incidence of ovarian cysts (Kesler *et al.*, 1977a; Kesler *et al.*, 1979) and to improve reproductive performance in cows with a retained placenta (Bosu *et al.*, 1988; Darson and Ekman, 1984).

It is well-known that there is an increase in the frequency of episodic LH pulse before the resumption of ovarian activity in post-partum cows (Peter *et al.*, 1981; Schams *et al.*, 1978). Riley *et al.* (1981) showed that there was an association between LH release and follicular development when repeated low doses of purified LH or of GnRH were injected to increase the frequency of episodic LH pulse, resulting in ovulation in acyclic cows. The LH response to a GnRH injection was significantly higher in cows injected on Days 7-10 post-partum and thereafter, than those injected on or before Day 5 post-partum (Foster *et al.*, 1980; Lamming, 1978; Kesler *et al.*, 1977). It is probable that the pituitary responsiveness to GnRH is low during the early post-partum period and increases thereafter (Lamming, 1978; Schallenberger *et al.*, 1978).

This present study was conducted in 8 spring-calving cows which were from 18 to 23 days post-partum. A single intramuscular injection of GnRH (buserelin 10 $\mu\text{g}/\text{cow}$) was administered to study the subsequent sequential effects.

OBJECTIVES

1. To induce earlier ovulation in post-partum dairy cows.
2. To study and compare follicular patterns after GnRH injection.
3. To study the effect of GnRH injection on subsequent oestrous cycles, and compare reproductive performance between treated and untreated control cows.

LITERATURE REVIEW

GONADOTROPHIN RELEASING HORMONE(GnRH)

Gonadotrophin Releasing Hormone(GnRH) is a decapeptide which is synthesised, stored and released from the hypothalamus. It is the hormone that controls the release of luteinising hormone(LH) and follicle stimulating hormone(FSH) from the anterior pituitary gland. The pulsatile secretion of LH from the pituitary gland is released by a pulse of GnRH released by the hypothalamus and delivered via the hypothalamo-hypophyseal portal vessels(Clarke and Cummins, 1982).

Because of the simple molecular structure of GnRH, many forms of agonists and antagonists of various potency have been synthesised. buserelin(D-Ser(TBU)⁶-EA¹⁰, Hoe766, Receptal®, Hoechst AG), one form of a potent analogue of GnRH, has been widely used in both human and animal medicine. It is a synthetic nonapeptide GnRH analogue that releases LH and FSH from the anterior lobe of the pituitary. Each ml of Receptal contains 0.0042 mg buserelin acetate, which is equivalent to 0.004 mg buserelin. This type of GnRH analogue is indicated for use in cattle for fertility disorders of ovarian origin such as follicular cysts, anoestrus, delayed ovulation and follicular atresia. It has also been used to induce ovulations post-partum and to increase the conception rate in artificial insemination procedures. Receptal can be used in prophylaxis of fertility disorders by administering it between the 10th and 14th day post-partum. This analogue is also recommended for use in cows with retained foetal membranes and in herds with an increased incidence of ovarian cysts. An improved conception rate is obtained, especially in cows with retained foetal membranes. It was reported that the potency of Receptal is 50 to 70 times higher in releasing LH than that of Lutal®(a synthetic form of natural GnRH)(Nawito *et al.*, 1977).

Numerous studies have shown the potential use of GnRH for treating infertility in cows, especially lactating dairy cows during the post-partum period. Macmillan(1985) suggested that GnRH can be used as a fertility drug to increase pregnancy rates in well managed herds which already have high reproductive performance. During the past 20 years, a number of researchers have studied the effects of a GnRH-induced release of LH, and the reproductive performance of treated cows was assessed in comparison with that of untreated controls. GnRH alone or in combination with other hormones such as PGF_{2α} has been used in order to improve reproductive performance and fertility in cows with normal placental membrane loss or with retained placenta.

USES OF GnRH DURING THE POST-PARTUM PERIOD

Induction of Ovulation Post-partum

High concentrations of plasma progesterone and oestradiol are circulating before calving. They suppress endogenous GnRH release and pituitary responsiveness to GnRH, resulting in a depression of basal plasma gonadotrophin levels as well as in ovarian follicular activity in the immediate post-partum period(Lamming *et al.*, 1982; Schallenberger *et al.*, 1978). Therefore, plasma LH concentrations are low at calving

and gradually increase as the post-partum interval increases (Erb *et al.*, 1971; Garverick *et al.*, 1973).

Pituitary responsiveness to GnRH stimulation has been reported to be regained after the first week post-partum (Kesler *et al.*, 1977; Fernandes *et al.*, 1976; Fernandes *et al.*, 1978). Kesler *et al.* (1977) showed that the peaks of LH concentrations in response to GnRH injection were significantly higher in cows injected after Day 7 post-partum than in those injected before Day 7 post-partum. Nawito *et al.* (1977) reported that LH increase in response to synthetic GnRH (10 µg of Hoe 766) in cycling heifers, and peaked at 49.4 ng/ml. Macmillan *et al.* (1985a,b) also showed that the same analogue of GnRH (5 µg of buserelin, Receptal) in cycling animals increased LH release by between 21 and 30 ng/ml. Levels of endogenous steroid hormones during GnRH injection, especially oestradiol-17β have been reported to influence pituitary responsiveness to GnRH by enhancing GnRH-induced LH release (Convey, 1973; Zolman *et al.*, 1974; Kesler *et al.*, 1977; Kesler *et al.*, 1978; Zaied *et al.*, 1980).

A GnRH-induced ovulation post-partum is not associated with oestrus and is frequently followed by a short luteal phase (Britt *et al.*, 1981), or a cycle of normal length, but with low levels of progesterone (Lamming *et al.*, 1982).

Induction of Early Ovulation Post-partum to Improve Reproductive Performance

GnRH has been extensively used to induce ovulation in dairy cows during the early post-partum period. The purpose is to improve the reproductive performance of herds, through increased conception rates (Lee *et al.*, 1983; Nash *et al.*, 1980), decreased intervals from calving to conception (Benmrad and Stevenson, 1986; Nash *et al.*, 1980) and fewer services per conception (Benmrad and Stevenson, 1986; Nash *et al.*, 1980).

However, some authors have shown no significant differences in the interval from calving to conception in treated and control cows which calved normally and with no post-partum pathology (Boiti *et al.*, 1982; Bostedt and Maurer, 1982; Bulman and Lamming, 1978). Britt *et al.* (1977) also showed that the interval from calving to first oestrus, calving to first service and calving to conception as well as services per conception, did not vary significantly between treated and control cows. Bostedt and Maurer (1982) used GnRH to improve uterine involution in cows with retained placenta. The interval from calving to conception was also significantly reduced, compared with cows without retained placenta. In fact, there were no differences in the interval from calving to first service in cows with and without retained placentae. Brown (1985) and Leslie *et al.* (1984) showed that cows which had retained placentae and were treated with GnRH had shorter intervals to conception and fewer services per conception than untreated controls.

GnRH injected on Day 15 post-partum decreased the interval from calving to first ovulation, increased the number of post-partum ovulations prior to breeding and decreased days open (Bosu *et al.*, 1988). They also showed that the interval to ovulation after a GnRH injection on Day 15 post-partum was 4.89 days.

In contrast to the above finding, Larsen and Ekman (1984) found that cows with retained placenta showed no beneficial effects from GnRH treatment.

Reduction of Abnormal Ovarian Activity Post-partum

It is well-documented that 5 to 18% of dairy cows develop ovarian cysts before their first post-partum ovulation (Morrow *et al.*, 1966; Whitmore *et al.*, 1974; Britt *et al.*, 1977). However, the rate of spontaneous recovery from the cysts has been reported to be about 50% within 60 days post-partum (Morrow *et al.*, 1966; Roberts, S.J., 1986). Many studies have shown that the incidence of follicular cysts was reduced after a GnRH treatment post-partum. For example, Britt *et al.* (1977) showed that the frequency of follicular cysts was significantly less in GnRH-treated cows than in saline-treated controls (5.7% vs 15.3%, respectively). In addition, Zaied *et al.* (1980) and Britt *et al.* (1974) showed reduced percentages of follicular cysts before first ovulation in GnRH-treated cows.

FOLLICULAR CHANGES AFTER GnRH INJECTION

Follicular growth and maturity are important for GnRH to induce an ovulation in post-partum cows (Kesler *et al.*, 1977; Zaied *et al.*, 1980). Cows which responded to GnRH had a large follicle (> 10mm in diameter) and high concentrations of plasma oestradiol-17 β at the time of treatment (Zaied *et al.*, 1980). Research on follicular changes after a GnRH injection is scarce. Macmillan and Thatcher (1991) showed that GnRH injected on Day 12 of the oestrous cycle increased the number of MF's, many of which were cloudy, and reduced the average number of LF's.

MATERIALS AND METHODS

EXPERIMENTAL FARM

This experiment was conducted at the Massey University Dairy Farm No4 between 25th September and 24th October, 1989. The No4 Dairy Farm is a spring-calving, seasonal supply herd.

ANIMAL SAMPLES

Eight Friesian cows which were at about 20 days post-partum and without significant luteal activity as determined by ultrasound examination were used in this study. The cows were randomly divided into treatment and control groups. Each cow was weighed and condition-scored at fortnightly intervals after the GnRH injection.

PROCEDURES

Treated animals were given a single intramuscular injection of Gonadotrophin Releasing Hormone (10 µg of buserelin {D-Ser(TBU)⁶-EA¹⁰, Hoe766, Receptal, Hoechst AG, NZ} after the morning milking (8.00a.m.). Control animals received a placebo. The dose of buserelin (10 µg) was considered to be adequate to release an ovulatory dose of LH (Bostedt and Maurer, 1982). Tailpaint (Coopers Tailpaint, Wellington, New Zealand) was applied to each cow after the injection.

Each animal was scanned ultrasonographically in order to confirm that they were in anoestrus with no significant luteal activity, before the GnRH injection. Blood samples were taken from a coccygeal vein into vacuum tubes containing sodium heparin powder (at 0 minutes (before injection), 30 mins, 2 hrs, 4 hrs and 24 hrs after the GnRH injection for LH determination. Blood samples were centrifuged at 3000 rpm for 20 mins soon after collection. Plasma samples were extracted and stored at -20 ° C for subsequent LH analysis by radioimmunoassay (RIA).

The ultrasound examinations in both treated and control animals were completed after the morning milking on Days 0, 2, 4, 6 and 8 after a GnRH injection, and twice a week thereafter (0 = Day of treatment). The techniques for ultrasound examinations, recording and reviewing on videotapes were the same as those described in Chapter 1 (Ultrasonography in post-partum cows). A milk sample was collected in a plastic vial after the morning milking on each day that an ultrasound examination occurred. The occurrence of oestrus was monitored in the yard twice daily before each morning or afternoon milking, or by determining the extent to which tailpaint had been removed when checked during ultrasound examinations.

RADIOIMMUNOASSAYS FOR LUTEINISING HORMONE

Plasma LH levels were measured by double antibody radioimmunoassay using assay kit ingredients supplied by NIDDK, NIH, Bethesda, Md., USA. Immunoreagents, prepared by Dr A F Parlow, Torrance, Ca, USA, were: NIADDK-oLH-I-3 for radioiodination; NIADDK-anti-oLH-I antiserum; and NIADDK-oLH-24 for assay standards. Separation of free and bound radioiodinated oLH was achieved with

donkey anti-rabbit IGG serum(IDS Ltd, Washington, England). Assay samples were processed in a single assay for which the limit of sensitivity was 0.23 ng/ml and the within-assay coefficient of variation was 12.16% at a mean plasma LH concentration of 1.56 ng/ml(n = 8).

MILK PROGESTERONE RADIOIMMUNOASSAYS

The techniques and methods for milk progesterone radioimmunoassays were the same as those described in Chapter 1(Ultrasonography in post-partum cows). The mean assay sensitivity of milk progesterone was 0.40ng/ml(n = 13). The intra-assays coefficients of variation were 21.67%, 10.51% and 21.23% while the inter-assays coefficients of variation were 22.59%, 10.29% and 20.1% for milk pool samples P11, P100 and P269, respectively(These were pools of known milk samples which had average concentrations of progesterone of 11.5, 42.4 and 18.0 ng/ml, respectively).

DATA ANALYSIS

The Panacea Database Program(Pan Livestock, Inc., Reading, United Kingdom) was used to analyse the data. The numbers within each follicle category(SF, MF, LF, TF), the size of LF(LF size), milk progesterone levels before and after injection between treated and control cows, including reproductive indices after GnRH injection were assessed by Analysis of Variance(ANOVA). Two-way classification of ANOVA was conducted in SAS(Statistical Analysis System, SAS Institute Inc., Cary, NC 27512-8000, USA) to analyse the mean number of each follicle category, the size of LF and milk progesterone levels before and after injection. The mean values of treated and control cows before the injection(Day 0) were adjusted and used as covariates, compared with those on Day 2 post-injection, and those from Days 2 to 9 post-injection.

Statgraphics(STSC, Statistical Software Corporation, Maryland, USA) was also used to draw patterns of the number of follicles in each category, the LF size and milk progesterone levels before and after the GnRH injection.

SOME TERMS USED IN THE TEXTS ARE:

GnRH = Gonadotrophin Releasing Hormone

PGF_{2α} = Prostaglandin F_{2α}

SF = Small-sized follicle(2-5 millimetres in diameter)

MF = Medium-sized follicle(6-9 millimetres in diameter)

LF = Large-sized follicle(> 9 millimetres in diameter)

LF size = The size of the largest follicle

CL = Corpus luteum

P₄ = Progesterone concentration

CIDR = Controlled Intravaginal Drug Release Device

PMSG = Pregnant Mare Serum Gonadotrophin

RESULTS

BEFORE A GnRH INJECTION

The mean age of the 4 treated cows was 5.7 years and for the 4 control cows was 4.2 years. The mean condition scores of the treated cows and control cows before injection were 3.7 and 3.8, respectively. The mean post-partum interval to GnRH injection of the treated cows was 20.7 days, compared with 18.7 days of the control cows (Table 2.1).

Table 2.1 shows that the mean size of LF's of the ovaries of treated cows before a GnRH injection was 13.0 ± 1.2 mm (ranging from 11 to 14.5 mm), compared with 13.5 ± 5.4 mm (ranging from 10 to 19.5 mm) of the control cows ($p = 0.8$). The mean milk progesterone levels (milk P_4) of treated cows and control cows were 0.09 and 0.08 ng/ml, respectively.

Table 2.1. Mean values describing the characteristics of cows included in the trial in which half of them were injected with GnRH from 18 to 23 days post-partum.

Parameters	Treated cows ^a	Control cows
Mean age(yrs)	5.7(3-12) ^b	4.3(2-9)
Mean condition score	3.7(3.5-4.0)	3.8(3.7-4.0)
Post-partum interval to treatment(days)	20.7(18-23)	18.7(18-20)
Mean LF size(mm)	13.0(12-14.5)	13.5(8-19.5)
Mean milk progesterone levels(ng/ml)	0.1(0-0.2)	0.1(0-0.3)

^a = 10 μ g buserelin, Receptal®, Hoechst(NZ) Ltd.

^b = mean(range)

AFTER A GnRH INJECTION

All the treated cows responded to the GnRH injection. Plasma LH concentrations increased in 2 cows by 30 minutes and were elevated at 2 hours and 4 hours after the GnRH injection in all 4 cows. No control cows had detectable concentrations of LH after the placebo injection, although one control cow(C55) had a detectable concentration of LH(0.6 ng/ml) before the GnRH injection(Table 2.2). Twenty four hours after the GnRH injection, LH was not detected in samples from any of the animals.

Table 2.2. Concentrations of LH(ng/ml) before and after GnRH injection of treated and control cows.

Cows	Before injection	Time after GnRH injection			
		30 min	2hrs	4hrs	24hrs
*T174	0	0.4	2.7	3.4	0
T314	0	0	0.6	1.7	0
T369	0	1.0	4.2	3.5	0
T427	0	0	3.6	5.0	0
^b C55	0.6	0	0	0	0
C349	0	0	0	0	0
C382	0	0	0	0	0
C435	0	0	0	0	0

*T = Treated cows injection intramuscularly with 10 μ g buserelin

^bC = Contemporary control animals

FOLLICULAR AND MILK PROGESTERONE PATTERNS BEFORE AND AFTER GnRH INJECTION

Figure 2.1-2.8 show individual follicular patterns and numbers of SF's, MF's, LF's, TF's, the size of LF's and milk progesterone levels for the treated and control cows before and after the GnRH injection.

Cow T174 ovulated without oestrus on Day 3 post-injection. The ovulatory follicle decreased in size from 13.5mm on Day 0 to 10.5mm(luteinised) on Day 2 and ovulated on Day 3 post-injection(Figure 2.1). A CL developed after the ovulation. P₄ was secreted for a short period until Day 9 post-injection when the CL was not detectable by ultrasound examination and milk P₄ was at a low level. When milk P₄ was low on Day 9 post-injection, another LF increased in diameter to 16mm, but this follicle did not ovulate(Figure 2.1).

After GnRH injection, the number of SF's increased as the diameter of LF's decreased in size, or the largest follicle(LF) ovulated. The number of SF's decreased when the LF diameters increased. The number of MF's increased after the number of SF's had increased and vice versa.

Cow T314 ovulated without oestrus on Day 2 post-injection. The ovulatory follicle was not the largest follicle detected on Day 0(before injection). It was another smaller follicle on the opposing ovary which subsequently ovulated. Milk progesterone levels increased slowly after ovulation(Figure 2.2). The length of the first cycle after the GnRH-induced ovulation in this animals was probably long(>26 days) since milk P₄ concentration on Day 28 post-injection was still high(14.0ng/ml).

Cow T369 ovulated with oestrus on Day 2 post-injection. The ovulatory follicle had a diameter of 14.5mm on Day 0. The P₄ pattern showed that the first cycle post-injection was 16 days in length(Figure 2.3). The number of SF's increased when the diameter of LF's declined, and the number was highest while the diameter of LF's was small(Figure 2.3). The number of MF's increased after the number of SF's had increased, and the number of MF's declined after the number of SF's had declined.

Cow T427 ovulated with oestrus on Day 12 post-GnRH injection. Figure 2.4 shows that the number of MF's increased after the GnRH injection. One large follicle, which was identified on one ovary with a diameter of 12mm on Day 0, disappeared by Day 2 post-injection.

FOLLICULAR CHANGES AFTER THE GnRH INJECTION

The mean number of SF's, MF's, LF's, TF's, the mean size of LF's and milk progesterone levels of treated and control cows before injection(Day 0) and those from Day 2 to Day 9 post-injection are shown in Table 2.3. Treated cows had significantly higher mean milk progesterone levels than control cows at 9 days post-injection(p<0.01). There were no differences in other mean parameters from Day 2 to Day 9 post-injection between treated and control cows.

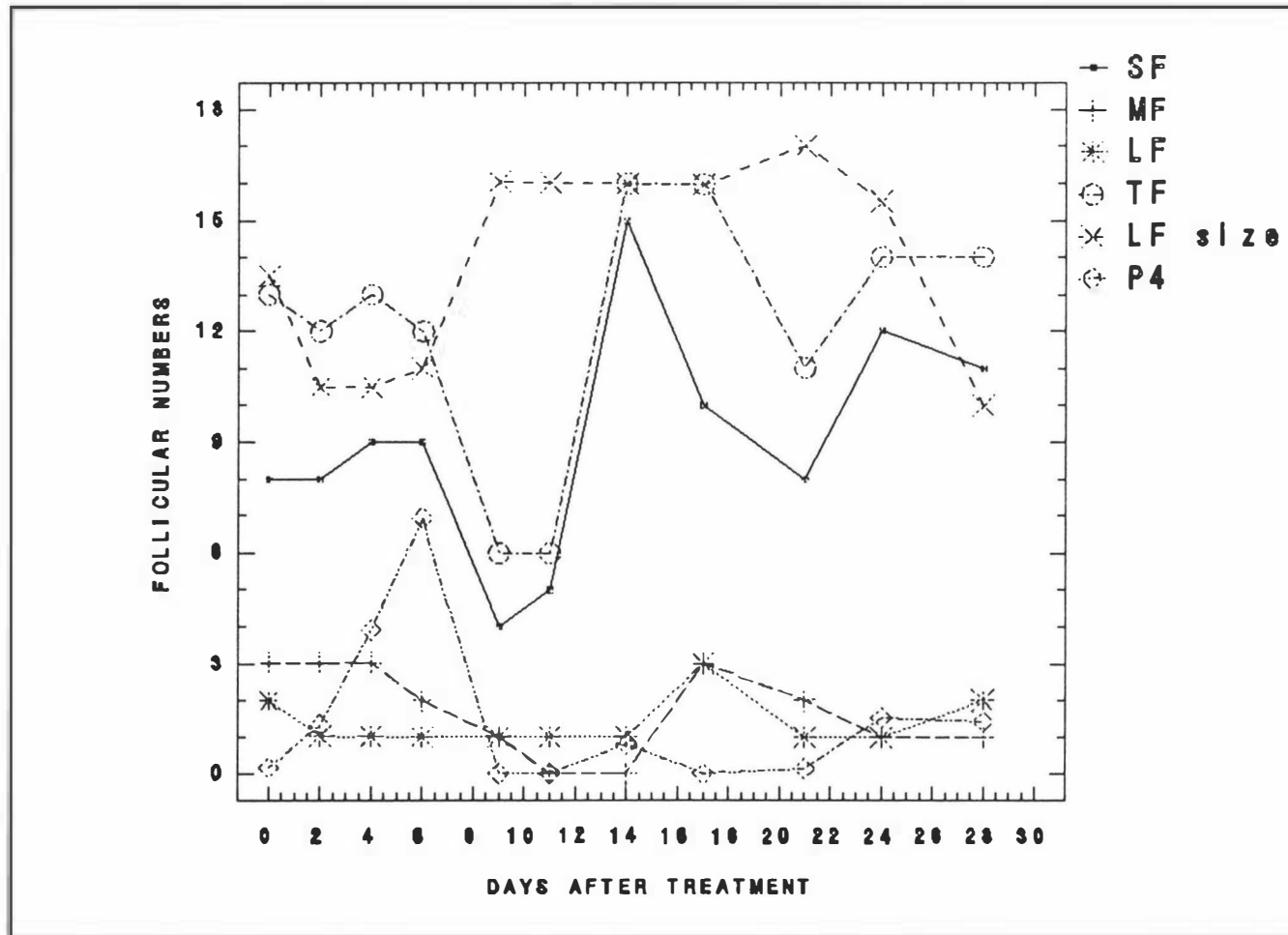


Figure 2.1. Follicular patterns and progesterone level(P₄) of CowT174 after GnRH treatment(0= Day of treatment). This cow ovulated without oestrus on Day3 post-injection.

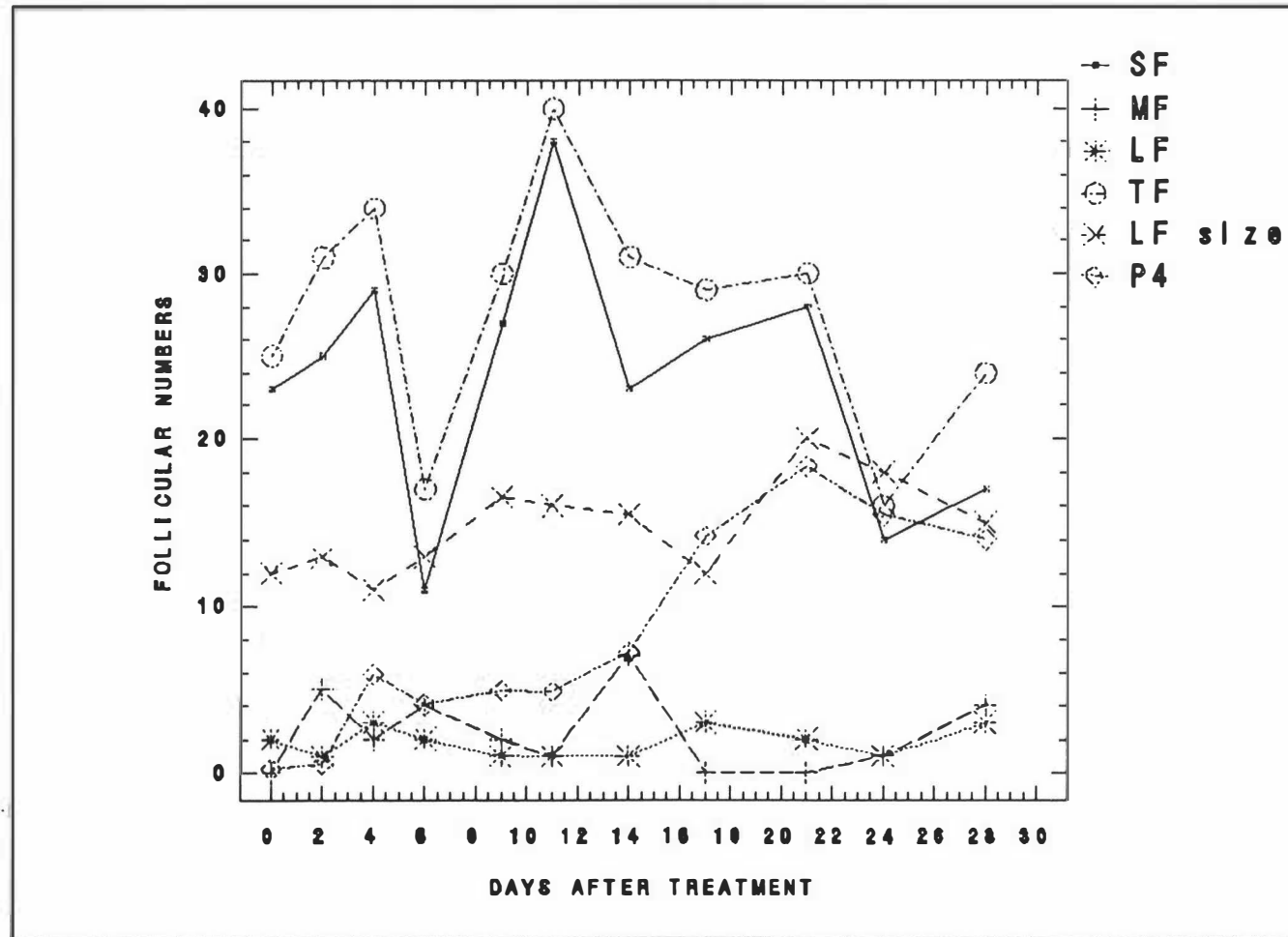


Figure 2.2. Follicular patterns and progesterone levels (P_4) of Cow T314 after GnRH treatment (0 = Day of treatment). This cow ovulated without oestrus on Day 2 post-injection.

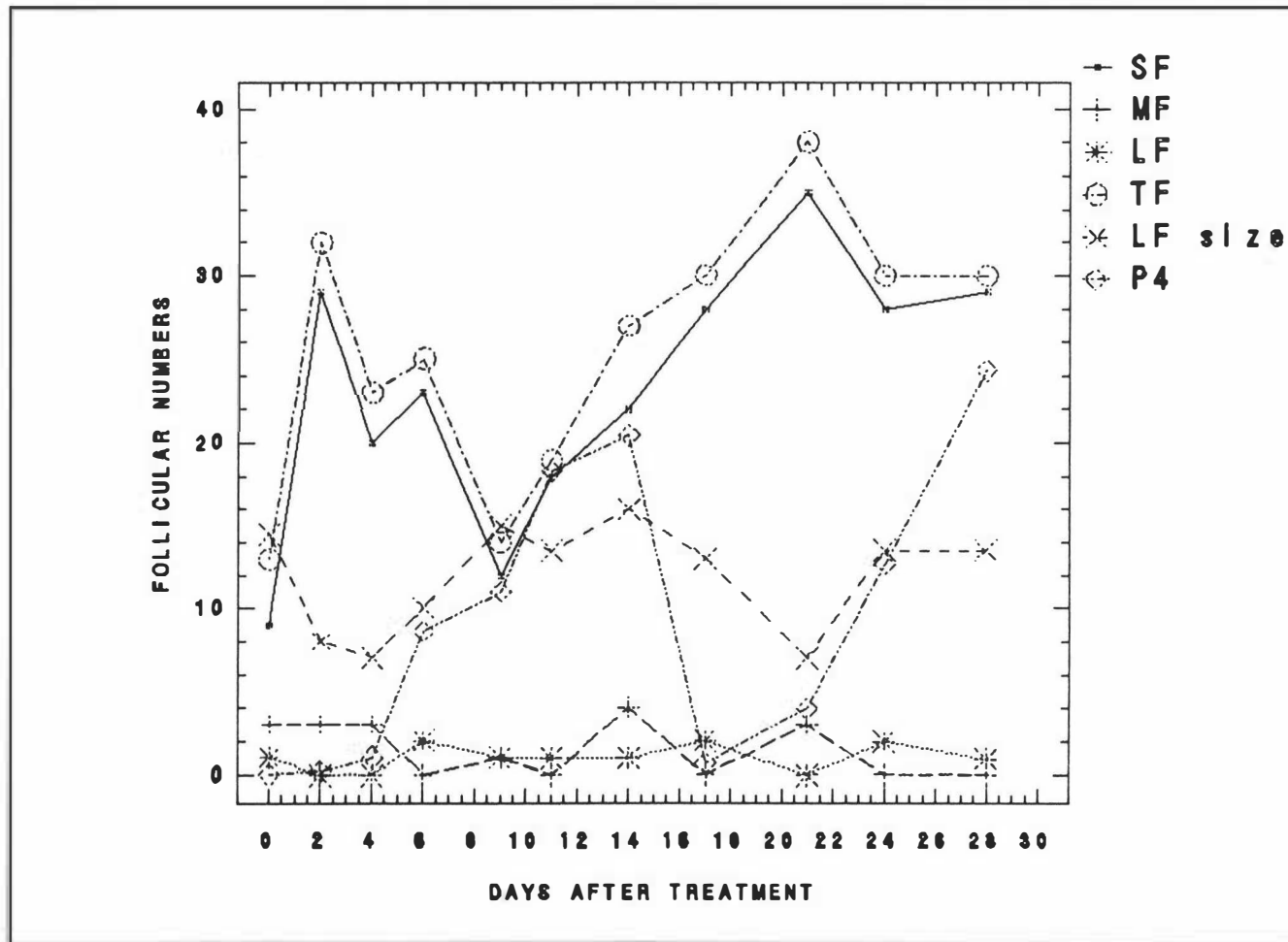


Figure 2.3. Follicular patterns and progesterone levels (P_4) of Cow T369 after GnRH treatment (0 = Day of treatment). This cow ovulated with oestrus on Day 2 post-injection.

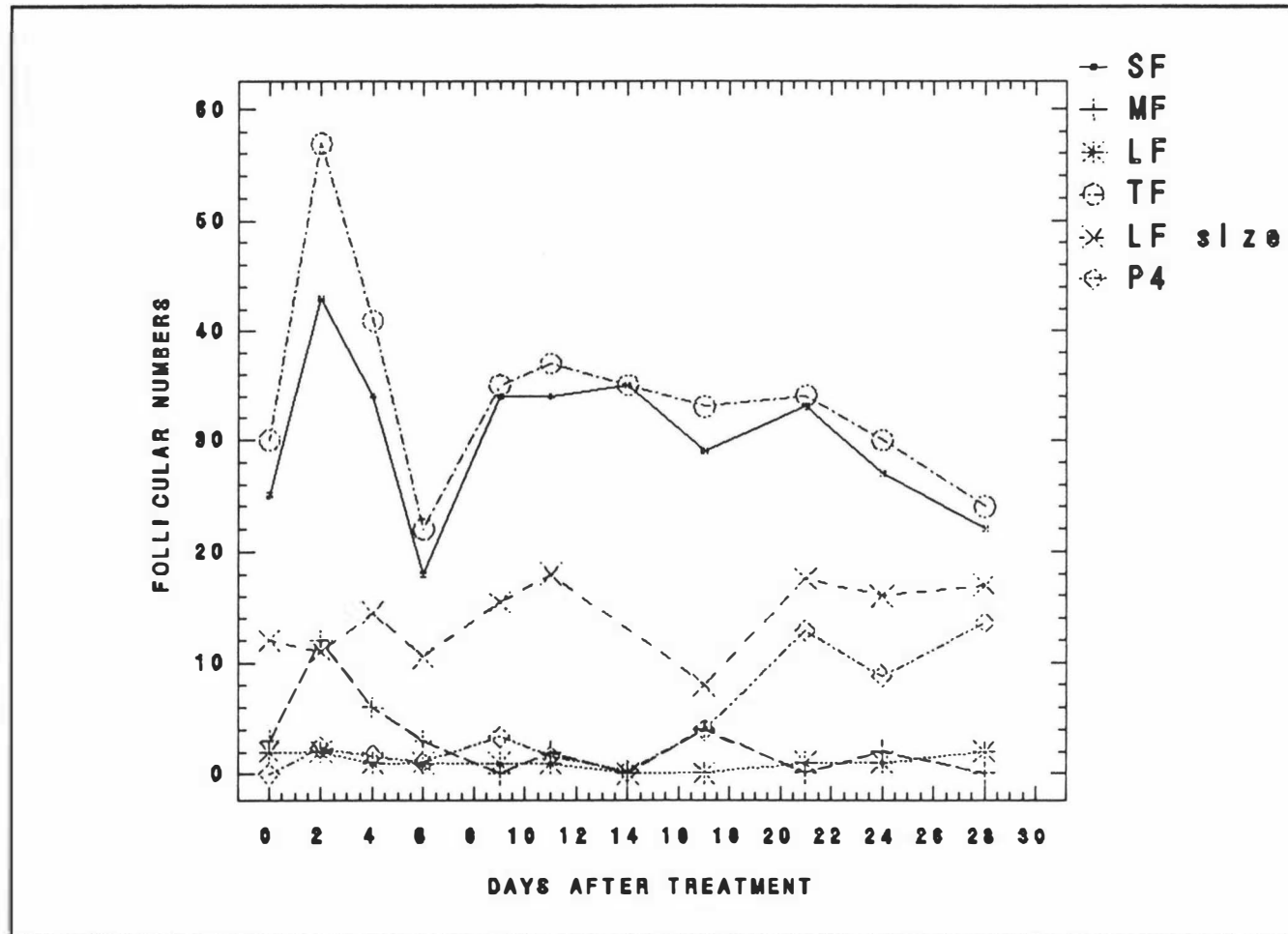


Figure 2.4. Follicular patterns and progesterone levels(P₄) of CowT427 after GnRH treatment(0= Day of treatment). This cow ovulated with oestrus on Day12 post-injection.

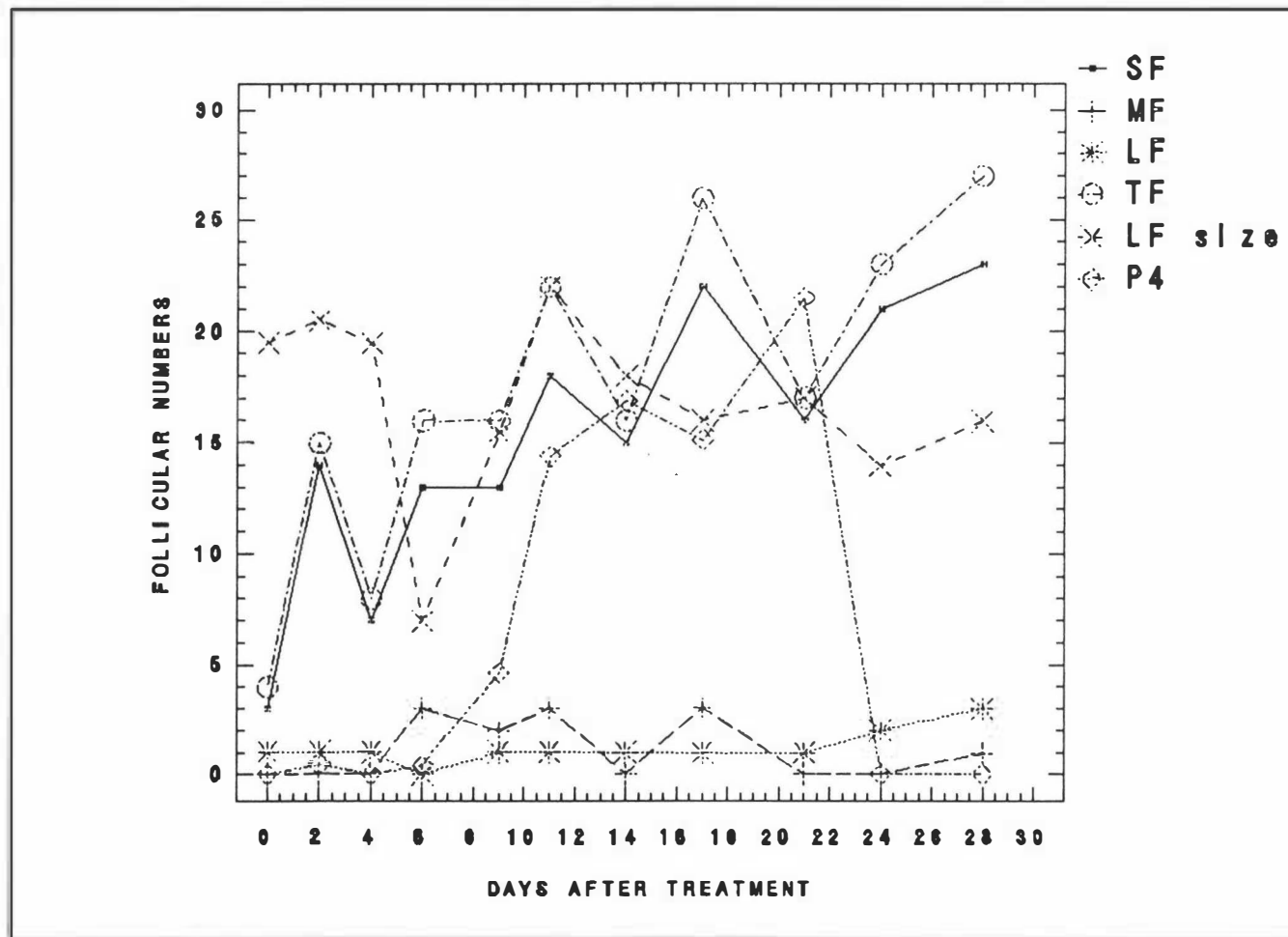


Figure 2.5. Follicular patterns and progesterone levels (P₄) of CowC55 (0 = Day of treatment in treated cows).

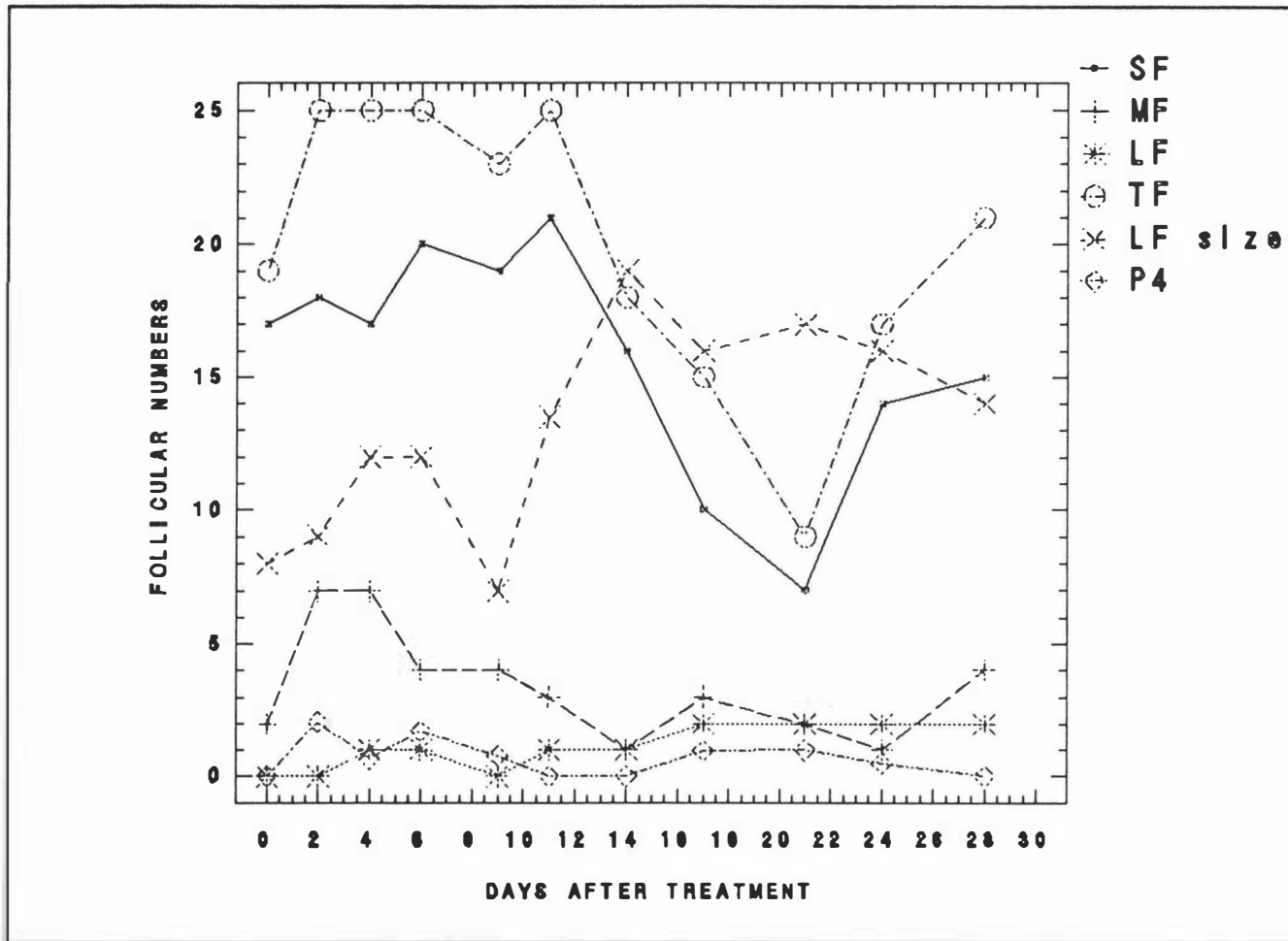


Figure 2.6. Follicular patterns and progesterone levels(P₄) of CowC349(0 = Day of treatment in treated cows).

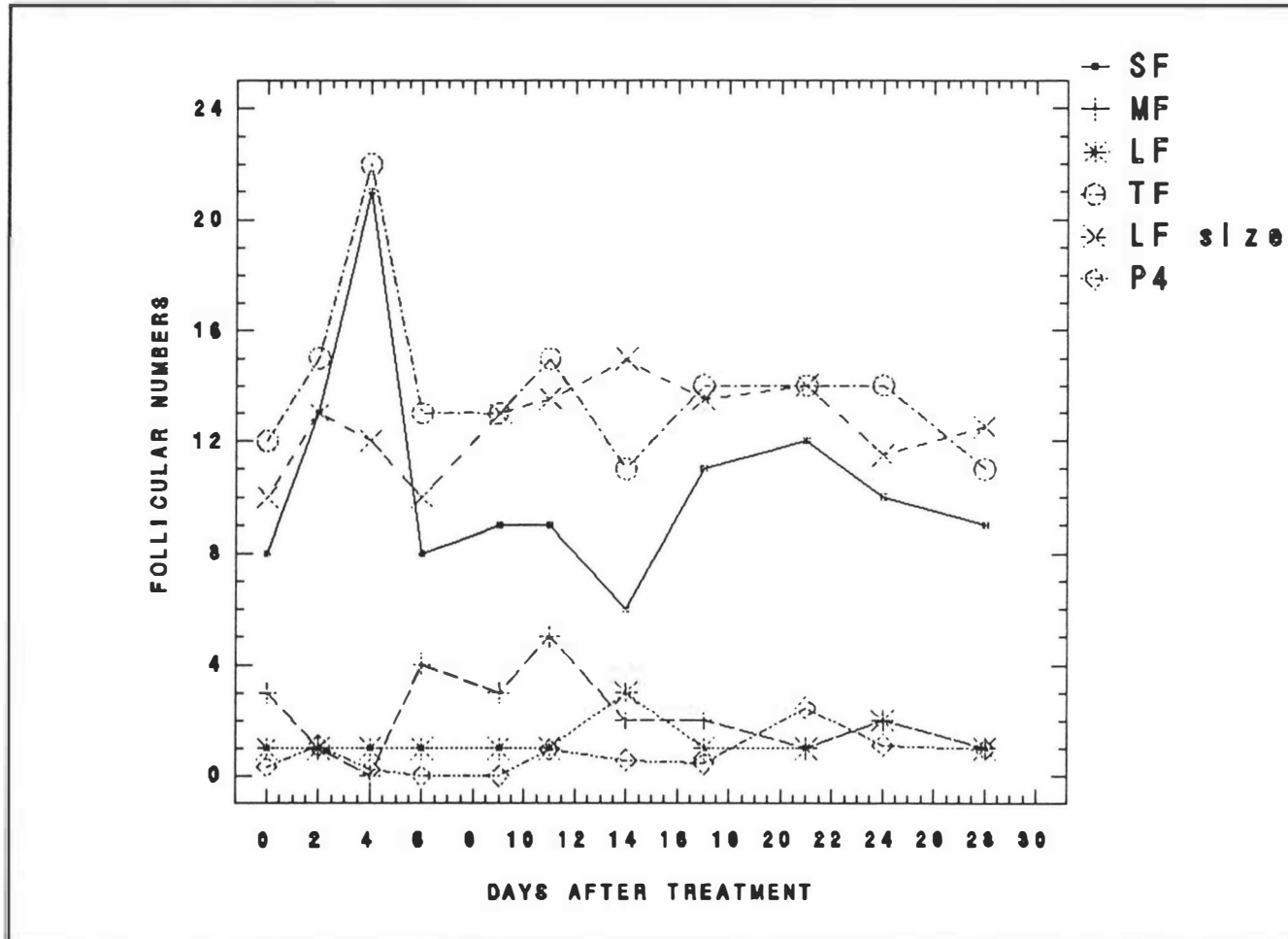


Figure 2.7. Follicular patterns and progesterone levels (P_4) of CowC382 (0 = Day of treatment in treated cows).

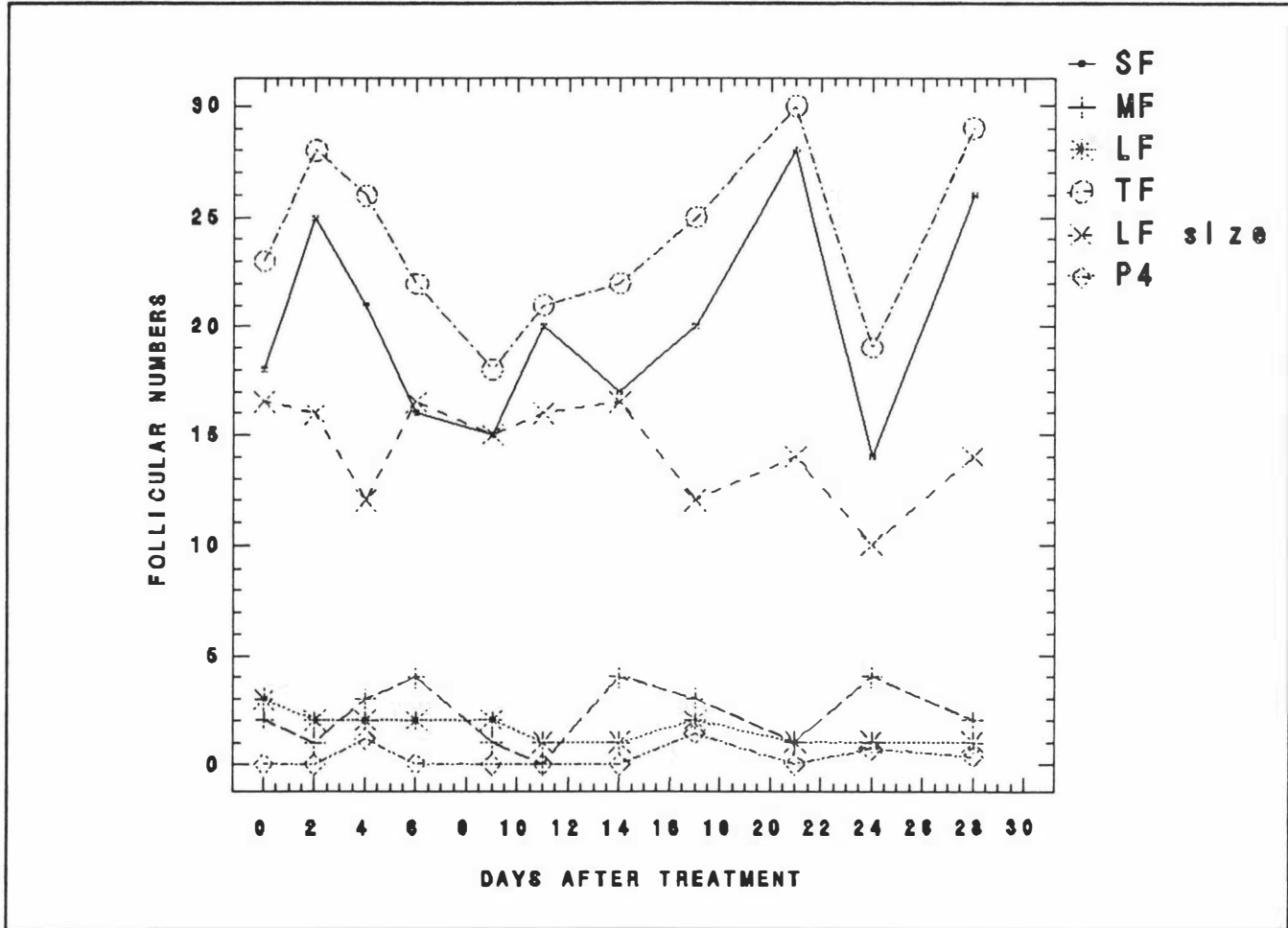


Figure 2.8. Follicular patterns and progesterone levels(P₄) of CowC435(0= DAY of treatment in treated cows).

Table 2.4 shows the mean number of follicles in each category and the size of LF's of treated and control cows before injection (Day 0) and 9 days after the injection. There were no treatment x day interactions for the mean number of follicles in each category and the mean size of LF's. The mean number of MF's of treated cows increased from 2.3 on Day 0 to 5.7 on Day 2 post-injection, compared with that in control cows which increased from 1.8 on Day 0 to 2.2 on Day 2 post-injection (Table 2.4, $p = 0.22$). The increase in the number of MF's on Day 2 after ovulation was also found in one control cow (C55, Figure 2.5). The mean number of SF's also increased post-injection (16.2 to 26.2, $p = 0.3$), compared with that in the control cows (from 11.5 to 17.5). The mean number of LF's of treated cows decreased from 1.7 to 0.7 ($p = 0.2$).

REPRODUCTIVE INDICES AFTER GnRH INJECTION

1. The Interval from Treatment to Ovulation

Treated cows ovulated in 4.7 ± 2.6 days, ranging from 2-12 days post-injection, while only one control cow (C55) ovulated on the equivalent of Day 5 post-injection (Table 2.5). The remaining control cows had not ovulated within 1 month of the examination. The mean interval from calving to first ovulation in treated cows was 25.5 ± 3.3 days (23-30 days).

Two cows (T369 and T427) showed oestrus at this first post-treatment ovulation. The mean milk progesterone at first post-injection ovulation of the treated cows was 1.1 ng/ml. The mean diameter of the size of LF on Day 2 post-injection of treated cows decreased in size (luteinised or ovulated), compared with those on Day 0 (Figure 2.1-2.4 and Table 2.4). The mean diameter of the LF's of treated cows was slightly smaller than that of control cows on Day 2 post-injection (10.6 ± 1.0 mm compared with 14.6 ± 2.5 mm, $p = 0.17$).

2. The Intervals from Calving to First Oestrus, Calving to First Service, Calving to Conception, First Service to Conception and Services per Conception.

The intervals from calving to first oestrus, to first service, to conception and services per conception of treated and control cows are shown in Table 2.5. It can be seen that the reproductive efficiency for all measures of treated cows after a GnRH injection was better than that of control cows, but these differences were not statistically significant with the group size used.

One treated cow (No. T314) and one control cow (No. C349) were culled because of low milk production.

Table 2.3. Mean number of follicles in each category, the size of the largest follicle(LF size) and milk progesterone levels(P₄, ng/ml) in treated and control cows before a GnRH injection(Day 0) and the mean from Day 2 to Day 9.

Parameters	Treated cows ^a		Control cows	
	Before injection	After injection	Before injection	After injection
Number of SF's ^d	16.3 ± 4.4 ^b	20.9 ± 2.8	11.5 ± 3.6	15.6 ± 1.2
Number of MF's ^d	2.3 ± 0.7	3.1 ± 0.7	1.8 ± 0.6	2.8 ± 0.5
Number of LF's ^d	1.7 ± 0.2	1.2 ± 0.1	1.3 ± 0.6	1.1 ± 0.1
Number of TF's ^d	20.2 ± 4.3	25.3 ± 3.3	14.5 ± 4.2	19.4 ± 1.5
The size of LF's	13.0 ± 0.6mm	12.1 ± 0.7mm	13.5 ± 2.7mm	13.1 ± 0.9mm
Milk progesterone levels(ng/ml)	0.1 ^{**°}	3.6 ^{**}	0.1	0.8

^a = injected with 10 µg buserelin.

^b = Mean ± std error, adjusted for Day 0(Before injection), values on Day 0 being used as covariates.

[°] = Significance level(^{**} = p < 0.01)

^d = SF = small-sized follicle(2 to 6mm), MF = medium-sized follicle(6 to 9mm), LF = largest follicle(>9mm in diameter), TF = total follicle(SF + MF + LF)

Table 2.4. The mean number of follicles in each category(SF = small follicle, MF = medium follicle, LF = large follicle and TF = Total follicles) and the size of the largest follicle(LF size) in treated and control cows before(Day 0) and after GnRH injection from Day 0 to Day 9(D0 to D9).

Days after treatment	Treated cows ^a					Control cows				
	SF	MF	LF	TF	LF size	SF	MF	LF	TF	LF size
D0	16.3 ±4.4	2.3 ^b ±0.7	1.7 ^c ±0.2	20.2 ±4.3	13.0 ±0.6	11.5 ±3.6	1.8 ^b ±0.6	1.3 ^c ±0.6	14.5 ±4.2	13.5 ±2.7
D2	26.2 ±7.2	5.7 ^b ±2.1	1.0 ^c ±0.4	33.0 ±9.2	10.6 ±1.0	17.5 ±2.7	2.2 ^b ±1.6	1.0 ^c ±0.4	20.7 ±3.4	14.6 ±2.4
D4	23.0 ±5.5	3.5 ±0.9	1.2 ±0.6	27.7 ±6.1	10.7 ±1.5	16.5 ±3.3	2.5 ±1.7	1.2 ±0.2	20.2 ±4.2	13.9 ±1.9
D6	15.2 ±3.2	2.2 ±0.8	1.5 ±0.3	19.0 ±2.7	11.1 ±0.7	14.2 ±2.5	3.7 ±0.2	1.0 ±0.4	19.0 ±2.9	11.4 ±2.0
D9	19.2 ±6.8	1.0 ±0.4	1.0 ±0.0	21.2 ±6.8	15.7 ±0.3	14.0 ±2.1	2.5 ±0.6	1.0 ±0.4	17.5 ±2.1	12.6 ±1.9

^a = injected with 10 µg buserelin

^b = The increase in the mean number of the MF's from Day 0 to Day 2 post-injection in treated cows, compared with that in control cows(p= 0.22).

^c = The decrease in the mean number of the LF's from Day 0 to Day 2 post-injection in treated cows, compared with that in control cows(p= 0.22).

Table 2.5. Reproductive indices of the treated and control cows after a GnRH injection(10 μ g buserelin).

Parameters	Treated cows	Control cows	Probability
1. Calving to treatment(day)	20.7 \pm 1.0	18.7 \pm 0.5	
2. Treatment to ovulation(days)	4.8 \pm 4.8	not measured	
3. Calving to first ovulation(days)	25.5 \pm 3.3	not measured	
4. Treatment to first oestrus(days)	15.2 \pm 9.1	50.7 \pm 18.8	0.14
5. Calving to first oestrus(days)	36.0 \pm 9.7	69.5 \pm 19.2	0.17
6. Treatment to first service(days)	42.0 \pm 5.4	57.2 \pm 13.9	0.34
7. Calving to first service(days)	62.7 \pm 5.9	76.0 \pm 14.4	0.4
8. First service to conception(days)	0	27.0 \pm 14.0	0.12
9. Treatment to conception(days)	43.7 \pm 7.3	78.0 \pm 14.0	0.09
10. Calving to conception(days)	64.3 \pm 8.1	96.7 \pm 14.4	0.12
11.Services per conception	1	2	

Mean \pm Std error

DISCUSSION

GnRH-INDUCED LH RELEASE

LH concentrations increase after injection of GnRH, administered from 10 days post-partum (Peters *et al.*, 1986). In the present study, LH concentrations increased from 30 minutes after a GnRH injection and continued increasing for the next 2 to 4 hours (Table 2.2). No detectable concentration of LH was measured in samples taken before, or 24 hours after injection. Only one of 20 samples from control animals contained a measurable concentration of LH (0.6 ng/ml). The LH increases produced by the GnRH analogue in post-partum cows in the present study were much lower than those reported in cycling cows by Nawito *et al.* (1977) and Macmillan *et al.* (1985a). The dose of only 5 µg injection of buserelin in cycling cows increased LH release by up to 21 to 30 ng/ml (measured from 2 to 2.5 h post-injection) (Macmillan *et al.*, 1985a). But none of the cows injected with that dose of the GnRH analogue "buserelin" on Days 7, 11 or 15 of the oestrous cycle, had induced ovulations. A further study by Macmillan and Thatcher (1991) using 10 µg of buserelin, injected on Days 11, 12 or 13 of the oestrous cycle produced at least one ovulation in 47% of treated heifers.

In the present study, the lower LH release after GnRH injection in post-partum cows is probably because the pituitary is less responsive to GnRH injection during the early post-partum period. Schallenberger *et al.* (1982) showed that release of LH and FSH occur spasmodically from 4 days post-partum, but normal pulse profiles of LH and FSH, and the hypothalamic responsiveness to stimulation are not detected until around 15 to 20 days post-partum (Lamming *et al.*, 1982). An increased pituitary response in terms of LH release to exogenous GnRH is shown by Day 10 post-partum compared with Day 5 (Kesler *et al.*, 1977; Lamming, 1978), and the response is greater between 12 and 15 days post-partum (Peters *et al.*, 1981). Therefore, the lower pituitary response to GnRH injection of treated post-partum cows in the present study may be associated with a prolonged recovery interval from the suppressive effect of steroid hormones of pregnancy, resulting in lower LH release.

However, three of the treated cows ovulated within 3 days of injection, even though the LH increases produced by the GnRH were low. The fourth cow (T427) ovulated with oestrus on Day 12 post-injection. This cow may have responded to the GnRH injection by follicle luteinisation, as the P₄ level increased on Day 2 post-injection. This latter ovulation may not have been a consequence of the GnRH injection, since a positive response is usually based on ovulations occurring one to 3 days following a GnRH injection (Kesler *et al.*, 1978; Zaied *et al.*, 1980). Results from Thatcher *et al.* (1989), and Macmillan and Thatcher (1991) showed that a GnRH injection did not always produce ovulation in cycling animals. Another possibility for the ovulation occurring on Day 12 post-injection might be that the high number of cloudy follicles after GnRH injection delayed the interval from injection to ovulation. It has been shown that an interval of 6 to 8 days after GnRH was required before a healthy follicle could be recruited and selected to become a dominant follicle (Thatcher *et al.*, 1989) for oestradiol production and stimulation of ovarian cycles.

Two treated cows in the present study ovulated with oestrus. Thatcher *et al.* (1989) reported that the number of spontaneous oestruses was reduced during the

7-day period after a GnRH injection, due to either luteinisation or atresia of existing follicles, or acute induction of ovulation.

FOLLICULAR CHANGES AFTER GnRH INJECTION

In the present study the mean number of SF's of treated cows increased slightly after the GnRH injection, compared with that of control cows (Table 2.3 and Table 2.4), but this was not statistically significant. This might have been due to plasma FSH which would be increased after the GnRH injection (Dissen *et al.*, 1988) and resulted in follicular development as well as an increase in the number of small follicles in the ovary. The patterns in the number of SF's in each treated cow in the present study tended to decline when the size of LF's increased. The largest follicle or dominant follicle has greater inhibin bioactivity and oestradiol content than do other follicles (Padmanabhan *et al.*, 1984). In addition, follicular fluid, which contains inhibin, and oestradiol both suppress FSH secretion (Kesner and Convey, 1982; Ireland *et al.*, 1983). Consequently, growth and recruitment of small follicles are both suppressed and the number of small follicles may be decreased.

One large follicle (12 mm in diameter) which was detected on one ovary of Cow T427 on Day 0 had disappeared without ovulation by Day 2 post-injection. It is likely that this follicle was either luteinised by the action of GnRH or became atretic. However, it is also possible that this large follicle once luteinised, had decreased in size to become an MF or SF (<10mm) and was not identified by ultrasound examination on Day 2.

The increase in the mean number of MF's on Day 2 post-injection in the present study was similar to trends reported in cycling animals by Macmillan and Thatcher (1991), following GnRH injection on Day 12 of the oestrous cycle. The GnRH injection also reduced the average number of LF's. This was also observed in the present study. In fact, cloudy follicles were found amongst the high number of MF's after the GnRH injection. The data from Macmillan and Thatcher (1991) also showed a decrease in oestradiol after GnRH injection from Day 13 to Day 15, which coincided with the increase in the mean number of MF's as well as a high number of cloudy follicles. The reason for this is unclear. It was hypothesised by Macmillan and Thatcher (1991) that the GnRH-induced changes may temporarily reduce the capacity of ovarian follicles to produce oestradiol, and consequently affect the role of this hormone in the initiation of luteolysis or in the completion of a PGF-induced luteolysis. Therefore, it can be speculated that the effect of the GnRH injection in the present study was to increase the mean number of MF's which were selected from the pool of small follicles. One of the MF's then became a dominant follicle, with increased oestradiol production. This finally initiated ovarian cycles in some animals.

One treated cow (T174) had a short luteal phase of 7 days after the GnRH injection. This animal then reverted to being anoestrus. It did not have the lowest LH response to the GnRH injection. The cause of the short lifespan of the corpus luteum induced by the GnRH injection is not known, but it is possible that the ovulatory follicle at the time of the injection was incompetent or deficient in some receptors for gonadotrophin. This follicle might have been either one of the cloudy follicles from the GnRH-induced luteinisation, or an old and partially atretic follicle (Macmillan *et al.*, 1985), even though it responded to the GnRH injection. This may result in abnormal corpus luteum formation. The concentration and/or the

duration of LH needed to prolong luteal function might not be insufficient in some animals injected with GnRH. Lemon *et al.*(1975) proposed that the release of LH after GnRH was of short duration(6 hours), compared with 10 hours or more in a cycling cow.

In contrast to Cow T174, Cow T314 had the lowest LH response to the GnRH injection and ovulated on Day 2 post-injection. The low response in this animal might have affected the formation of luteal tissue after ovulation. This was shown by low concentrations of milk P₄ during the first 12 days after the ovulation(Figure 2.2). However, the reason for the prolonged luteal lifespan thereafter is not apparent. Macmillan and Thatcher(1990) showed that repeated GnRH injections from Day 12 of the oestrous cycle extended the inter-oestrous interval to a mean of 56 days. It appeared that the presence of cloudy follicles during GnRH injections did not permit CL regression and the induction of oestrous behaviour(Thatcher *et al.*, 1989; Macmillan and Thatcher, 1990).

REPRODUCTIVE INDICES AFTER GnRH INJECTION

The average interval from injection to ovulation for the GnRH-treated cows in the present study was 4.7 days(ranging from 2 to 12 days). This was similar to the results reported by Kesler *et al.*(1978), Garverick *et al.*(1980) and Bosu *et al.*(1988) where the interval in cows injected with GnRH on Day 15 post-partum was 4.9 days. The mean interval from calving to first ovulation in the treated cows in the present study was 25.2 days(ranging from 23 to 30 days). This interval is shorter than that found in a previous study(Chapter 1) where the interval from calving to first ovulation among untreated cows examined by ultrasound(which were in the same herd used for this study was 36.6 days).

None of the reproductive indices in the present study was significantly different, probably due to the small number of animals. Nonetheless, there was a trend in the interval from treatment to first oestrus, to first service, to conception and first service to conception of the treated cows to be shorter than those of control cows. There were also fewer services per conception in treated cows(Table 2.5). These results are in accordance with the findings of Britt *et al.*(1977), Nash *et al.*(1980), Lee *et al.*(1983), Bostedt and Maurer(1982), Benmrad and Stevenson(1986), and Stevenson and Call(1988). Others studies found no significant differences in the interval from calving to conception(Boiti *et al.*, 1982; Bulman and Lamming, 1978; Langley and O'Farrel, 1979).

It has been shown that cows injected with GnRH post-partum ovulated with no behavioural oestrus, and that this is frequently followed by a short luteal phase(Zaied *et al.*, 1980; Britt *et al.*, 1981; Peter and Bosu, 1988). Two out of the 4 treated cows in the present study did not show oestrus at ovulation post-injection.

From the results of the present study, the dose of 10 µg of buserelin and the post-partum interval of 18 to 23 days were sufficient to result in induced ovulations. In terms of the follicular response to GnRH injection, more research is needed in order to ultrasonographically study the ovarian follicles(health or cloudy) before injection and then each day after injection, concurrently with the animal's endocrine patterns. This would need to include anoestrous animals at different stages post-partum and of varying ovarian status in terms of palpable follicular activity.

Since the injection of 10 μg of buserelin in the present study induced ovulations in 3 out of 4 treated animals, and possibly follicle luteinisation in one treated animal, an application for GnRH use might be to induce ovulation in anoestrous cows after they have been treated with a CIDR and PMSG. In addition, results from Dick(1990) have shown that the largest follicle or dominant follicle after CIDR removal did not ovulate in some anoestrous animals and this follicle was found to be an unovulated luteinised follicle on Day 14 after CIDR removal. It is possible that GnRH can be given after insemination. However, more research should be conducted to study the effect of GnRH on follicles and/or fertility after CIDR + PMSG in anoestrous cows at different stages post-partum. This may rectify the effect of these CIDR treatments when used with anoestrous cows, by reducing the incidence of multiple ovulation but increasing or maintaining fertility.

CONCLUSION

The results of the present study showed that the GnRH-induced LH release by 10 μ g of buserelin(Receptal[®]) is capable of inducing ovulation in anoestrous post-partum dairy cows. The LH increases produced by the GnRH injection in the post-partum treated cows were low, compared with earlier reports. Three of the treated cows ovulated within 3 days after the GnRH injection, while only one control cow had ovulated in the same period. One treated cow ovulated on Day 12 post-injection. Two treated cows ovulated with oestrus.

The follicular response to GnRH injection did not show a clear follicular development pattern after injection, as only the mean number of MF's tended to increase and the mean number of LF's tended to decline. Treated cows had significantly higher mean milk progesterone level at 9 days post-GnRH injection than control cows.

The reproductive indices such as the intervals from calving to first ovulation, to first oestrus, to first service, to conception and services per conception were reduced in GnRH-treated cows, compared with untreated contemporary herd mates.

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CHAPTER 3

OESTROUS BEHAVIOUR

IN

SYNCHRONISED TAURINDICUS HEIFERS

ABSTRACT

Sixteen Taurindicus heifers (Sahiwal x Holstein-Friesian crossbreds) were used to study oestrous behaviour after oestrus synchronisation treatment. The animals were initially treated with a CIDR (Controlled Intravaginal Drug Release, Easi-breed, AHI Plastic Co., Hamilton, New Zealand) for 10 days. Non-cycling animals were given an intramuscular injection of 400 I.U. of PMSG (Pregnant Mare Serum Gonadotrophin, Folligon, Intervet, New Zealand), while cycling animals were given an intramuscular injection of 5ml of prostaglandin $F_{2\alpha}$ (PGF, Lutalyse, Upjohn, New Zealand). Tailpaint was applied to all animals when the treatment started. Oestrus observation was made at 3 observation periods of 20-30 minute duration during the first day after CIDR removal. The animals were observed continuously for oestrus during daylight of the second day between 7.00 a.m. and 6.00 p.m.. The 3 observation periods were also made in the following night between 8.00 p.m. and 5.00 a.m.. Tailpaint scoring was completed on the days of set-time inseminating (at 48 or 72 h after CIDR removal). A bull was run with the animals from 5 days after CIDR removal. Rectal palpation was performed 10 days after CIDR removal.

Each animal in several SAGs (Sexually Active Groups) was observed for the frequencies of mounting and being mounted. The onset of oestrus was taken as the time when an animal first stood well when mounted, and the end of oestrus was the last time the animal stood well when mounted.

The mean interval from CIDR removal to the onset of oestrus (for 10 of the 16 animals) was 31.5 ± 2.3 h, ranging from 23.2 to 43.2 h. The duration of oestrus was 8.3 ± 1.9 h, ranging from 1.5 to 19.7 h.

Most non-cycling animals injected with PMSG at CIDR removal were observed in oestrus within 48 h. Oestrus was detected by visual observation and tailpaint scoring in 75 and 83.3% of these animals, respectively. There were two cycling animals which had been injected with PGF $_{2\alpha}$ at CIDR removal, but which were not detected in oestrus by either of these two methods during the observation period.

Based on observation for several one-hour periods, the percentages of animals in a SAG which were in oestrus, pro-oestrus, met-oestrus and di-oestrus were 51.2, 19.5, 9.8 and 19.5%, respectively. Di-oestrous animals were not involved in a SAG all of the time; they came in for short periods. Di-oestrous, pro-oestrous and met-oestrous animals mounted oestrous animals, while oestrous animals were both mounting oestrous animals and standing well when mounted.

The average frequency of an oestrous animal being mounted by other oestrous and non-oestrous animals was 6.3 ± 1.6 times per hour, while the average frequency of mounting by oestrous animals was 3.6 ± 1.1 times per hour ($p=0.18$). This indicated that Taurindicus heifers in the present study tended to prefer being mounted than to mount other animals when in oestrus. The frequency of mounts of an oestrous animal by other animals in a SAG did not increase when the number of oestrous animals in a SAG increased.

Visual observation and tailpaint scoring were compared as methods to detect

oestrus in a group of Taurindicus heifers. The visual observation and the tailpaint scoring had high accuracy, with equal figures in the sensitivity and specificity of 71.4% and 100%, respectively. The combination of visual observation and tailpaint scoring had a sensitivity of 85.7% and specificity of 100%. Rectal palpation could identify all animals which had ovulated.

The results in the present study suggested that Taurindicus animals when in oestrus preferred to be mounted rather than to mount. In addition, the use of visual observation in combination with tailpaint scoring could detect all oestrous animals.

INTRODUCTION

Oestrus detection is important if artificial insemination is to be practised in a dairy herd. Poor oestrus detection rates can result in low submission rates and consequently low calving rates. In order to achieve a high oestrus detection rate with precise selection of oestrous cows for artificial insemination, signs of oestrous behaviour among cows in a herd must be recognised. Williamson *et al.* (1972) studied oestrous behaviour and oestrus detection aids in a large dairy herd and found that "standing to be mounted" was the definitive sign for detecting oestrous cows in the herd. Tailpainting as an aid in detection of oestrus has been developed and extensively used in seasonal dairy herds (Macmillan and Curnow, 1977; Williamson, 1980). The widespread use of tailpainting in New Zealand herds has reduced the incidence of oestrus detection errors and increased conception rates (Macmillan *et al.*, 1984).

Zebu cattle crossbreds (mixed *Bos taurus* and *Bos indicus* genotype) are produced specially for a tropical environment. Crossbreeding combines the characteristics of the *Bos taurus* for high milk production and fertility, with the greater resistance to disease, parasites and high temperatures in the *Bos indicus*.

The name "Taurindicus" was selected and trademarked by New Zealand Agricultural Exports Ltd. to describe Sahiwal x Holstein-Friesian cattle, produced in and exported from New Zealand. A programme has been established for further study and improvement of Taurindicus cattle by New Zealand Agricultural Exports Ltd and Ruakura Animal Research Station, Ministry of Agriculture and Fisheries, Hamilton. The programme includes breeding Taurindicus cattle with suitable proportions of *Bos indicus* and *Bos taurus* gene for high milk production and management in terms of ease of machine milking and agreeable temperament.

Oestrous behaviour in zebu cattle is slightly different from that in taurine cattle in terms of the frequency of mounting and being mounted. The successful use of artificial insemination with these animals needs a high oestrus detection rate. Previous reports from a Ruakura study showed that the Taurindicus animals preferred to be mounted when they were in oestrus rather than mounting their oestrous herd mates. This is in contrast to Friesian and Friesian x Jersey heifers which preferred to mount rather than to be mounted (Hurnik *et al.*, 1975; Helmer and Britt, 1985). Galina *et al.* (1982) and Mattoni *et al.* (1988) reported that the number of mounts in zebu cattle when they were in oestrus was less than in taurine cattle. This might be due to the longer duration of oestrus in the taurine cattle (Esslemont and Bryant, 1976; Rollingson, 1963; Mattoni *et al.*, 1988; Plasse *et al.*, 1970). In addition, oestrous behaviour in some zebu animals may involve allowing other animals in a herd to mount only once during an oestrous experience (De Alba *et al.*, 1961; Galina *et al.*, 1982).

The present study was conducted in the No.3 Dairy, Ruakura Agricultural Centre, Hamilton, New Zealand, in order to fulfil the following objective:

To study oestrous behaviour by using visual observation in combination with tailpainting in Taurindicus heifers after oestrus synchronisation.

LITERATURE REVIEW

OESTROUS BEHAVIOUR

Female cattle reach puberty at 6 to 12 months of age. Dairy heifers reach puberty earlier than beef heifers. In zebu cattle (*Bos indicus*), age at puberty in tropical and subtropical zones ranges from 16 to 37 months (Plasse *et al.*, 1968a; McDowell *et al.*, 1976; Reynolds *et al.*, 1963; Ronningen *et al.*, 1972). *Bos indicus* cattle reach puberty later than *Bos taurus* × *Bos indicus* crossbreeds, or pure breed taurine cattle. For example, Reynolds *et al.* (1963) estimated the average age at puberty in Brahman heifers in Louisiana, USA, to be 27.2 months, compared with 14.4 months for Angus heifers. Genetic and environmental factors, including nutrition, disease and parasite infestation, temperature and season of birth are reported to affect heifer growth rates and age at puberty (Hafez, 1980; Wiltbank *et al.*, 1966; Wiltbank *et al.*, 1969; Smith *et al.*, 1976; Post and Reich, 1980; Macfarlane and Worrall, 1970).

1. Behaviour of Oestrous Cows

Williamson *et al.* (1972), Esslemont *et al.* (1985) and Kilgour (1984) reported that cows coming into oestrus may show some of the following behavioural features:

- restless and walking around boundary fences;
- usually found separated, or with cows which are not their normal associates; and,
- much more aggressive towards other cows.

Cows which are in oestrus may show some of the following symptoms:

- standing close to other cows, with chin resting and rubbing on their backs, and attempting to mount;
- swelling of the vulva and a clear mucus discharge from the vagina;
- tail raising and switching;
- bellowing and walking around followed by other herd mates;
- mounting other cows; and
- standing to be mounted by other cows.

Hurnik *et al.* (1975) found that there were changes in cow activity before, during and after the day of oestrus. They found that the resting and eating activity of oestrous cows were less during the day of oestrus, which was when walking and fighting activity increased.

The manifestation of oestrous behaviour in cattle is believed to be due to the action of oestrogens which are elevated during oestrus and are low during other stages of the oestrous cycle (Hansel *et al.*, 1973; Chenault *et al.*, 1975; Lemon *et al.*, 1975; Schams *et al.*, 1977; Glencross *et al.*, 1981).

2. Signs of Oestrus

2.1. Standing to be Mounted by Other Cows.

This is the most important characteristic of oestrus that reveals the cow is in full oestrus. The cow will not make any initial effort to escape when mounted by other cows. Cows which are not in full oestrus will walk away when mounted by other cows. Williamson *et al*(1972) showed that 79%(41 of 52 cows suitable for insemination) were detected in oestrus by continuous observation for evidence of standing to be mounted.

2.2. Mounting Other Cows

Most of the mounting activity involved cows which were in late pro-oestrous, oestrous or early met-oestrous(Williamson *et al.*, 1972). Cows with cystic follicles were also found to mount other cows. Additionally, Mylrea and Beilharz(1964) and Williamson *et al*(1972) and Helmer and Britt(1985) found that in a Sexually Active Group(SAG), oestrous cows were mounted by non-oestrous cows. They indicated that mounting other cows was not the most reliable sign to use in deciding to present a cow for artificial insemination.

2.3. Ruffling of the Rump Hair and Abrasion of the Rump Skin.

Animals standing to be mounted often develop ruffling of the rump hair and tail-base hair, and abrasion of skin over the hip, the rump, pinbone or tail-base. The abrasions of skin are moist with blood or exudating serum.

2.4. Vulval Relaxation, Moistness and Erythema.

These signs were found in only a small number of oestrous cows and were less reliable as a definitive sign of oestrus(Williamson *et al.*, 1972). This was because of individual variation in the vulval and vestibular colour, size and shape.

2.5. Mucus from the Vulva.

Some cows may discharge copious quantities of mucus from the vagina when they are in oestrus. The clear mucus may be found over the buttocks and tail of oestrous cows. However, this is not observed commonly enough to be diagnostically useful.

2.6. Sensitivity to Palpation of the Rump.

Oestrous cows may show a depression of the back and raising of the tail when the rump is firmly rubbed. This has been suggested as a valuable aid in the diagnosis of oestrus and can be used to diagnose oestrous cows when combined with other signs such as vulval mucus or abrasions of the rump skin.

These symptoms of oestrus can be used for detecting oestrus mainly among animals grazing pasture. However, cows kept tethered in tie-stalls or in limited space such as loose housing, are less likely to be detected when standing to be mounted because there is less opportunity for this form of interaction. In this situation, other signs such as restlessness, bellowing, reduced milk production and vaginal mucus may need to be used more frequently to detect animals in oestrus.

3. The Onset of Oestrus

It has been reported that the expression of some oestrous signs in dairy cows (such as mounting activity) occur more frequently during the night (Williamson *et al.*, 1972; Hurnik *et al.*, 1974; Hurnik *et al.*, 1975; Esslemont and Bryant, 1976; Kilgour *et al.*, 1977) and in zebu cattle (Rollinson, 1963; Zakari *et al.*, 1981; Orihuela *et al.*, 1983). Esslemont and Bryant (1976) reported that an increase in mounting activity occurred in dairy cattle during late evening and early morning. This may be due to the effects of management activities such as milking, movement of the cows or feeding during the day (Hurnik *et al.*, 1975; Esslemont and Bryant, 1976). These activities reduce the inclination of oestrous cows to exhibit mounting activity. In zebu cattle, Orihuela *et al.* (1983) reported that up to 63% of mounting activity occurred at night in zebu cows in Mexico, while Rollinson (1963) observed it was about 34.8% in Nganda cattle in Uganda. All of these studies in zebu cattle showed that these animals displayed oestrous activity when they were confined during the night.

4. The Duration of Oestrus

There is wide variation in the duration of oestrus in zebu cattle, ranging between 2 and 20 hours (Rollinson, 1963; Baker, 1967; Plasse *et al.*, 1970; Alberro, 1983; Martinez *et al.*, 1984; Vaca *et al.*, 1985; Mattoni *et al.*, 1988). This may be due to variation in observation methods and climatic conditions, and breed variation in the expression of oestrus. Baker (1967) reported that the mean duration of oestrus in Sahiwal x Shorthorn heifers was 13.4 hours, and that the mean lengths of pro-oestrus and met-oestrus were 3.5 and 2.8 hours, respectively. In dairy breeds, Esslemont and Bryant (1976) reported that the duration of oestrus in British Friesian cows was about 15 hours. Wishart (1972) also observed European breeds and found that the duration of oestrus was about 14.7 hours. The duration of oestrus in zebu cattle tends to be shorter than in *Bos taurus* dairy breeds.

5. Sexually Active Group (SAG)

The Sexually Active Group (SAG) is a social group of sexual active animals in a herd. It consists of at least one oestrous animal, with other pro-oestrous, oestrous and met-oestrous animals and frequently nymphomaniac cows (Williamson *et al.*, 1972; Kilgour *et al.*, 1977). Di-oestrous animals are involved less frequently in the SAG (Mylrea and Beilharz, 1964; Helmer and Britt, 1985). The di-oestrous riders were indicated by Kilgour *et al.* (1977) as "one-time mounters" and may only express the mounting activity when the SAG moves near to them. During pro- and met-oestrus, cows are often seen only as mounters in the SAG, while oestrous cows stand to be mounted or mount other oestrous cows in the group.

It is easy to identify the SAG in a herd because all animals in the group are more active and move around the paddock. The animals in the SAG are the only ones standing during the night, while other non-oestrous herd mates are lying down (Williamson *et al.*, 1972). The occurrence of the SAG in the herd is the most important activity which facilitates detecting oestrous cows in the herd (Williamson *et al.*, 1972; Esslemont and Bryant, 1976; Kilgour *et al.*, 1977; Blockey, 1978).

OESTROUS BEHAVIOUR IN ZEBU CATTLE

Oestrous behaviour in *Bos taurus* dairy breeds has been frequently reviewed. Signs of oestrus in zebu cattle are the same as those of taurine cattle. The intensity of oestrous behaviour and the duration of oestrus have been reported to be less in zebu cattle than in taurine cattle (Plasse *et al.*, 1970; Esslemont and Bryant, 1976; Vaca *et al.*, 1985; Mattoni *et al.*, 1988).

Standing to be mounted is also the most characteristic sign of oestrus in zebu cattle. The number of mounts accepted by oestrous animals in zebu cattle (Galina *et al.*, 1982; Mattoni *et al.*, 1988) was less than that in taurine cattle (Esslemont and Bryant, 1976). The reason for this as indicated by Esslemont and Bryant (1976), might be that the longer duration of oestrus in taurine cattle allowed oestrous cows to be mounted more often during the oestrous period. De Alba *et al.* (1961) and Galina *et al.* (1982) noted that the oestrous behaviour in some zebu cows did not allow other cows to mount more than once during oestrus. Galina *et al.* (1982) also reported that zebu × Charolais crossbreeds allowed their herdmates to mount only once per hour, compared with 2.8 mounts per hour for Charolais. In addition, as observed in taurine cattle, Esslemont *et al.* (1985) reported that the number of mounts per cow tended to be greatest when three animals were in oestrus at the same time. Furthermore, Johnson and Oni (1986) observed that crossbred bulls mounted crossbred heifers more than did Bunaji bulls or herdmates. However, a result from one Ruakura study showed that during oestrus, Friesian and Friesian × Jersey heifers were more "sexually aggressive", preferring to mount rather than to be mounted, whereas the Sahiwal × Friesian animals preferred to be mounted (Abdul Rachid b. Baba, Unpublished).

Factors Affecting the Expression of Oestrus

1. Management and Management Activity in the Herd.

Williamson *et al.* (1972); Hurnik *et al.* (1975); Esslemont and Bryant, (1976) and Kilgour *et al.* (1977) indicated that management activity in the herd during the day such as milking, movement of cows and feeding exerted a profound effect on oestrous activity in oestrous animals. It was also observed that mounting activity appeared to occur during late evening and early morning (Esslemont and Bryant, 1976) after routine management activity during the day had finished.

Types of housing and feeding may affect the expression of oestrus. Britt *et al.* (1986) showed that oestrous cows mounted more frequently and also stood more often when on a dirt lot than on clean, grooved concrete. It was more difficult to detect oestrus in cows kept tethered in tie-stall and free-stall areas, compared with cows which were allowed to graze. Signs of oestrus other than mounting activity, such as bellowing, clear mucus from the vagina and restlessness, can also be used to detect oestrous cows.

Underfeeding delays puberty in animals. It also resulted in cessation of oestrus and ovarian activity in heifers that were already cycling (Bond *et al.*, 1958). Wiltbank *et al.* (1962) showed the same effect in Hereford cows.

2. Season and Climate

Pennington *et al*(1985) reported that climate can affect mounting and total sexual activity in lactating dairy cows. They showed that cows in hot weather were in oestrus for longer with less intensity of mounting than those in cold weather. Consequently, cows had more total oestrous activity in cold temperatures than cows in hot temperatures. De Alba *et al*(1961) reported that heat stress reduced the intensity of oestrus in zebu cattle and sometimes, *Bos taurus* cattle raised in the tropics. The incidence of oestrus in Sahiwal × Shorthorn heifers was significantly higher during the summer months than during the winter months(Baker, 1967). Heavy rain stopped all oestrous activity, but only for a short period(Williamson *et al.*, 1972).

3. Number of Animals in Oestrus

When the SAG is formed in a herd, there is a greater mobility of the group around the paddock. Hurnik *et al*(1975) observed that the number of mounts per cow increased from 11.2 with only one oestrous cow, to 52.6 with three cows in oestrus on the same day. Similar results were observed by Mylrea and Beilharz(1964) and Helmer and Britt(1985).

4. Breed Effects

Breed differences have been observed in the expression of oestrus. Galina *et al*(1982) reported that the number of mounts accepted in Charolais was greater than in Charolais × Brahman crossbreds. They also found that zebu cattle, when in oestrus, did not allow themselves to be ridden repeatedly. A result from one Ruakura study also showed that Friesian and Friesian × Jersey heifers or lactating cows when in oestrus, were more "sexually aggressive" than the Sahiwal × Friesian animals. It was observed that the Sahiwal × Friesian animals preferred to be ridden, while Friesian and Friesian × Jersey animals preferred to ride.

5. The Presence of Bull in the Herd

Mounting activity within the SAG was reported to be inhibited by the presence of bulls(Kilgour *et al.*, 1977).

OESTRUS DETECTION

Detection of oestrus is the most important part of reproductive management when artificial insemination is practised. Poor oestrus detection causes low submission rates and consequently delays conception.

There are many methods used to detect oestrus in cattle.

1. Visual Aids

This method uses signs of oestrous behaviour such as "standing to be mounted activity", to detect oestrous cows. Other behavioural features of oestrous cows have been reviewed in previous sections.

Only 50 to 60% of the oestrous cows were observed in a herd when mounting activity was used to detect oestrus(Williamson *et al.*, 1972; Esslemont, 1974; Fulkerson *et al.*, 1983). Williamson *et al.*(1972) used continuous observation for 24 hours to detect all oestrous cows, while Fulkerson *et al.*(1983) used 12 hour observation with a detection rate of 83%. However, continuous observation for oestrous cows in most dairy herds is unlikely to be practical.

Oestrus detection aids such as tailpainting, Heat Mount Detectors and Hormone-treated steers have been developed and used to improve oestrus detection rates in seasonal dairy herds(Macmillan and Curnow, 1977; Williamson *et al.*, 1972; Williamson, 1980; Sawyer and Fulkerson, 1981). The use of one of these oestrous detection aids, namely, tailpainting can produce high detection rates of more than 90% when combined with visual observation in well-managed New Zealand dairy herds.

2. Non-visual Methods

1. Rectal Palpation

An experienced practitioner can predict when a cow is likely to come into oestrus by rectal palpation of the ovaries and uterus. The corpus luteum and follicles in the ovaries can be identified by rectal palpation. The turgidity and engorgement of the uterus can also be felt when a cow is in oestrus.

2. Cervical or Vaginal Mucus Crystallisation Characteristics.

The characteristics of crystallisation patterns of mucus collected at different stages of the oestrous cycle can be used to detected oestrus(Goel and Rao, 1971).

The crystallisation patterns before and after oestrus were "fern-like", and were more visible near oestrus than during the luteal phase(Alliston *et al.*, 1958). Crystallisation patterns of vaginal mucus were less reliable indicators of oestrus than those of cervical mucus(Bone and Rajakoski, 1961).

3. Cervical or Vaginal Mucus Resistance and Conductivity

Changes in the electrical resistance of mucus in the anterior vagina can be associated with oestrus in cattle. Electrical resistance was lower at oestrus than during di-oestrus(Leidl and Stolla, 1976). This technique was related to milk progesterone levels during the 4 days before oestrus(Gartland *et al.*, 1976; Heckmann *et al.*, 1979; McCaughey and Patterson, 1981).

4. Vaginal pH

It was reported that the intravaginal pH of a cow tends to decrease during oestrus(Schilling and Zust, 1968). The pH was nearly constant during di-oestrus, ranging from 6.86 to 6.98 at the cervix, from 7.26 to 7.38 at the mid part and from 7.54 to 7.71 at the caudal part of the vagina. The pH at the cervix decreased from 7.0 to 6.72 one day before oestrus and further decreased to 6.54 at the beginning of oestrus. The lowest pH(6.45) was recorded at the end of oestrus and prior to ovulation.

MATERIALS AND METHODS

This study was conducted at Ruakura Dairy farm No3, Ruakura Agricultural Centre, Hamilton, New Zealand between 27th November, 1989 and 2nd December, 1989.

ANIMAL SAMPLE

Sixteen *Taurindicus* heifers in good condition, with mean age of 17.5 months, but ranging from 16 to 26 months, were used in this study. The mean weight of these animals was 242 kg, ranging from 184 to 324 kilograms. They were Sahiwal x Holstein-Friesian crossbreds. There were 4 animals that were 75% Sahiwal breed while the others were 50% Sahiwal X Friesian. All animals were grazed together in the same paddock for 5 weeks before the study commenced.

METHODS

All animals were rectally palpated by an experienced veterinarian to identify cycling animals. The size of each ovary and of follicles on each ovary of the animals were recorded. Then the animals were synchronised by using CIDR-B devices (Control Intravaginal Drug Release-Bovine type, Eazi-breed, AHI Plastic Co., Hamilton, New Zealand) which were inserted for 10 days together with oestradiol benzoate (10 mg) in a capsule, inserted into the grooved surface of the CIDR) at device insertion. Non-cycling animals were given an intramuscular injection of 400 I.U. of PMSG (Pregnant Mare Serum Gonadotropin, Folligon, Intervet, Auckland, New Zealand) at device removal, whereas cycling animals were given an intramuscular injection of PGF_{2α} (2 ml of Estrumate, Coopers Animal Health, NZ). Each animal was tailpainted when the synchronisation treatment started. Tailpaint (Coopers Animal Health, New Zealand) was applied; approximately 20 cm long and 5 cm wide, starting from about the first coccygeal vertebra (Macmillan and Curnow, 1977).

Before the animals were brought into the observation paddock, each animal was painted by raddle with large numbers along its side to clearly identify each animal from the observation place and to be seen clearly by spotlighting during night observations. During each night observation, the observer had to go to a nearby paddock or even into the paddock containing the heifers to record the numbers of the animals where were sexually active.

All animals, except Nos. 10, 12 and 15, were artificially inseminated once at 48 hours (Day 2) after CIDR removal. The remaining 3 animals and No. 11 were inseminated at 72 hours (Day 3) after CIDR removal. Each animal was tailpaint-scored at insemination using the method described by Macmillan *et al* (1988).

A bull was brought in to run with the animals for natural mating those animals which did not show signs of oestrus during the observation period. Ten days after CIDR removal, the group of animals were rectally palpated by an experienced veterinarian for luteal activity in their ovaries. The size of each ovary and of follicles and luteal tissue on each ovary was also recorded. All animals were palpated for pregnancy diagnosis about 90 days after mating.

OESTRUS OBSERVATION

Because most cows and heifers were expected to be in oestrus within 48-72 hours after CIDR synchronisation (Macmillan *et al.*, 1988), the oestrus observation was made occasionally during the first day after CIDR removal. However, continuous observation was made after the first day (24 hours after the CIDR removal) in order to record the oestrous behaviour of the animals. The period for continuous daily observation during the subsequent day was between 7.00 a.m. and 6.00 p.m.. Intermittent observations were made during the following night and day from 8.00 p.m. to 12.00 a.m. (at 8 p.m., 10 p.m. and sometimes during very early morning).

Because Taurindicus animals may have less overt oestrous behaviour than *Bos taurus* and their behaviour may be altered or be interfered with by the observer, the observation place was about 50 metres away from the observation paddock. Binoculars were used to identify the sexually-active animals.

The animals were recorded as mounting and as being mounted, walking away when mounted and standing well when mounted by other animals. Sometimes during the observation, the frequency of mounting and being mounted by the animals, and the number of the animals in a sexually-active group (SAG) were also recorded within a one hour period.

DETERMINATION AND CONFIRMATION OF OESTRUS

A rectal examination was not performed to confirm oestrus during the observation period. The following criteria were used to determine and confirm oestrus.

1. The onset of oestrus was taken as the time when an animal first stood well when mounted. The end of oestrus was taken as the last time the animal stood well when mounted. In those cases where the onset of oestrus was not observed, it was estimated to be between the time an animal was just seen standing well when mounted and the previous time when "standing well when mounted" was not observed. Similarly, when the end of oestrus was not observed, it was estimated to be between the last time the animal stood well when mounted and the first time the animal did not stand well when mounted.
2. Tailpaint scoring was completed on the days of insemination (48 and 72 hours after CIDR removal) and was used to confirm oestrus by the method described by Macmillan *et al.* (1988).
3. A corpus luteum was detected on the ovaries by palpation 10 days after CIDR removal.

The total number of each animal's involvement in mounting others or in being mounted by others in each SAG in a one hour observation period, the duration of oestrus and the interval from the CIDR removal to the onset of oestrus were determined for each animal. Each animal in each SAG was also identified as being in pro-oestrus, oestrus, met-oestrus or di-oestrus.

TAILPAINT SCORING

The Taurindicus heifers were observed for oestrous behaviour after CIDR removal. At the time of artificial insemination, these animals were checked for paint which had been removed of the time they had been in oestrus and had been mounted by other animals. The tailpaint score was given to each animal according to the amount of paint which had been lost during oestrus, as described by Macmillan *et al*(1988):

Score 5 : 100 to 90% of paint remaining

Score 4 : 90 to 70% of paint remaining

Score 3 : 70 to 50% of paint remaining

Score 2 : 50 to 30% of paint remaining

Score 1 : 30 to 10% of paint remaining

Score 0 : $\leq 10\%$ of paint remaining

In those cases where a tailpaint score of ≥ 4 was given and the tailpaint score had not been reduced by at least 2 units during the 2 days of the tailpaint scoring (at 48 and 72 hours after the CIDR removal), the animal was considered not to have been in oestrus (no sign of "being mounted" activity).

DATA ANALYSIS

Panacea Database Program (Pan Livestock Inc., Reading, United Kingdom) was used to analyse the data. Analysis of Variance was used to analyse the frequencies of mounting and being mounted during oestrus, pro-oestrus, met-oestrus and di-oestrus among animals in the SAGs.

DEFINITIONS OF SOME TERMS USED IN THE TEXT

Mounted frequency is the number of mounts accepted by an oestrous animal.

Mounting frequency is the number of mounts attempted by an animal involving in a SAG.

Sensitivity is the ability of a test to give a positive result when the animal is in true oestrus.

Specificity is the ability of a test to give a negative result when the animal is not in oestrus.

RESULTS

There were 87.5% (14 out of 16 animals) of the Taurindicus heifers which responded to the oestrus synchronisation treatment, but only 62.5% of the animals were detected by visual observation and tailpaint scoring. The animals were detected to be in oestrus by standing well when mounted by other animals within 43.2 h after CIDR removal.

1. Oestrus Manifestation

The mean interval from CIDR removal to the onset of oestrus (for 10 of the 16 animals) was 31.5 ± 2.3 h, ranging from 23.2 to 43.2 h (Table 3.1 and Figure 3.1). The duration of oestrus was 8.3 ± 1.9 h, ranging from 1.5 to 19.7 h (Table 3.1 and Figure 3.2).

Signs commonly observed in a SAG, such as signs of following oestrous cows by other animals which were coming into oestrus, mounting oestrous animals and walking away when mounted by other animals were observed during the first day of the observation period. The average interval from first observing signs of following oestrous animals to the onset of oestrus (by time first seen to accept mounting) was 2.5 ± 0.1 h (ranging from 2.2 to 2.6 h). The interval from signs of starting to mount oestrous animals to the onset of oestrus was 2.7 ± 0.8 h, ranging from 0.2 to 6.7 h. The average interval from first observing signs of walking away when mounted by other animals to the onset of oestrus was 4.6 ± 1.7 h, ranging from 0.7 to 10 h.

Among the four cycling animals which were 75% Sahiwal x 25% Holstein Friesian and treated with a CIDR device for 10 days and PGF_{2α} at CIDR removal, only one animal (No. 11) was observed in oestrus (at 43.2 h after CIDR removal), while the other three animals (Nos. 10, 12 and 15) were not observed in oestrus during the observation period.

Among 12 animals which were treated with a CIDR device for 10 days and PMSG at CIDR removal, 9 animals were detected in oestrus by visual observation (75%), while 10 animals were detected by tailpaint scoring (83.3%). There were 8 animals which were detected in oestrus by visual observation and tailpaint scoring within 36 h after CIDR removal (Figure 3.1).

The pregnancy rate (% PR) to the set-time insemination at 48 or 72 h after the CIDR removal was 35.7% (5 from 14 animals which ovulated). Three out of five animals which conceived at the set-time insemination were those which were not detected in oestrus by visual observation, but were detected by tailpaint scoring and rectal palpation. The PR was 20% of animals which were visually in oestrus (2 from 10 animals). The PR was 50% of animals which were tailpaint detected (5 from 10 animals).

The PRs were 25 and 50% for animals which ovulated to a CIDR device + PMSG (3 from 12 animals) and a CIDR device + PGF_{2α} (2 from 4 animals), respectively.

Table 3.1. The mean interval from CIDR removal to the onset of oestrus and the duration of oestrus in 10 taurindicus heifers.

Parameters	Mean \pm S.E. (ranges)
1. The interval from CIDR removal to the onset of oestrus(h)	31.5 \pm 2.3 (23.2-43.2)
2. The duration of oestrus (h)	8.3 \pm 1.9 (1.5-19.7)

2. Sexually Active Group(SAG)

Each sexually active group observed during selected one hour periods consisted of at least two oestrous animals. It also included pro-oestrous, met-oestrous and di-oestrous animals. The percentages of animals which were in oestrus, pro-oestrus, met-oestrus and di-oestrus in a SAG were 51.2%, 19.5%, 9.8% and 19.5%, respectively. Di-oestrous, pro-oestrous or met-oestrous animals showed signs of mounting oestrous animals, while oestrous animals were seen both mounting oestrous animals and standing well when mounted.

In each SAG, di-oestrous animals were not involved in the SAG all of the time; they came in for short periods. It was also observed in each SAG that one animal(No.13) which may or may not have been in oestrus during the observation period(she was naturally mated two days after the observation had finished, and rectal examination 7 days after the observation revealed that she had ovulated and had a corpus luteum on one ovary), was involved in mounting oestrous animals in every SAG. She walked away when mounted and did not allow other animals to mount. This animal frequently mounted only one specific oestrous animal in each SAG. Animal No.15 was in di-oestrus, but was never involved in a SAG during the observation period. One cow with a calf which grazed with these heifers in the same paddock did not become involved in any SAG.

3. Mounting and Mounted Frequency in a Sexual Active Group

In 5 SAGs observed in this study, oestrous animals were mounted by other oestrous animals and non-oestrous animals(pro-oestrous, met-oestrous and di-oestrous animals). The frequency of mounting and being mounted varied between individuals and between each SAG. The average frequency of being mounted in an oestrous animal by other oestrous and non-oestrous animals was 6.3 ± 1.6 times per hour, while the average frequency of mounting

by oestrous animals in a SAG was 3.6 ± 1.1 times per hour ($p = 0.18$). Oestrous animals did not always accept mounting by some animals. They walked away when mounted, even though they were still in oestrus and they had previously accepted mounting. It was also observed that 80.9% of oestrous animals (17 out of 21 oestrous animals in 5 SAGs) mounted other oestrous animals, while the remaining four oestrous animals were not observed to mount other oestrous animals in the SAGs during each one hour observation period.

The frequency of mounts of an oestrous animal by other animals in a SAG did not increase when the number of oestrous animals in a SAG increased. For example, 40 mounts were observed when 2 oestrous animals were in one SAG, while only 29 mounts were observed when there were 6 oestrous animals in another SAG.

4. Oestrus Detection Techniques (Visual Observation, Tailpaint Scoring and Rectal Examination)

Animals were detected in oestrus by signs of being mounted through the visual observation, and the use of tailpaint scoring at 48 and 72 h after the CIDR removal. Rectal palpation of the ovaries was also performed on Day 10 after CIDR removal to confirm the occurrence of ovulation by corpus luteum formation. In the 16 animals, 10 animals were detected in oestrus by signs of being mounted and 10 animals were detected by tailpaint scoring, while 14 animals were found to have ovulated by rectal palpation (Table 3.2).

In six animals which were not seen to be mounted by visual observation, two animals (Nos. 6 and 7) were detected by the tailpaint scoring and rectal examination. Two animals only showed signs of mounting oestrous animals and walking away when mounted by other animals during the observation period in the SAG. They were finally confirmed pregnant to the set-time insemination (48 h after CIDR removal).

Another two animals (Nos. 12 and 13) were not detected by visual observation or by tailpaint scoring, but had a corpus luteum palpated. This showed that these two animals might not have displayed signs of oestrus (mounted activity) during the observation period. They may have been being mounted only for a short period during the night. These two animals mounted oestrous animals but walked away when mounted by other animals. Animal No. 12 was pregnant to the set-time insemination.

The remaining two animals (Nos. 10 and 15) were not detected in oestrus by any of the three methods (visual observation, the tailpaint scoring and rectal palpation). No. 10 was naturally mated 4 days after the end of the observation period and conceived. This animal did mount oestrous cows in the SAG. No. 15 was also naturally mated and conceived 12 days after the end of the observation period. She was not observed in oestrus and was not involved in any SAG.

Table 3.2. Positive(+), negative(-) or equivocal(?) occurrence of oestrus as determined by visual observation(VO), tailpaint scoring(TP) or rectal palpation(RP) of the ovaries to detect the presence of a corpus luteum(CL) in a group of 16 synchronised Taurindicus heifers.

Animals	PMSG or PGF _{2α}	VO	TP	RP	AI or NM	P or NP
1	PMSG	+	+	+	AI	NP
2	PMSG	+	+	+	AI	NP
3	PMSG	+	+	+	AI	NP
4	PMSG	+	+	+	AI	NP
5	PMSG	+	+	+	AI	NP
6	PMSG	-	+	+	AI	P
7	PMSG	-	+	+	AI	P
8	PMSG	+	+	+	AI	NP
9	PMSG	+	?	+	AI	NP
10	PGF _{2α}	-	?	-	AI	NP
11	PGF _{2α}	+	?	+	AI	P
12	PGF _{2α}	-	?	+	AI	P
13	PMSG	-	?	+	NM	NP
14	PMSG	+	+	+	AI	P
15	PGF _{2α}	-	?	?	NM	NP
16	PMSG	+	+	+	AI	NP
16 animals		10 positive	10 positive	14 positive		

Visual observation(Sensitivity = 71.4% and specificity = 100%)

Tailpaint scoring(Sensitivity = 71.4% and specificity = 100%)

Visual observation + Tailpaint scoring(Sensitivity = 85.7% and specificity = 100%).

(AI= Artificial insemination, NM= Natural mating, P= Pregnant and NP= Not-pregnant).

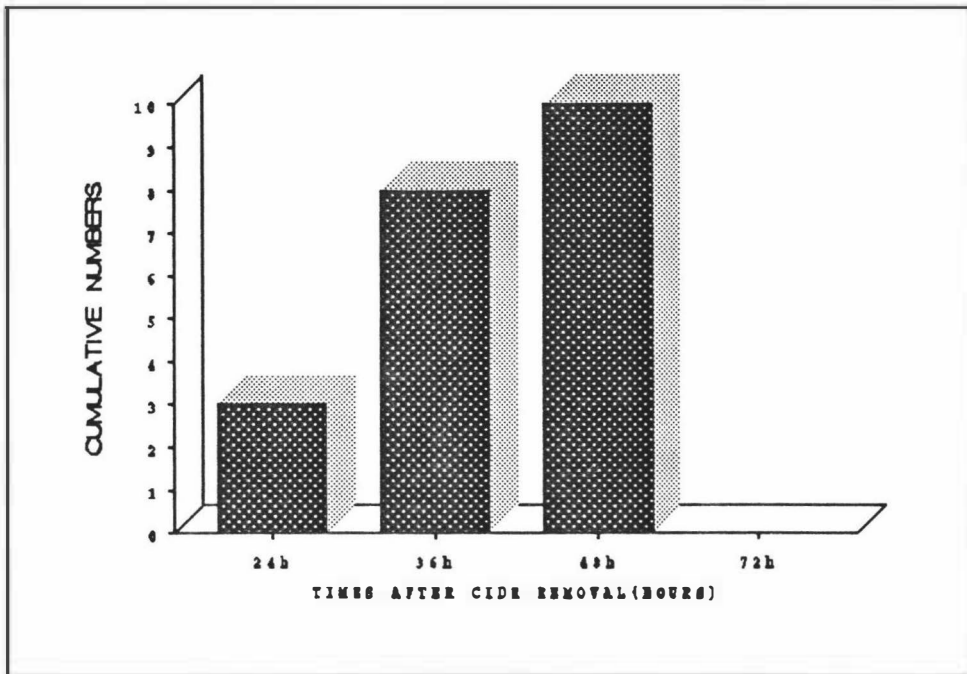


Figure 3.1. The distribution of the onset of oestrus after CIDR removal in 10 Taurindicus heifers.

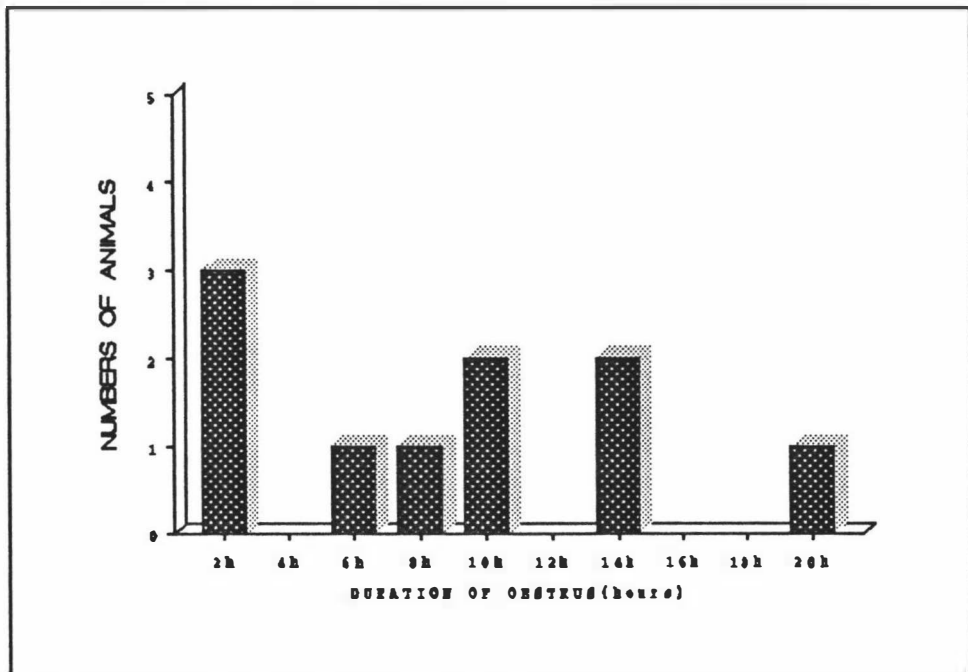


Figure 3.2. The distribution of the duration of oestrus in 10 Taurindicus heifers.

Two animals(Nos.9 and 11) had a negative response(≥ 4) to tailpaint scoring, but oestrus was detected by visual observation and rectal palpation. These two animals were seen to be mounted by other animals only twice and once during an oestrus of short duration(1.5 and 1.7 h, respectively).

It can be seen from Table 3.2 that two animals(Nos.10 and 15) were palpated without luteal activity, and oestrus was neither detected by visual observation nor by tailpaint scoring. The visual observation and the tailpaint scoring had a sensitivity of 71.4% and specificity of 100%. The visual observation combined with tailpaint scoring had a sensitivity of 85.7% and specificity of 100%. These two methods for detection of oestrus did not detect signs of being mounted in 4 oestrous animals which were confirmed as ovulating by rectal palpation.

DISCUSSION

Manifestation of Oestrus

The interval from CIDR removal to the onset of oestrus of the Taurindicus heifers in the present study was 31.5 h, ranging from 23.2 to 43.2 h. The duration of oestrus in the animals was 8.3 hours, ranging from 1.5 to 19.7 h. The variation in the duration of oestrus in the present study was consistent with that reported by Rollingson(1963), Baker(1967), Plasse *et al*(1970), Alberro(1983), Martinez *et al*(1984), Vaca *et al*(1985) and Mattoni *et al*(1988). They reported that the duration of oestrus in zebu cattle ranged from 2 to 20 h.

Most non-cycling animals which were treated with a CIDR device(+ oestradiol bezoate in oil) for 10 days and PMSG at CIDR removal in the present study were observed in oestrus within 48 h(75 and 83.3% of these animals were detected by visual observation and tailpaint scoring, respectively). Macmillan *et al*(1988) have shown that 79% of dairy heifers treated with 12 day CIDR and oestradiol benzoate at CIDR insertion, were detected in oestrus and inseminated within 48 h after CIDR removal. Only 49% of heifers treated with 10 day CIDR and PGF_{2α} at CIDR removal, were detected and inseminated within 48 h. Dick(1990) also showed that 70% of cycling heifers(7 out of 10 animals) treated with a CIDR device for 10 days and PGF_{2α} at CIDR removal, were detected in oestrus within 66 h after CIDR removal.

In unsynchronised animals(these were two cycling animals treated with PGF_{2α} at CIDR removal and detected in oestrus after the observation period), it has been reported by Macmillan *et al*(1988) that a prolonged pro-oestrus was frequently found after treatments involving PGF_{2α}. The presence or absence of a corpus luteum and concentration of plasma progesterone at the end of treatment also influenced variation in the distribution of oestrus after CIDR treatment.

The duration of oestrus in animals Nos.8, 9 and 11 was short(1.5, 1.5 and 1.75 hours, respectively). No.8 was detected in oestrus by the three methods, while both Nos.9 and 11 had a tailpaint score of 4, and rectal palpation revealed corpus luteum formation. The tailpaint score of 4 means that 70 to 90% of paint remained when they were scored before insemination(Macmillan *et al.*, 1988). Because of the short duration of oestrus in two animals(Nos.9 and 11), they were mounted only twice and once, respectively, by other animals in the SAG when they were in oestrus. The longer duration of oestrus as observed in taurine cattle should mean that oestrous cows will be mounted more frequently during the oestrous period(Esslemont and Bryant, 1976). This may be one of the reasons why the tailpaint still remained and the tailpaint score of 4 was given to these Taurindicus animals. In addition, these two animals were heavier than others in the group. It may have been difficult to remove tailpaint when they were mounted by lighter animals(Macmillan *et al.*, 1988). Furthermore, Macmillan *et al*(1988) noted that tailpaint could be seen to be removed after 4 dismounting sequences.

Sexually-Active Group

At least two oestrous animals in the present study were identified in each SAG which was observed during several one-hour observation periods. The SAG consisted of oestrous, pro-oestrous, met-oestrous and di-oestrous animals, with the percentage of 51.2%, 19.5%, 9.8% and 19.5%, respectively. These proportions are consistent with results reported by Kilgour *et al.*(1977), Mylrea and Beilharz(1964) and Helmer and Britt(1985). Pro-oestrous, met-oestrous and di-oestrous animals only mount others in the SAG, while oestrous animals stand to be mounted and mount other oestrous cows(Kilgour *et al.*, 1977; Helmer and Britt, 1985). One animal(No.13) was involved in every SAG by mounting oestrous animals, but only for short periods.

Mounting and Mounted Frequency

The frequency of being mounted among oestrous animals by oestrous and non-oestrous animals in the present study was 6.3 mounts per hour, and the frequency of mounting in oestrous animals was 3.6 mounts per hour. The percentage of mounting frequency of 79.3% by oestrous animals agrees with results reported by Hurnik *et al.*(1975) and Helmer and Britt(1985). The frequency of being mounted by oestrous animals in the Taurindicus heifers was consistent with a Ruakura study(Rachid bin Baba, unpublished) which showed that Sahiwal x Holstein-Friesian animals preferred to be mounted when they were in oestrus rather than to mount, compared with Friesian or Jersey animals which preferred to mount. However, Galina *et al.*(1982) and De Alba *et al.*(1961) noted that some zebu cattle did not allow other cows to mount more than once when there were in oestrus. Some animals which were not observed to be in oestrus during the observation period in the present study(Nos.6 and 7), were detected by tailpaint scoring and rectal palpation of the corpus luteum. Oestrus in these two animals may have been missed if they were in oestrus only during the night or during very early morning. Orihuela *et al.*(1983) and Rollingson(1963) showed that 35 to 63% of mounting activity in zebu cattle occurred at night. Also, these two animals showed signs of mounting and of walking away when mounted by other animals during the observation period.

The frequency of mounts received by an oestrous cow has been reported to increase when the number of oestrous cows in the SAG increased(Mylrea and Beilharz, 1964; Hurnik *et al.*, 1975). In the present study, the number of mounts observed in a one hour period was different from the above authors who observed the number of mounts per oestrus per cow. The frequency of mounts received by an oestrous animal in the present study did not increase when the number of oestrous animals increased in a SAG. The reasons for this, firstly, may be because during the one hour observation period some oestrous animals just came into oestrus while others were in the middle or last stages of the oestrous period. This may have produced the difference in the frequency of mounting and being mounted in oestrous animals in the SAG(Helmer and Britt, 1985). In addition, in the present study, the frequency of mounting and being mounted increased when the time after the onset of oestrus increased, except in animals Nos.9 and 11. It could be that the duration of oestrus in some zebu animals was short, and the habits of zebu cattle did not allow other animals to mount more than once(Galina *et al.*, 1983; De Alba *et al.*, 1961).

Oestrus Detection

The use of visual observation and tailpaint scoring to detect oestrus in a group of Taurindicus heifers could be compared in this study. The visual observation and the tailpaint scoring in the present study had high accuracy with equal figures for sensitivity and specificity of 71.4% and 100%, respectively. This shows that the two methods can detect 71.4% of oestrous animals when they are in true oestrus, but the two methods could also rule out the possibility of oestrus in non-oestrous animals with 100% accuracy. The combination of visual observation and tailpaint scoring in the present study meant that all animals which had ovulated were detected in oestrus (Table 3.2). In other words, the sensitivity of the two tests used in parallel was 100%. This shows that oestrus synchronisation for an artificial insemination programme was successful in a group of Taurindicus heifers if combined with visual observation and tailpaint scoring.

The results in the present study showed that most of the Taurindicus heifers which were treated with a CIDR device for 10 days (+ oestradiol benzoate) and PMSG at CIDR removal were in oestrus in 31.5 h on average after CIDR removal. It is recommended that if a single set-time insemination is to be used, then it should be performed at 36 h after CIDR removal. The set-time insemination at 48 h after CIDR removal in the present study might not be the right time, since the majority of the animals were in oestrus before 36 h and some animals had a short duration of oestrus. It is possible that oestrus in some animals might have been finished before they were inseminated. These animals might not conceive and would then return to oestrus.

If natural oestrus occurs in a group of animals, and possibly only one animal is in oestrus, a SAG may not be formed or be formed with only a few animals in the group. It may be difficult to detect oestrous animals by tailpaint scoring due to the low frequency of an oestrous animal being mounted by other animals in the group, which would result in less paint being removed. Other oestrus detection aids such as penis-deviated bulls fitted with a chin-ball harness or vasectomised bulls should be used in the detection of oestrus in small groups of Taurindicus heifers, although this method has not always proved as successful in practice as it appears in theory (Morris, Personal Communication).

The results from the present study suggest that the use of a CIDR device for 10 days and PMSG at CIDR removal in the group of Taurindicus heifers can synchronise oestrus within 48 h after CIDR removal. The use of PGF_{2α} at CIDR removal in these cycling animals did not synchronise 4 animals within the observation period. Visual observation in combination with tailpaint scoring can detect most oestrous animals. It is recommended that another study should be performed on the oestrous behaviour of Taurindicus cows, and results should be compared with those in the heifers in the present, study since it has been reported that the response to synchronised treatments in taurine dairy cows is different from that in heifers.

CONCLUSION

The present study showed that the use of a CIDR device for 10 days and PMSG at CIDR removal in non-cycling Taurindicus heifers could produce synchrony of oestrus within 36 h after CIDR removal. One cycling animal treated with PGF_{2α} at CIDR removal was detected in oestrus within the observation period, but three others did not demonstrate oestrus. The mean interval from CIDR removal to the onset of oestrus was 31.5 h and the mean duration of oestrus was 8.3 h. A SAG consisted of oestrous, pro-oestrous, met-oestrous and di-oestrous animals with the proportions of 51.2, 19.5, 9.8 and 19.5%, respectively. Di-oestrous, pro-oestrous and met-oestrous animals mounted oestrous animals, while oestrous animals were both mounting other oestrous animals and standing well when mounted. The frequency of mounts of an oestrous animal by other animals in a SAG did not increase when the number of oestrous animals increased. Taurindicus animals when in oestrus tended to prefer being mounted rather than mounting other oestrous animals. The use of visual observation in combination with tailpaint scoring in the present study could identify most oestrous animals and could minimise the possibility that oestrus had occurred in non-oestrous animals.

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CHAPTER 4

EVALUATING

THE REPRODUCTIVE PERFORMANCE

OF TWO

INTENSIVELY MANAGED RESEARCH DAIRY HERDS

USING THE DAIRYMAN PROGRAMME

ABSTRACT

Breeding records from the Ruakura Dairy Herd No1 and No2 (Ruakura Agricultural Centre, Hamilton, New Zealand) were analysed by using a herd health and management programme (The DairyMAN Programme, Department of Veterinary Clinical Sciences, Massey University, New Zealand). Those in the No1 herd ($n = 527$) were taken over the period from 1984 to 1988 and those in the No2 herd ($n = 1315$) from 1982 to 1988. The Panacea Database Programme (Pan Livestock Inc., Reading, United Kingdom) was also used to analyse reproductive indices.

The calving rates at 4 and 8 weeks after Planned Start of Calving (PSC) were high (77 to 98% and 72 to 88% for the No1 and No2 herds, respectively) when compared with the predicted calving spread from mating records in the previous season. The induction of premature parturition shortened pregnancies of late calving cows and produced a concentrated calving pattern. The first service pregnancy rate (PR) in the No2 herd was lowest in 1985 (43%) and highest in 1986 (71%), while those in the No1 herd were below the target value (59%) in 1985 to 1987 (52 to 57%). The first service PR in the No2 herd was low in every age group and cows which had calved ≥ 40 days at PSM. The overall 3 and 4 week submission rates (SR) were well above the target values (90 and 92%, respectively) in the two herds. The mean condition score at mating of cows in 1985 was 3.75, compared with 4.57 at calving.

The return to service intervals were divided into short (1-17 days), normal (18-24 days) and long return intervals (≥ 25 days). The long return intervals were also divided into 25-38 days, 39-45 days and > 45 days. The total of short return to service intervals (1-17 days) as a proportion of all intervals in the No1 herd (natural mating) was high (46.7%, ranging from 32 to 57%), while that in the No2 herd (artificial insemination) was lower (15.1%, ranging from 6 to 22%). Both herds had more short intervals than typically seen in commercial herds. Oestrus detection efficiency, as measured by the ratio of single to double cycles, was high in both herds.

The mean intervals from calving to first oestrus in the No1 and No2 herds were 43.1 and 43.8 days, respectively. There was a significant difference in the mean interval from calving to first oestrus between age groups in the No2 herd (51.7, 47.8, 39.6 and 37.3 days for the 2, 3, 4-8 and 8+ year old cows, respectively, $p < 0.0001$). Cows which had body condition score (BCS) of ≥ 4.0 at calving had a shorter interval than those with a low BCS (≤ 3.5) [40.3 days vs 59.9 days, $p < 0.005$]. Cows with calving difficulty which were assisted to calve had the longest interval (51.7 days), compared with those which calved normally (43.1 days, $p < 0.001$) and cows induced to calve (41.2 days, $p < 0.001$). Cows which had been induced to calve prematurely with BCS of ≥ 4.5 had a significantly shorter interval than those with BCS of ≤ 4.0 (39.0 days vs 54.0 days, $p < 0.01$).

Crossbred cows in the No1 herd had a significantly shorter interval to first oestrus than Friesian or Jersey herdmates (38.5 days vs 43.5 or 46.1 days, respectively, $p < 0.05$).

The mean intervals from Planned Start of Mating (PSM) to first service in the

interval from PSM to first service was significantly different in cows which had BCS at mating of ≤ 3.5 and BCS of ≥ 4.0 (13.9 days vs 11.4 days, $p < 0.0001$). Cows which were induced to calve prematurely had the longest interval (15.3 days), compared with those which were assisted to calve or calved with or without retained foetal membranes (12.2, 11.7 or 10.2 days, respectively, $p < 0.005$). Cows which had records of pre-mating heat (PMH) before PSM had a significantly shorter interval than those without PMH (11.1 days vs 16.0 days, $p < 0.0001$).

The mean intervals from PSM to conception in the No1 and No2 herds were 18.0 and 22.3 days, respectively. Cows which had BCS at mating of ≥ 4.0 had a significantly shorter interval than those which had BCS at mating of ≤ 3.5 (21.3 days vs 25.2 days, $p < 0.005$). Cows induced to calve prematurely had a significant longer interval than those which were assisted to calve or calved with or without retained foetal membranes (31.3 days vs 24.0, 21.2 or 18.0 days, respectively, $p < 0.05$).

The results showed that the reproductive performance of cows in the No1 herd was above the target values specified in DairyMAN. The reproductive performance of cows in the No2 herd was also high. It is clear that several factors can affect the reproductive performance of the herd. The programme can examine these factors in detail. Each major component of herd performance which is known to contribute to the problems can be dissected into more detailed sub-items such as age groups and post-partum intervals at PSM which can be used to explain more precisely why some aspect of performance may be unsatisfactory.

INTRODUCTION

The DairyMAN Programme is a computerised dairy herd health and management programme which has been developed for use in reproduction, health and production recording for seasonal dairy herds. This programme can analyse herd and farm performance simply and effectively to assist veterinarians, farm advisors and dairy farmers. The programme can also monitor changes in the performance and identify the target problem. Reasons for the change in performance or failure to achieve optimum targets of performance can be identified, recommendations for improvement made, and performance monitored continuously to assess the effectiveness of the action taken (Radostits and Blood, 1985). The use of herd health programmes in monitoring reproductive performance has been shown to produce profitable improvements in reproductive efficiency (Galton *et al.*, 1977; Moller, 1978; Williamson, 1980b).

The primary objective of a breeding programme in a seasonal dairy herd is to produce a calving pattern related to pasture growth (Macmillan, 1985b). The calving pattern is concentrated to precede the period of most rapid pasture growth. Dairy cows in seasonal dairy herds have a calving period of only 8 to 11 weeks from Planned Start of Calving (PSC) date, and 8 to 12 weeks in the mating period starting from the date of Planned Start of Mating (PSM). This is about 85 days after PSC. Cows which may have due calving dates out of the calving period or late in the calving period may be induced to calve prematurely in order to maintain the concentrated calving pattern.

Heifer calves of high genetic merit are produced in the herd in order to replace adult cows which die or must be culled due to voluntary (low producers) or involuntary (empty cows, mastitis) causes. These heifers should be mated to conceive and calve at about 24 months of age.

The field use of the DairyMAN Programme in conjunction with an advisory service has been adopted by a number of New Zealand dairy farmers. The return on investment of roughly 175% reported by McKay (1988) arose in part from a concentrated calving pattern with more cow days in milk, and more calf sales because of a reduced need for calving induction. In addition, the decrease in involuntary losses from the herd produced the greatest improvement on the farm studied by McKay (1988).

Special efforts have been made in the Ruakura No1 and No2 dairy herds to achieve and maintain high reproductive efficiency, and to keep comprehensive records of herd health, reproduction and body condition. This study was therefore designed to:

1. Use computer programme to determine the values for various important reproductive indices in herds with comprehensive and reliable records over a period of years, as an aid in setting targets for other New Zealand herds.
2. Examine factors influencing variation between categories of animals and between years in the various reproductive indices.

LITERATURE REVIEW

ISSUES KNOWN TO INFLUENCE REPRODUCTIVE PERFORMANCE

In most seasonal dairy herds, there are only 83 days from PSC until the breeding programme commences. Cows should get in calf during the first 3 to 4 weeks of the breeding programme, irrespective of their post-partum interval. Events which occur during the post-partum period are of critical importance to the success of the breeding programme (Macmillan, 1985a).

1. Conception Pattern

The conception pattern is a consequence of the interaction between the submission rate and the conception rate (Macmillan, 1985a). This pattern is a reflection of when cows were inseminated in relation to the PSM date, what proportion of cows conceived to first or subsequent matings, and the interval between the matings.

2. Submission Rate

The submission rate (SR) is controlled by the oestrus detection efficiency of the herd (the ability of herdsman to detect oestrous cows and present them for service) (Moller, 1978; Williamson, 1987) and the percentage of cows in the herd which have a PMH (+PMH cows) before the breeding programme starts. The percentage of +PMH cows before PSM is influenced by the interval from calving to the PSM date and the duration of post-partum anoestrus.

There are many factors which affect the submission rate in seasonal dairy herds. These include:

2.1. Previous calving pattern Late calving cows are less likely to return to cycle before the PSM and hence will be mated at their first post-partum oestrus (Macmillan, 1985a). Cows which have calved more than 40 days at PSM are more likely to cycle before the breeding programme starts or possibly during the early part of the breeding programme, since the interval from calving to first oestrus in New Zealand dairy herds is 47 to 50 days (Macmillan and Clayton, 1980).

2.2. Nutritional deficiencies before and after calving may prolong the interval from calving to first ovulation and first oestrus (Butler *et al.*, 1981; Terqui *et al.*, 1982). Feeding shortages before or after calving may reduce a cow's body condition score, resulting in a prolonged interval from calving to first oestrus (McGowan, 1981). The effects of feed shortage are more pronounced in young cows (2 and 3 year old cows) than in older cows (Fielden *et al.*, 1976, Moller, 1978). Macmillan and Clayton (1980) showed that first calving heifers have a post-partum interval to first oestrus 9 to 16 days longer than mature cows.

2.3. Periparturient diseases such as calving difficulties, retained foetal membranes and metritis will delay the interval from calving to first oestrus (Eddy,

1980; Sandals *et al.*, 1979). Moller and MacDiarmid(1981) showed that late calving cows which were induced to calve prematurely had prolonged intervals from calving to first oestrus in 2 out of 18 survey herds, with an average interval of 74.6 days, compared with a mean interval for induced cows in the other herds of 36.9 days. They suggested that the induced cows in these 2 herds were in poor condition at the time of calving.

2.4. Accurate and thorough oestrus detection is an important factor which influences submission rates. The detection of oestrus has been identified as the major factor reducing reproductive efficiency in many dairy herds(Esslemont and Ellis, 1974; Morris, 1976, de Kruif and Brand, 1978; Jensen *et al.*, 1987, Macmillan, 1985b; O'Farrell, 1984).

3. Conception Rate(CR)

Macmillan(1985a) and Williamson(1987) described factors influencing reproductive efficiency in terms of conception rate. These included female factors(cow fertility), male factors(sires, semen processing, semen quality and inseminating) and management factors(herd management issues such as detection of oestrus and nutrient supply).

3.1. Female factors

Female factors which may affect a herd's conception rate may also have an effect on submission rates, so that some factors can influence reproductive performance in at least two ways. For example, a nutritional factor which may cause anoestrus and prolong the interval from calving to first ovulation and oestrus, and subsequently lower submission rate, may also reduce conception rate(Morris, 1976; Radostits and Blood, 1985; Erb and Smith, 1987; Williamson, 1987). The female factors are:

3.1.1. Post-partum Interval

Cows which are inseminated within 60 days post-partum(pp) have a lower conception rate than those inseminated more than 60 days pp(Macmillan and Clayton, 1980, Williamson, 1987). Macmillan and Clayton(1980) also showed that conception rate reduced if the interval from calving to first service was less than 40 days irrespective of whether there had been a PMH.

Inter-service intervals of more than 24 days may sometimes be associated with early embryonic death(O'Farrell, 1984). In a New Zealand study(Moller *et al.*, 1986), it was shown that 8.6% of cows(196 out of 2274 cows) returned to service more than 35 days after first insemination. Only 56% of these intervals were associated with embryonic death, while the remainder were mainly associated with errors in detection of oestrus at first insemination(15%). About 23% of these cows failed to be detected in oestrus around 3 weeks later, or were pregnant to first insemination(5%). In addition, cows which have uterine pathology may also have prolonged cycles with an extended luteal phase during the early post-partum period(Ball, 1982).

3.1.2. Cow Condition at Calving

Condition of cows at calving has been shown to affect post-partum interval and subsequent fertility of the herd. McGowan(1981) related body condition at calving to the interval from calving to first oestrus and found that the interval decreased when the condition scores increased at calving. Macmillan(1985a) showed that the conception rates were not affected by condition scores at calving within the range of condition score of 4.0 to 6.5. There was a decline in the conception rate at first service when the condition at calving was below or above this range. Rutter and Randel(1984) showed that cows which maintain body condition after calving have a shorter interval to first oestrus than those which lose body condition.

3.1.3. Age Effects

Fielden *et al*(1976) showed that two year old cows had the highest percentage of inactive ovaries(85% of pre-service anoestrus), compared with 74% and 47% in the 3 year and 4 or more year old cows, respectively. They also indicated that the two year-old animals form a problem group in a herd and that this was associated with stage of physical maturity, with nutrition and with social stress within the herd. These young animals had an interval from calving to first oestrus 10 to 16 days longer than the older cows in the herd(Macmillan and Clayton, 1980). They also showed that in old Jersey cows the interval from Planned Start of Mating(PSM) to Mean Conception Date(MConD) was 23 days, compared with 36 days in 2 year old Jersey cows.

3.1.4. Breed Effect

The pregnancy rate to first insemination was not different between Jersey and Friesian x Jersey cows, but the pregnancy rate to second and subsequent inseminations were higher in Friesian x Jersey crossbreds than Jersey cows(Macmillan and Clayton, 1980). In addition, Macmillan *et al*(1981) showed that the average interval from PSM to MConD for the crossbreds(Friesian x Jersey) was 3 days less than for the Jersey herdmates(23 days vs 26 days).

3.1.5. The Effect of Parturient Diseases

Individual cows affected with parturient diseases often show a delayed return to oestrus after calving. Dystocia, retained foetal membranes and metritis cause a delay in the interval to first oestrus(Eddy, 1980; Morant, 1984).

Body condition can be increased during late pregnancy in order to provide tissue reserves which can be mobilised during early lactation. Reid(1984) found that 30% of high-producing cows developed fatty infiltration after calving. This resulted in a delay in onset of post-partum ovarian activity, and consequently reduced fertility.

Pelisser(1976) reported that the incidence of retained foetal membranes was 24% in cows with milk fever, compared with 12% in the main herd. The conception rates were found to be reduced in cows with retained placenta(Pelisser, 1976; Erb and Smith, 1987).

Induction of premature calving contributes to lower fertility. Moller and MacDiarmid(1981a) showed that 16.7% of the 276 cows induced to calve prematurely were non-pregnant and the calving rate after first mating was 44.9%. They also indicated that poor body condition at the time of induction and the high incidence of retained foetal membranes resulted in a lengthening of the post-parturient anoestrous period and reduced subsequent fertility. Macmillan *et al.*(1987) also showed that induced cows had lower fertility than herdmates which had calved normally. The technique of inducing cows to calve prematurely should be used only with young and healthy cows(Moller and MacDiarmid, 1981a).

3.1.6. Environmental Effect

Environmental factors may affect fertility. Ron *et al.*(1984) showed that seasonal factors affect pregnancy rates: conception rates during summer were half of those for winter(25% vs 50%). Similar results were also obtained in a large herd in Florida(Badinga *et al.*, 1985). Results from the study of ovarian activity in the post-partum cows by the author(Chapter 1) showed that the reproductive aspects in spring-calving cows was higher than in autumn-calving cows.

High temperature on the day after insemination influenced pregnancy rate with significant reductions occurring when the temperature exceeded 30°C(Gwazdauskas *et al.*, 1981; Badinga *et al.*, 1985).

3.1.7. Milk Production

It has been suggested that nutritional regimes combined with sire selection for milk production to increase milk yields to over 6,000 and even 10,000 kg/cow/lactation have contributed to reduced fertility. Bar-Anan *et al.*(1985) showed that on a within herd basis, the change in daily milk yield during the month of insemination had a significant effect on conception rate. The genetic correlation coefficient between annual yield and conception rate was only 10%, but it was 42% between lactational persistence(a measure of rate of decline in yield) and conception rate. Macmillan(1985a) suggested that the relationships between annual yield, lactational persistence and conception rate indicated that lactational persistence could be regarded as " a marker for adaptability of an animal to lactational stress".

3.2. Male Factors(Sire and Semen Effects)

Male factors include the variation of fertility due to the effect of individual sires and inseminators, semen processing, semen quality and semen batches. The conception rates to individual sires could be increased or reduced by +7% to -6% around the mean(Ron *et al.*, 1984). Semen from 18 sires was classified by Davidson and Farver(1980) into 3 categories; namely low(38.2%), medium(55.7%) and high(66.15) conception rates. Cows inseminated with semen from high conception rate sires had an average calving to conception interval of 85 days, compared with 109 days for the sires in the other groups.

It has been shown that stage of oestrus at insemination has a significant effect on conception rate obtained only by sires of below average fertility. Delaying insemination reduces but does not eliminate between sire variation in

fertility(Macmillan and Watson, 1975a; Macmillan and Curnow, 1977b). The routine use of semen from sires of average or above average fertility can allow single daily insemination times to be used without any loss of fertility(Foote, 1979; Macmillan, 1979; Gwazdauskas *et al.*, 1981).

Inseminator ability is also a " male " factor that may affect conception rate(de Kruif and Brand, 1978; Macmillan, 1985a; Williamson, 1987). The skill of the operator to place the semen and the training of the technician may lead to variations of 5 to 10% in non-return rates(de Kruif and Brand, 1978).

3.3. Management Factors

Management factors influencing conception rate are oestrus detection and nutritional supply.

3.3.1. Oestrus Detection

The detection of oestrus has been identified as the most important factor reducing reproductive efficiency in many dairy herds(Esslemont, 1974). A high detection rate is obtained when the characteristics of oestrous behaviour in a group of cows in the herd is recognised. In seasonal dairy herds with pasture feeding, many oestrous cows tend to congregate together to form sexually active groups(SAGs). Mounting activity is most obvious among these groups of oestrous cows. Tailpainting is extensively used as an aid to detect oestrus in these herds in New Zealand(Macmillan and Curnow, 1977a). The technique was originally developed in Victoria(Williamson, 1980). The wide-spread use of tailpainting in New Zealand dairy herds has been associated with an increase in conception rate of 7%(Macmillan *et al.*, 1984; Macmillan, 1985a) and the reduction in the incidence of short(< 18 days), normal(18-24 days) and long(25-49 days) return intervals(Macmillan and Curnow, 1977a). The greatest reduction in short return intervals has occurred in herds of over 250 cows(14% to 8%) where conception rates have increased from 52% to 66%(Macmillan *et al.*, 1984; Macmillan and Watson, 1971). Macmillan(1975) stated that the incorrect submission of a cow for insemination resulted from either the misinterpretation of behavioural symptoms associated with oestrus or incorrect identification of oestrous animals.

Oestrous cows which are observed to stand when mounted can be expected to have the highest conception rates(Stevenson *et al.*, 1983; Reimers *et al.*, 1985). Those with less obvious symptoms associated with oestrus may have average conception rates which are only 4% to 5% lower(Gwazdauskas *et al.*, 1983).

The average conception rate to first insemination increased from 60.6% in 1969 to 67.7% in 1982(Macmillan *et al.*, 1984). This increase was associated with reductions in all 3 categories of return intervals(short, normal and long returns). The change in herd size effects was mainly due to improved accuracy in the detection of oestrus in larger herds.

3.3.2. Nutritional Supply

Nutritional insufficiency during lactation is associated with loss of body weight and poor body condition, and low milk production. Nutritional problems are frequently seen as low conception rates in a herd with a large number of anoestrous cows(Williamson, 1987). The expression of the nutritional problems depends on when it occurs(before/early or late/after calving). If the feed shortage occurs 70 to 80 days after calving, only a low conception rate may result. If it occurs before or soon after calving it will also reduce the number of cycling animals(Morris, 1976). Specific nutritional deficiency such as phosphorus, copper, cobalt, manganese and iodine have been shown to be associated with infertility in cattle.

OESTRUS DETECTION RATE(DR)

The oestrus detection rate(DR) has been estimated by a variety of calculations. Two simple forms to estimate DR involve the use of selected return-to service intervals or the average inter-service interval(Warren, 1984).

The first form compares the proportion of single cycle return intervals(18-24 days) with double cycle return intervals(36-48 days) as follows:

$$DR = \frac{(\% \text{ 18-24}) - (\% \text{ 36-48})}{(\% \text{ 18-24})} \times 100$$

The second estimation of DR is:

$$DR = \frac{21}{(\text{Mean Inter-service interval})} \times 100$$

The disadvantage of the first form is that it does not take account of embryonic death which may occur from 36 to 48 days after insemination.

The proportion of short return intervals(1-17 days) can also be used to estimate the frequency of errors in detection of oestrus(Macmillan, 1975). The proportion of return intervals of 8 to 12 days which are genuine short oestrous cycle and the frequency of cows being inseminated on consecutive days should not be included(Macmillan and Watson, 1971). These short oestrous cycles are mostly found in young cows in large herds(Macmillan and Shannon, 1973) due to the consequence of environmental stress which probably exerts its effect by inhibiting the formation of a corpus luteum following ovulation(Macmillan and Watson, 1971). Whereas the unadjusted incidence of short return intervals in New Zealand herds has remained at 19% to 20% of all return intervals <50 days, the adjusted incidence has declined from 14% to 7%(Macmillan *et al.*, 1984). Macmillan(1970) showed that short return to first service intervals(less than 17 days) of 18.0 and 16.3% were obtained in data from two areas of New Zealand.

Macmillan(1970) showed that of all return to service intervals of < 50 days, 18.0 and 16.3%(for the Auckland and Taranaki Herd Improvement Associations,

respectively), were short (i.e. < 18 days). Macmillan and Watson (1971) reported that 31.4% of all the short return intervals occurred from 8 to 12 days after first insemination. They also showed that the incidence of these return intervals of 8 to 12 days following first insemination as a proportion of all short return intervals was largest among 3 year old cows (42.6%), compared with 31.5 and 29.1% for 2 year old cows and mature cows, respectively.

MEASUREMENT OF REPRODUCTIVE PERFORMANCE IN SEASONAL DAIRY HERDS

Reproductive efficiency in a seasonal dairy herd can be calculated by relating reproductive performance to Planned Start of Calving (PSC) or to Planned Start of Mating (PSM).

1. CALVING PATTERNS IN DAIRY COW

The most important objectives of the breeding programme for a seasonal dairy herd is to have a concentrated calving pattern relative to pasture growth.

The system used to determine the calving pattern in New Zealand dairy herds as described by Macmillan (1985b) includes:

1. PSC to mid-point (the time from PSC date by which half of the cows in the herd have calved (i.e. the median calving date));
2. Mid-point to 75%, which is the interval over which the next 25% of cows calve;
3. 75% to end of calving with the end of calving being defined as the date from when no cow has calved for a period of at least 7 days; and
4. Total calving spread which is the interval from PSC to end of calving.

Macmillan *et al* (1984) analysed calving records in 35 herds and showed that the distribution of calving dates from PSC was skewed, with the median interval of 18.3 days being 4.7 days less than the interval to mean calving date. PSC to mid-point is now recognised as a major indicator of reproductive efficiency in New Zealand dairy herds (Macmillan, 1985b). Macmillan *et al* (1984) showed that 68% of cows in 1982 calved in the 4 weeks from PSC, compared with 60% in 1972. They also suggested that the use of median intervals and cumulative frequency distributions will be more appropriate when studying reproductive efficiency in a seasonal dairy herd.

The interval from PSC to mid-point will be a reflection of the success of the herd's insemination programme during the first 3 weeks after PSM in the previous season. The interval of 15 days or less should be achieved with a high submission rate and a satisfactory conception rate to first insemination. The interval from mid-point to 75% is influenced by the conception rate and the efficiency of oestrus detection in the second 3 weeks of the breeding programme.

The widespread use of calving induction in New Zealand dairy herds has significantly altered herd calving patterns (Welch and Scott, 1979). The shorter

interval from PSC to mid-point has been reduced by improved oestrus detection with high submission rates and conception rates (Macmillan *et al.*, 1984) and the total spread of calving pattern has been reduced by calving induction.

The other indicator used to compare the reproductive efficiency of the herd is submission rate (SR). The result achieved in most well managed herds is over 90% in 3 and 4 weeks SRs after PSM.

2. CALVING PATTERNS IN HEIFERS

The calving pattern of the first calving 2-year-old heifers is the result of the conception pattern when they were bred as 15 month-old animals. They may be artificially inseminated or naturally mated. Since the average interval from calving to first oestrus in first calving heifers is from 50 to 60 days (9 to 16 days longer than mature cows, Macmillan and Clayton, 1980), in some herds these two year-old animals are mated to calve about 7 to 10 days before the PSC of the main herd. Anoestrus is a problem among 2 year-old heifers (Fielden *et al.*, 1973, Macmillan and Clayton, 1980) because of inadequate growth rates from birth or inadequate feeding post-partum. Macmillan *et al.* (1975) and Macmillan and Watson (1975b) showed that conception rates in these young animals were lower, compared with older animals in the herd.

3. CONCEPTION PATTERNS

Calving pattern is a reflection of the conception pattern during the preceding season breeding programme (Macmillan, 1985a). The conception pattern is in turn a reflection of when cows were inseminated in relation to the PSM date, what proportion of cows conceived to first or subsequent mating, and what was the interval between the matings.

The fertility of cows in seasonal dairy herds in New Zealand is relatively high (Macmillan, 1979). In well managed herds, an average pregnancy rate to first insemination of over 65% can be maintained (Macmillan and Clayton, 1980). The conception rates or non-return rates are 3 to 5% higher than confirmed pregnancy rates (Macmillan *et al.*, 1977a; Macmillan and Taufa, 1983). Macmillan (1970) and Macmillan *et al.* (1977a) showed that the increased incidence of 8 and 10 day returns to first service was associated with normal conception rates to second insemination. The conception rates to second insemination after normal return intervals of 18-24 days were higher than that after short return intervals (1-17 days). These lower CR's were associated with a higher frequency of short return intervals after these second inseminations and may arise through more errors in diagnosis of oestrus (Macmillan *et al.*, 1977a). Macmillan (1970) suggested that the lower conception rates to second insemination are partly due to the re-insemination of a cow not in oestrus after a first insemination at the correct time.

BREEDING MANAGEMENT STATISTICS

The submission rate and conception rate are used to monitor breeding management which is applied to reduce the interval from PSM date to the herd mean conception date (MConD), and maintain an empty rate of no more than 5% (Macmillan, 1985b).

In seasonal dairy herds, the interval from the PSM date to the herd's mean conception date (MConD) and the interval from the PSM date to the herd's mean first insemination date (MFID) are also used to monitor the breeding management of the herd. Macmillan (1985b) showed that in a herd in which all cows were cycling at 18 to 24 day intervals and the DR was 100%, the average interval from PSM date to MFID would be 11.5 days. If the DR was 90%, the interval from PSM to MFID would be increased to 13.5 days, and if it was 80% the interval would be 16.2 days.

The incidence of anoestrus and the level of oestrus detection efficiency influence the interval from PSM to MFID. The PSM to MConD and the interval between MFID and MConD are influenced by the conception rate of the herd.

The conception rate, submission rate and the distribution of return intervals influence the interval from PSM to MConD. Cows which failed to conceive during the breeding programme will be excluded from the calculation of MConD. Macmillan (1985b) used various examples of different values for the incidence of anoestrus, detection rate and pregnancy rate to calculate the interval from PSM to MFID and MConD. He also concluded that improvements in the breeding management would be expected to reduce the interval from PSM to MFID and MConD towards 12 days and 21 days, respectively. For example, the average intervals from PSM to MFID and MConD in the Ruakura No2 herd over a 9 year period from 1968 to 1976 were 17 and 28 days, respectively. In addition, the interval from PSM to MConD in Jersey cows (> 8 years old) was 23 days, compared with 36 days in 2 year old Jerseys (Macmillan and Clayton, 1980). They also showed that the average intervals from PSM to MConD for the cross-bred cows (Friesian x Jersey) was 3 days less than for the Jersey herd mates (23 days vs 26 days).

Macmillan (1983) showed that when 53.2% of cows from 8 herds were injected once with PGF_{2α}, the average interval from PSM to MFID for all cows was 7.2 days with 3 week SR of 91%. In addition, the empty rate among the PGF-treated cows was only 3.9%, compared with 6.9% in untreated herd mates.

INCREASING FERTILITY WITH HORMONAL TREATMENT

Hormonal treatments have been extensively used to stimulate ovarian activity (GnRH or PMSG) or vary the length of the oestrous cycles [using prostaglandin F_{2α} or progesterone implants such as the CIDR device (Controlled Intravaginal Drug Release)]. The use of these hormonal treatment can reduce the interval from calving to conception (Ball, 1984; Ball and Jackson, 1984). Macmillan (1983) used PGF_{2α} in a treated group of cows and showed an average pregnancy rate to first insemination of 68%, compared with 59% in untreated herd mates. This improvement was not related to improved accuracy in oestrus detection (Macmillan *et al.*, 1980), but did require treated cows to be detected in oestrus before insemination because of the variation in the post-treatment interval to oestrus (Macmillan and Henderson, 1984). Macmillan and Day (1987) used CIDR devices combined with Pregnant Mare Serum Gonadotrophin (PMSG) to treat anoestrous cows and showed an increased incidence of oestrus within 7 days of CIDR removal. The fertility of that oestrus was normal.

The injection of gonadotrophin releasing hormone (GnRH) several hours before or at the time of insemination has also been shown to increase pregnancy rates by 7 to 10% (Chauhan *et al.*, 1984). An injection of a GnRH analogue during dioestrus does have several effects on corpus luteum function (Macmillan *et al.*, 1985a,b).

Macmillan *et al* (1986) showed that an average pregnancy rate to first insemination was increased by 11.5% when a single injection of the GnRH analogue "Buserelin" (10 μ g, Hoechst AG) was given 11, 12 or 13 days after first insemination. Injected cows which failed to conceive at first insemination had pregnancy rates to second insemination increased by 15.6%.

MATERIALS AND METHODS

Data used in the study were collected from breeding records of the Ruakura Dairy Herds No.1 and No.2, Ruakura Agricultural Centre, Hamilton, New Zealand. Records in the No1 herd were from 1984 to 1988 and in the No2 herd from 1982 to 1988.

RUAKURA DAIRY HERD NO1

This herd comprises identical twins which have a single seasonally concentrated calving pattern. The identical twin animals were bought in as calves and raised in this herd. There were about 100 cows milked each year. These animals comprised Holstein Friesian, Jersey, Friesian x Jersey and Ayrshire x Friesian or Jersey crossbreds. They were used for experimental comparisons between pairs of twins. Age groups comprised 2, 3 4-8 and 8+ year old cows in the proportion of 38.4, 24.5, 34.2 and 2.9%, respectively. The Planned Start of Calving(PSC) and Planned Start of Mating(PSM) dates in this herd varied between seasons according to the management of the herd.

Most cows were weighed at fortnightly intervals after calving. Each cow was tailpainted, soon after PSC so that PMH could be recorded. Cows in this herd were of varied genetic potential, so that bulls were run with the herd for natural mating. Those which had not been recorded having a PMH before PSM were examined and sometimes treated. Most cows were palpated to confirm pregnancy status from 35 to 45 days after their last mating date.

RUAKURA DAIRY HERD NO2

The Ruakura Dairy Herd No2 is a seasonal calving dairy herd. Among New Zealand dairy farms, it has exceptionally complete individual animal records, and has superior reproductive indices. Cows milked on this farm also have one of the highest herd averages of for Breeding Index(BI) and Production Index(PI).

There were about 200 cows milked each year, and most of them were of the Friesian breed. Jersey cows were introduced and milked in this herd during the 1987/88 season. Age groups comprised 2, 3, 4-8 and 8+ year old cows, in the proportion of 22.4, 19.2, 53.5 and 4.8%, respectively.

The date of the Planned Start of Calving(PSC) was the 15th July, with a 6-week calving period. The mean calving date was around the 31st July to 1st August. Cows in this herd calved with condition scores of about 4.5 to 5.0. Most cows are weighed and condition-scored at fortnightly intervals after calving. The condition score of cows which were induced to calve prematurely was around 5.0 to 6.0.

Planned Start of Mating(PSM) occurred from the 1st to the 4th of October. Each cow had tailpaint applied soon after calving to record pre-mating heat(PMH) dates. Cows not observed in oestrus before PSM were examined per rectum to determine whether they were cycling. The breeding programme lasted for 12 weeks(4th October to 24th December) which was 3 weeks less than in most herds.

The first 6 weeks involved the intensive use of artificial insemination. Bulls with chin-ball harness were run within each herd thereafter. Most cows were pregnancy-diagnosed per rectum about 30-45 days after mating and again in March and before being dried off.

During January or February each year, some cows would be dried off and culled due to poor production, empty or health problems or mastitis. The main herd was dried off from mid April to mid May.

About 20 to 25% of the herd was replaced by home-reared heifers each year.

The DairyMAN programme has been used in this herd for recording and analysing herd data since 1988.

There were trials for pasture grazing management each year, and cows in the herd were divided into small groups and grazed in different paddocks.

DATA ANALYSIS

In the analysis of reproductive data from the two herds, the data were divided into two parts.

Part I.

Data from the Dairy Farm No2 which had been already been stored in a statistical computer programme, were transferred into Panacea Database Program (Pan Livestock, Inc., Reading, United Kingdom). The effect of year, age, body condition scores (BCS) at calving and mating, cow status at calving and breeds (only in the No1 herd) on the different reproductive indices such as intervals from calving to first oestrus, interval from Planned Start of Mating (PSM) to first service, to conception and first service to conception interval, including milkfat yield/cow/day at the start of mating, were analysed by one way analysis of variance, and these reproductive indices were compared between various values of each independent variable. Multiple regression analysis was used to test the relationship between the reproductive indices and independent variables such as age, years, BCS at calving and mating and post-partum intervals.

Because data from the Dairy Farm No1 from 1984 to 1988 were kept in manual records, all data over the period from 1984 to 1988 were manually entered into the Panacea Database Programme. The methods of analyses were similar to those in the No2 herd.

Part II.

Data from both the No1 and No2 herd were converted from the Panacea Database Programme to the DairyMAN Programme (A herd health and management programme, Department of Veterinary Clinical Sciences, Massey University, Palmerston North, New Zealand).

The patterns for each reproductive index across the series of years were analysed and compared.

DEFINITIONS OF SOME TERMS USED IN THE TEXT

Planned Start of Calving(PSC) is the date when the calving period in a seasonal dairy herd is expected to commence and is 282 days after the first day of the preceding seasonal breeding programme.

Planned Start of Mating(PSM) is the date when the mating process in a seasonal dairy herd is planned to commence. Cows are detected in oestrus and mated after the PSM date irrespective of their previous calving date.

Calving Rate is the percentage of eligible cows which calve per unit of time; for example, four or eight weeks after the Planned Start of Calving(PSC).

Premating Heat(PMH) is behavioural oestrus events which are detected and recorded before PSM.

Submission Rate(SR) is the proportion of cows which are submitted for first service by a defined time from PSM date. The most common periods used are either 21 days or 28 days after PSM date.

Conception Rate(CR) is the proportion of services that lead to a successful conception. The pregnancy rate and the non-return rate are used to estimate the conception rate of the herd.

Pregnancy Rate(PR) is the proportion of services that are subsequently confirmed successful by a positive pregnancy diagnosis. The confirmation of pregnancy is usually made by rectal palpation 35 to 42 days after service.

Non Return Rate(NRR) is the proportion of services which have not had a return to service recorded within a defined number of days after the service date. This figure relies on high oestrus detection efficiency after service. The 42 day Non-Return Rate is displayed in the report.

Herd in-calf Rate is the proportion of eligible cows which are in calf by a defined time in relation to PSM date. The four and eight week herd-in-calf rates are displayed on the reproductive performance summary.

Empty Rate is the proportion of cows present during the mating period which are found to be empty at any point in time. This figure will change as breeding progresses.

Induction Rate is the proportion of total cows for which the expected calving dates are beyond the 8-12 week calving period after PSC, and hence are induced to calve prematurely.

+ **PMH cows** are cows which have records of at least one PMH before PSM.

-**PMH cows** are cows which have no record of a PMH before PSM.

Target values are the default values in the DairyMAN programme set for each reproductive index. This value can be adjusted to suit each farm.

CIDR = Control Intravaginal Drug Release device(Carter Holt Harvey, Agricultural Division, Hamilton, New Zealand)

GnRH = Gonadotrophin releasing hormone

PGF_{2α} = Prostaglandin F_{2α}

DESCRIPTION OF RECORDS ANALYSIS PROGRAMME USED

The DairyMAN Programme(a Massey Animal Management programme) is a dairy herd health and management programme which has been developed by the Department of Veterinary Clinical Sciences, Massey University, Palmerston North, New Zealand. This programme is designed to be a reproduction, health and production recording and analysis system for use on either annual or twice yearly seasonal calving dairy herds. It has also been used as a computerised information system to support the activities of veterinarians and farm advisors who are involved in provision of herd health management services to dairy farmers(McKay, 1988).

DairyMAN Data Handling

The type of information that the DairyMAN is able to accept includes farm, herd and individual cow data.

Farm data

This includes the name and address of the enterprise, the herd manager or sharemilker. The farm topography, labour units, management system and number of paddocks are also included, together with the type and analyses of soil and pasture, and type and amounts of fertilizer applied. Farm economics(both income and expenditure to estimate the gross margin of the enterprise) are briefly included.

Herd data

The sources of herd data and events such as drenching and vaccinations are obtained from the farmer, the veterinarian and the local dairy factory. The farmer may enter information as follows; vaccinations, diseases, prevention procedures, herd health problems, drenching, herd group mean body weights or condition scores, trace element supplementation and non-milking herd stock transactions.

The veterinarian may supply results of herd health investigations such as internal parasites and trace element investigations, metabolic profiles, drug sensitivity results and preventive measures.

The dairy factory can supply information on the quantity and quality of milk sold, via production records from the factory sheets.

Cow data

The cow data is based on individual events which are associated with a date of occurrence. The events may relate to reproduction, health and production. Each cow's record should contain information of animal identification, age, breed, genetic worth and within herd phenotypic ranking.

The farmer can supply information relating to cows details, reproductive events, animal health treatment, drying off dates and cow fates.

The veterinarian can supply information on the results of reproductive and health examinations, and treatments used.

The New Zealand Dairy Board can provide information on individual cows for sire progeny testing, the artificial insemination service and the milk recording service. This may include cow ancestry, breeding index, production index, herd test results, both production and individual somatic cell counts.

Details of the information on the data are presented in the thesis by McKay(1988).

DairyMAN Performance Reports

From information that has been entered into the DairyMAN programme, the following reports may be generated.

1. Performance Indicators

The performance indicators cover the areas of reproduction, production and health.

The calculation of performance indicators allows herds to be monitored and compared against standard or target values. Failure to achieve targets can be used as a cue to investigate and define problems. If performance targets are not being met, diagnostic reports should be generated to further investigate the decrease in performance. Once the problem has been defined, changes in management should be assessed economically to optimize production efficiency of the herd.

1.1. Reproductive Performance Indicators

Herd fertility in seasonal calving herds is assessed by the spread of calving pattern of the herd which is produced to relate to pasture growth. The measures used in seasonal herds are an attempt to describe the skewedness of the calving pattern, beginning at the Planned Start of Calving(PSC) date(Macmillan, 1985b). The reproductive indices reported in the summary page are as follows:

1.1.1. Calving Rate

The spread of the calving pattern is measured in the programme by the calving rate which is the percentage of eligible cows calving per unit of time in relation to the PSC

date. Reports for the calving rate produced by the programme are analysed in weekly intervals and only the four and eight week calving rates are presented on the "reproductive performance summary".

The induction of calving is common for up to 10% of each herd in one season. The induction is usually performed in late calving cows in which calving dates are beyond 8 to 12 week after the PSC date. This induction modifies the calving pattern from that predicted from pregnancy data, since it shortens gestation in cows which conceived late in the breeding period.

1.1.2. Predicted Calving Spread next season

The spread of calving pattern in adult cows of one season is a reflection of the conception pattern for the herd in the preceding season (Macmillan, 1985b). The conception pattern is the rate at which cows in the herd become pregnant. The predicted calving spread next season is similar to the calving pattern, the difference is that the predicted calving spread next season of cows culled before the calving period are included in the conception data and are not included in the actual calving pattern.

1.1.3. Herd-in-calf Rate

The conception pattern is measured by the herd-in-calf rate. This is defined as the percentage of eligible cows in calf by defined times in relation to the Planned Start of Mating (PSM) date. The four and eight week herd-in-calf rates are presented on the reproductive performance summary.

1.1.4. Premating Heat (PMH)

Before the period of the breeding programme commences, it is helpful for reproductive management if the dates are recorded when individual cows are detected in oestrus. This allows those which are not detected in oestrus, to be examined and treated before the breeding programme starts. The prevalence of cows which had records of PMH (+ PMH cows) are displayed as well as the first and total service 42 day non-return rates in cows with or without + PMH.

Before the conception pattern can be calculated, the cows should be diagnosed pregnant. This may be determined by two components which produced the conception pattern; the submission rate and the conception rate.

1.1.5. Submission Rate (SR)

The submission rate is defined as the percentage of eligible cows which showed oestrus and were mated for the first time within a specified time interval from the PSM date (Macmillan, 1972). The 3 and 4 week SRs are displayed on the reproductive performance summary.

1.1.6. Conception Rate(CR)

The conception rate is defined as the proportion of services that lead to a successful conception.

The two methods commonly used to estimate conception rate are pregnancy rate and the non-return rate.

The pregnancy rate(PR) is defined as the proportion of services that are subsequently confirmed successful by pregnancy diagnosis. This is usually made by rectal palpation 35 to 42 days after service.

The non-return rate(NRR) is defined as the proportion of services which have not had a return to service recorded within a defined number of days after the date of service. This figure relies on good post-service oestrus detection efficiency in the herd. The time chosen for the calculation of the non-return rate which is presented on the reproductive performance summary is 42 days after the date of service. The NRR reports by the DairyMAN Programme reproductive performance summary is an actual pregnancy rate(PR). A target PR of 59% (which is equal to 62% NRR) is used in the report [NRR are 3 to 5% higher than PR (Macmillan *et al.*, 1977a)].

1.2. Health Performance Indicators

The health status can influence productivity of the herd. The health problems which generally occur in a herd are calving difficulties, post-partum infections, metabolic problems, mastitis and lameness. These conditions reduce production and the animals' resistance to other diseases, cause loss of body condition, and increase death and premature culling.

1.3. Demographics

The performance monitor gives the number of cows in the milking herd, the number of dry, and the number which were sold or which died in each of the time periods displayed.

1.4. Production Summary

The herd production data and the number of cows in milk for each period of time of the herd can be calculated. A summary of the production details such as milk volume, milk fat and protein is shown as total dairy herd production, total per cow per day, and total per hectare per day.

2. Diagnostic Indicators

The diagnostic reports are to examine in detail, factors which are known to contribute to the problem. Each major component of herd performance can be dissected into more detailed sub-items which can be used to explain more precisely why some

aspects of performance are unsatisfactory.

The structure of the diagnostic profiles developed within the DairyMAN programme is based on factors known to influence reproductive performance. The epidemiological technique of cohort comparison is used to analyse the performance of epidemiologically valid sub-groups within the herd.

The cohort groups for the diagnostic reports

1. Age

The animals in the herd are divided into 4 age groups. The four groups are the two year, the three year, the four to eight year and the nine or more year old cows.

2. Calving Date

The cows are divided into two groups; cows which calved more than a chosen number of days before the PSM and those which calved less than the chosen number of days before the PSM.

3. Health Problem Group

The health problem cows are those involving with parturient health problems such as calving problems, parturient infections, metabolic disorders, and inductions and abortions.

4. Sires used for Service

Each of sires used is compared with the rest used in the herd in the non-return rate analysis.

5. Technicians used for Artificial Inseminations

Results for each of the technicians who carried out inseminations in the herd are compared with others who performed inseminations in that herd. This item is only considered in the non-return rate analysis.

6. Time of Mating in the Breeding Programme relative to PSM

The non-return rate during a defined time periods of the breeding programme such as weekly intervals, may be analysed separately.

3. Management Aids

These are lists of cows for which an event is due to occur, a decision to be made, or a cow is due for veterinary examination.

There are three types of management aids produced from the programme; cow histories, management guides, and veterinary visit lists.

The cow histories may be produced at any stage of lactation. The lists produced may be up-to-date lists of cows in the whole herd, which show current reproductive status and full event histories. Selected groups or particular of cows can also be listed.

The management guides used to aid the day-to-day management of the cows in the herd. The guides are calving guides, mating guides, drying off guides, and culling guides.

The calving guide lists are the herd numbers of cows due to calve on each day in the next season.

The mating guide lists are: cows due to cycle, cows calved x days and not yet cycled, and cows calved x days and not yet mated.

The drying off guide is to aid in the selection of cows which are to be dried, off and there is also an option to select cows for drying off therapy with intramammary antibiotics. The programme can be set at different selection degrees based on cases of clinical mastitis, records of individual somatic cell counts, or results from rapid mastitis tests during lactation.

The culling guide lists cover production history, reproductive status and health history for the cows in the list. This information can be used to make culling decisions on the cows.

The veterinary visit lists are lists of individual cows or groups of cows which fail to achieve reproductive performance objectives and are selected for veterinary examination. These cows include; late calving cows, pre-breeding examination cows (cows with discharge or which experienced some abnormalities, cows with no visible oestrus, nymphomania cows, cows which fail to conceive, cows for pregnancy diagnosis, revisit cows and new cows.

The veterinary visit lists of selected cows consist of 3 forms. The first is a simple list giving the cow's herd number for farmer or herdsman to present the appropriate cows for veterinary examination. The second and third lists are designed for the veterinarian as cow-side histories, with spaces to record the examination findings.

RESULTS

THE RUAKURA DAIRY HERD NO1

DAIRYMAN PERFORMANCE ANALYSIS

Results from the analysis reports produced by the DairyMAN Programme in the Dairy Herd No1 over the period from 1984 to 1988 were compared across the series of years.

1. Reproductive Performance Summary

The reproductive performance of cows from the Dairy Herd No1 over the period from 1984 to 1988 are shown in Table 4.1. The four and eight week calving rates were above the target value of 66% in all 5 years. The four week calving rates in 1984 and 1985 were slightly lower than those in the following years. The induced calving rates were highest in 1985, 1986 and 1987.

The 3 and 4 week submission rates(SR) were high in every year from 1984 to 1988. This index shows the high oestrus detection efficiency which was achieved in the herd in association with natural mating.

Since the 42 day NRR in the No1 herd is actual pregnancy rate(PR), the NRRs reports produced by the DairyMAN Programme were changed to PR with a target value of 59%. The first service PR were slightly low in 1985, 1986 and 1987, compared with the rest of the years and the target value. However, the total service PRs were high in every year, except in 1987 in which the index was equal to the target value.

The four week and eight week herd-in-calf rates were well above the target values in every year.

It can be seen from Table 4.1, as measured by the 4 and 8 week calving rates in the years 1985 to 1988 that the reproductive performance of the cows in the No1 herd was high after 1985. In 1985, a high proportion of late calving cows were induced to calve prematurely. In addition, oestrus synchronisation had also been used in this herd in 1985. These techniques produced high 3 and 4 week SRs of the herd in 1985, and they continued thereafter. However, the first service PR in 1985 and in the years thereafter were slightly lower, but the total service PR was within the target range. This means that most cows were pregnant within the desired breeding period after PSM as shown by the high herd-in-calf rates at four and eight weeks after PSM, resulting in high calving rates at four and eight weeks after Planned Start of Calving(PSC) in 1986. The slightly low first service PR in 1985 may result from the low occurrence of cows which showed one or more pre-mating heats(+ PMH cows) in 1985(74%). In addition, this was in part, from the low occurrence of + PMH in the 2 year old cows(66%, Table 4.3). However, the 3 and 4 week SRs of cows in 1985 were clearly above the target values(Table 4.4) due to oestrus synchronisation of the herd. A number of cows(26%) were in anoestrus before the PSM and were

Table 4.1. Summary of reproductive performance of cows in the No1 herd from 1984 to 1988.

Reproductive performance monitor	Years					Target values(%)
	1984	1985	1986	1987	1988	
1. 4 week calving rate(%)	77%	88	98	96	94	66
8 week calving rate(%)	99	97	100	100	96	90
2. Induction rate(%)	1	20	21	15	13	11
3. 3 week submission rate(%)	88	94	98	95	98	90
4 week submission rate(%)	92	99	100	97	100	92
4. First service PR(%)	63	57	56	52	61	59
Total service PR(%)	68	62	64	59	66	59
5. 4 week herd-in-calf rate(%)	71	69	77	69	68	57
8 week herd-in-calf rate(%)	92	98	100	95	92	86
6. 4 week predicted calving rate	76	71	77	70	68	66
8 week predicted calving rate	98	100	100	96	92	90
7. Empty rate(%)	6	2	-	2	-	7

PR= Pregnancy Rate

synchronised, concurrently with the +PMH cows of the herd. These cows consequently were in oestrus and naturally mated within 4 weeks after PSM. There must have been some specific causes such as feed shortage in this herd after calving in 1985, resulting in only 74% of cows being detected in oestrus(+PMH) before PSM. Cows without a PMH have been shown to have lower conception rates than cows which had at least one PMH.

A low first service PR was observed in 1985. Cows which did not conceive at first service showed an adequate conception rate to later services. This is shown by the total service PR, which was higher than the target value(59%), and high herd-in-calf rates at four and eight weeks after PSM. The high herd-in-calf rates in 1985 produced the high calving rates in 1986, although a high induction rate of 21% was used to move calvings forward.

2. Comparison of Herd Sub-Groups for Reproductive indices

2.1. Calving Rate

There were approximately 100 cows milked in this herd. The calving rates at four and eight weeks are summarised in Table 4.2. The calving rates were lowest in 1984 and 1985, compared with those in the following years, but above the target values. This was also found in the 2 year old cows in 1984, 1985 and 1988. The calving rates at four weeks after PSC were also lower in other age groups in 1984.

2.2. Premating Heat(PMH)

The occurrence of pre mating heat(+PMH) and first service 42 day PRs in +PMH and -PMH cows are shown in Table 4.3. There was a high occurrence of +PMH in the summary, and in each age group and the post-partum interval(≥ 40 days) in some years. Therefore, there were only a few cows in the -PMH sub-groups. The occurrence of +PMH was lowest in 1985 and 1987 in the 2 year old, 4-8 year and 8+ year old cows.

The first service PRs in +PMH cows were high in 1984, 1985 and 1988. In contrast, the first service PRs of +PMH cows and -PMH cows in 1986 and 1987 were below the target value of 59%. It seems that nutritional factors during early lactation and during the mating period may have influenced the low occurrence of +PMH and the low first service PR in +PMH and -PMH cows in this herd. The first service PRs in both +PMH and -PMH cows were also found to be low in each age group in 1986 and 1987.

The 2 year old cows with -PMH had the lowest first service PR. Surprisingly, the 3 year old cows had a higher occurrence of +PMH and higher first service PR than other age groups.

Cows which had calved ≥ 40 days at PSM in 1985 and 1987 had low occurrence of +PMH. The first service PR in +PMH cows which had calved ≥ 40 days at PSM was higher than those without PMH. Few cows calved < 40 days at PSM in each year.

Table 4.2. Summary of the 4 and 8 week calving rates of cows in each age group in the No1 herd.

Calving rates	Years					Targets
	1984	1985	1986	1987	1988	
Summary	77,99	88,97	98,100	96,100	94,96	66,90
Age groups						
: 2yr	86,97	69,91	94,100	93,100	84,91	66,90
: 3yr	79,100	94,100	100,100	100,100	100,100	66,90
: 4-8yr	71,100	97,100	100,100	100,100	100,100	66,90
: 8 + yr	40,100	100,100	100,100	-	-	66,90

First and second values in each column represent the 4 and 8 week calving rates, respectively.

Table 4.3. Summary of the occurrence of Premating Heat(PMH) and the first service PR of +PMH and -PMH cows in each age group and in relation to the post-partum intervals(± 40 days at PSM).

Premating Heat	Years					Targets
	1984	1985	1986	1987	1988	
Summary:						
Occurrence of + PMH(%)	91	74	84	76	96	85
First service PR(+ PMH)	65	63	56	54	62	59
First service PR(-PMH)	44	43	53	46	50	59
Age groups: 2yr						
Occurrence of + PMH(%)	94	66	82	76	91	75
First service PR(+ PMH)	59	67	61	53	63	59
First service PR(-PMH)	50	36	33	43	50	59
3yr						
Occurrence of + PMH(%)	83	85	95	75	100	80
First service PR(+ PMH)	75	62	53	56	69	59
First service PR(-PMH)	25	80	100	50	-	59
4-8yr						
Occurrence of + PMH(%)	90	74	81	79	100	90
First service PR(+ PMH)	73	60	54	55	55	59
First service PR(-PMH)	67	33	67	50	-	59
8 + yr						
Occurrence of + PMH(%)	100	63	50	-	-	90
First service PR(+ PMH)	40	60	100	-	-	59
First service PR(-PMH)	-	33	-	-	-	59
Post-partum intervals:						
≥ 40 days at PSM						
Occurrence of + PMH(%)	91	76	83	78	96	85
First service PR(+ PMH)	66	64	56	55	62	59
First service PR(-PMH)	50	46	53	42	50	59
< 40 days at PSM						
Occurrence of + PMH(%)	67	43	100	33	100	85
First service PR(+ PMH)	50	33	50	-	50	59
First service PR(-PMH)	-	25	-	-	-	59

PR = Pregnancy Rate

2.3. Submission Rate(SR)

The 3 and 4 week submission rates after PSM are shown in Table 4.4. The 3 and 4 week SRs were lowest in 1984 in each age group, except the 8+ year old cows. This was different from Table 4.3 which showed that there was a high proportion of +PMH cows before PSM in each age group in 1984. The SRs after 1984 were well above the target values in each age group.

The 3 and 4 week SRs in cows which had calved ≥ 40 days at PSM were within the target range. Only a few cows which had calved < 40 days at PSM contributed to the low 3 week SR in 1985 and 1987, and hence the values have wide confidence intervals.

2.4. First and Second Service Pregnancy Rates(PR)

The first and second services PRs of each age group and post-partum intervals at PSM are shown in Table 4.5. The first service PRs were below the target value of 59% in 1985, 1986 and 1987. The values were found to be low in all age groups, except the 3 year old cows in 1984, 1985 and 1988, and the 4-8 year old cows in 1984, not just in a limited sub-group of the population.

The second service PRs were high, compared with the first service PRs, except in some age groups and in some years(Table 4.5). For example, the 2 year old cows in 1985 and the 3 year old cows in 1987 had second service PRs lower than the first service PRs. The lower first service PRs of cows in each age group in 1985 and 1986 were probably the result of a feed shortage before and during the mating period. The low occurrence of +PMH cows in each age group(except the 3 year old cows) was also found in 1985(Table 4.3).

The first service PRs in 1984 were well above the target values; only the 2 year old cows had slightly low PR. This might be the result of the high calving rate at four and eight weeks after PSC(Table 4.2) and the high proportion of +PMH cows(Table 4.3) in 1984. Cows may have been in good condition before and after calving and this hastened the onset of early ovarian cyclicity.

Cows which had calved ≥ 40 days before PSM had a higher first service PR than those which had calved < 40 days at PSM(Table 4.5). These were found in every year, except in 1987(only a few cows) which had high first service PR in cows which had calved < 40 days at the PSM.

Table 4.4. Summary of 3 and 4 week submission rates(SR) of cows in the No1 herd in each age group, and in relation to the post-partum intervals(± 40 days at PSM) from 1984 to 1988.

Submission rates	Years					Target
	1984	1985	1986	1987	1988	
Summary :						
3 and 4 week SR(%)	88,92	94,99	98,100	95,97	98,100	90,92
Age groups :						
2yr						
3 and 4 week SRs	89,97	94,97	100,100	91,97	98,100	90,92
3yr						
3 and 4 week SRs	83,83	94,100	100,100	100,100	100,100	90,92
4-8yr						
3 and 4 week SRs	87,90	94,100	96,100	96,96	97,100	90,92
8 + yr						
3 and 4 week SRs	100,100	100,100	100,100	-	-	90,92
Post-partum intervals:						
≥ 40 days at PSM						
3 and 4 week SRs	87,91	95,99	98,100	95,97	98,100	90,92
< 40 days at PSM						
3 and 4 week SRs	100,100	86,100	100,100	67,100	100,100	90,92

First and second values in each column represent at 3 and 4 week submission rates after PSM, respectively.

Table 4.5. Summary of the first and second service Pregnancy Rates(PR) of cows in the No1 herd in each age group and in relation to the post-partum intervals(± 40 days at PSM).

1 st and 2 nd service PR(%)	Years					Target
	1984	1985	1986	1987	1988	
Summary :						
1 st and 2 nd service PR(%)	63,79	57,63	56,77	52,60	61,67	59,59
Age groups : 2yr	58,73	56,50	56,93	51,62	62,59	59,59
3yr	65,86	65,92	55,56	54,45	69,89	59,59
4-8yr	72,75	53,63	56,73	54,69	55,63	59,59
8+ yr	40,100	50,25	50,100	-	-	59,59
Post-partum intervals :						
≥ 40 days at PSM	64,67	59,61	56,76	52,62	62,68	59,59
< 40 days at PSM	33,100	29,80	50,100	67,-	50,-	59,59

First and second values in each column represent the first and second service PRs, respectively.

Table 4.6. Summary of the percentages of the total return to service intervals which were short(1-17 days), normal(18-24 days) and long(≥ 25 days) cycles of cows in the No 1 herd in each age group, and in relation to the post-partum intervals(± 40 days at PSM) from 1984 to 1988.

Return interval analysis(%)	1984	1985	1986	1987	1988	Target
Summary :						
Total return interval of						
1-17 days	51	45	53	57	32	15
18-24 days	36	45	24	32	41	69
25-38 days	13	8	17	8	16	8
39-45 days	3	3	5	1	3	7
> 45 days	-	-	-	1	7	2
Ratio of 18-24 days and 39-45 days intervals	14.0	14.0	4.7	24.0	13	> 10.0
Post-partum intervals :						
≥ 40 days at PSM						
Total return interval of						
1-17 days	53	46	55	59	32	15
18-24 days	37	44	24	32	42	69
25-38 days	8	7	18	7	17	8
39-45 days	3	4	5	1	3	7
> 45 days	-	-	-	1	7	2
Ratio of 18-24 days and 39-45 days intervals	14.0	12.5	4.3	23.0	12.5	> 10.0
< 40 days at PSM						
Total return interval of						
1-17 days	-	34	-	-	50	15
18-24 days	-	51	100	50	50	69
25-38 days	100	17	-	50	-	8
39-45 days	-	-	-	-	-	7
> 45 days	-	-	-	-	-	2
Ratio of 18-24 days and 39-45 days intervals	0	0	0	0	0	> 10.0

2.5. Return Interval Analysis

The summary of the return intervals of 1-17 days, 18-24 days, 25-38 days, 39-45 days and >45 days of cows in the No1 herd are shown in Table 4.6. The incidence of return intervals of 1-17 days(32 to 57%) was above the target value of 15%, while the return intervals of 18-24 days were lower than the target value(24-45%, compared with the target value of 69%). The return intervals of 25-38 days were high in 1984, 1986 and 1988.

The return intervals of 39-45 days were below the target maximum value in all 5 years, which is the desirable situation. The high percentages of return intervals of 25-38 days in 1984, 1986 and 1988 would most likely be due to oestrus detection errors associated with the misinterpretation of chin-ball harness marks.

Cows which had calved ≥ 40 days at PSM were also observed to have a high percentage of short return intervals of 1-17 days in all 5 years, ranging from 32 to 59%. The patterns of other return intervals for cows calved ≥ 40 days and all return intervals for cows calved ≤ 40 days were similar to those in the summarised patterns for the whole herd(Table 4.6). Only a small numbers of cows had calved <40 days at PSM, so the figures for this group cannot be taken as representative.

2.6. Herd-in-calf Rate

The summary of four and eight week herd-in-calf rates in each age group and the ± 40 days post-partum intervals at PSM are shown in Table 4.7. It can be seen from Table 4.7 that the four and eight week herd-in-calf rates were well over the target values(57 and 86% for the four and eight week herd-in-calf rates, respectively) from 1984 to 1988. The herd-in-calf rates were highest in 1986(77/100). They were also high in each age group in 1986. The 3 year old cows had high herd-in-calf rates, compared with other age groups.

2.7. Predicted Calving Spread Next Season

This report is similar to the herd-in-calf rate reports. The difference is that the empty cows and those removed from the herd for other reasons, have been removed from the report. The denominator used to predict the calving rates is the total cows predicted to calve rather than the total cows eligible to be in calf as the case in the herd-in-calf report.

The summary of the predicted calving spread next season at four and eight week after PSC in the No1 herd are shown in Table 4.8. The reports of this index were above the target values(66, 90%) in every year from 1984 to 1988. The predicted calving spread next season at four week period after PSC was only below the target of 66% in the 4-8 year old cows in 1985 and 1988.

The patterns at four and eight weeks after PSC in cows which had calved ≥ 40 days at PSM from 1984 to 1988 were similar to those summarised in Table 4.8.

Table 4.7. Summary of the percentages of 4 and 8 week herd-in-calf rates of cows in each age group, and in relation to the post-partum intervals (± 40 days at PSM) in the No1 herd.

Herd-in-calf rates	1984	1985	1986	1987	1988	Target
Summary :						
4 and 8 week herd-in-calf rates	71,92	69,98	77,100	69,95	68,92	57,86
Age groups :						
2yr	61,100	69,100	88,100	67,91	69,91	57,86
3yr	79,83	82,100	70,100	67,96	77,100	57,86
4-8 days	74,87	59,94	71,100	75,100	61,87	57,86
8+ yr	80,100	63,100	99,100	-	-	57,86
Post-partum intervals :						
≥ 40 days at PSM	72,91	70,98	77,100	69,94	68,92	57,86
< 40 days at PSM	33,100	57,100	50,100	67,67	50,100	57,86

First and second values in each column represent the 4 and 8 week herd-in-calf rates, respectively.

Table 4.8. Summary of the percentages of 4 and 8 week predicted calving spread next season of cows in each age group, and in relation to the post-partum intervals (± 40 days at PSM) in the No1 herd from 1984 to 1988.

Predicted calving spread next season	Years					Target
	1984	1985	1986	1987	1988	
Summary:						
Predicted calving spread next season	76,98	71,100	77,100	70,96	68,92	66,90
Age groups:						
2yr	61,100	69,100	88,100	70,95	69,91	66,90
3yr	95,100	82,100	70,100	67,96	77,100	66,90
4-8yr	79,93	63,100	71,100	75,100	61,87	66,90
8 + yr	80,100	63,100	100,100	-	-	-
Post-partum intervals:						
≥ 40 days at PSM:	77,100	72,100	77,100	70,96	68,92	66,90
< 40 days at PSM:	33,100	57,100	50,100	67,100	50,100	66,90

First and second values in each column represent the 4 and 8 week predicted calving spread next season, respectively.

MEASUREMENT OF REPRODUCTIVE EFFICIENCY(the No1 Herd)

1. Interval from Calving to First Oestrus

The mean interval from calving to first oestrus in the No1 herd was 43.1 ± 0.8 days (Table 4.9). There were no significant differences in this interval between each age group (43.9 ± 1.5 , 42.1 ± 1.7 , 43.5 ± 1.3 and 37.4 ± 0.5 days for the 2, 3, 4-8 and 8+ year old cows, respectively). There were also no significant differences in the interval between each age group in each year.

The interval from calving to first oestrus was the longest (52.6 days) in 1987, while cows which calved in 1984 had the shortest interval (35.3 days, $p < 0.005$). The longest intervals were also found in each age group in 1987 (51.3 ± 2.8 , 54.7 ± 4.3 and 53.5 ± 3.6 days for the 2, 3 and 4-8 year old cows, respectively, Table 4.9). There were significant differences in the interval of the 2, 3 and 4-8 year old cows between years from 1984 to 1988.

Cows which calved normally returned to first oestrus earlier than those calved with difficulty or were induced to calve prematurely (41.7 days vs 48.6 days or 48.7 days, respectively, $p < 0.05$).

Crossbred cows (FJ, 3/4 F or J) had a significantly shorter interval to first oestrus than Friesian or Jersey cows (38.5 ± 1.7 days vs 43.5 ± 1.2 days or 46.1 ± 1.6 days, respectively, $p < 0.05$).

Cows which had average milkfat production of < 0.4 kg/cow/day had a significantly shorter interval than those which had average milkfat production of 0.4-0.5 and ≥ 0.6 kg/cow/day (40.6 ± 1.4 vs 44.9 ± 2.2 and 44.4 ± 1.2 days, respectively, $p < 0.05$).

Body condition score at calving and mating had not been recorded in this herd.

2. Interval from Planned Start of Mating (PSM) to First Service

The mean interval from PSM to first oestrus in the No1 herd was 9.6 ± 0.3 days (Table 4.10). There were no differences in the mean intervals between each age group and between years from 1984 to 1988. The mean intervals were 9.4 ± 0.5 , 9.4 ± 0.5 , 10.1 ± 0.5 and 9.7 ± 1.5 days for the 2, 3, 4-8 and 8+ year old cows, respectively.

There was no difference in the average intervals between cows which had calved ≥ 40 days at PSM and < 40 days at PSM (9.7 ± 0.3 days vs 8.2 ± 1.3 days). Cows which were induced to calve prematurely tended to have longer interval from PSM to first service than those which calved normally (11.0 ± 0.8 days vs 9.6 ± 0.3 days, $p = 0.08$).

There were no differences in the mean intervals between breeds of cows (9.5, 9.6 and 9.8 days for crossbred, Friesian and Jersey cows, respectively).

3. Interval from Planned Start of Mating to Conception

The mean interval from PSM to conception was 18.0 ± 0.7 days (Table 4.11). There were no differences in the intervals between each age group (18.5 ± 1.2 , 15.4 ± 1.1 , 19.2 ± 1.2 and 20.0 ± 4.0 days for the 2, 3, 4-8 and 8+ year old cows, respectively) and between years in each age group.

Cows which were induced to calve prematurely had a significantly longer interval from PSM to conception than those which calved normally or which had an assisted calving (24.9 ± 2.1 days vs 17.1 ± 0.7 or 14.1 ± 3.3 days, respectively, $p < 0.0001$).

The intervals from PSM to conception were not different in cows which had at least one PMH before PSM and without PMH (17.8 ± 0.7 days vs 19.7 ± 2.2 days) or in cows which had calved ≥ 40 days at PSM and < 40 days at PSM (17.9 ± 0.7 days vs 21.1 ± 3.5 days).

Breed of cow (crossbred vs Friesian or Jersey cows) did not affect the interval from PSM to conception (17.4 days vs 18.3 days or 18.0 days, respectively).

4. Interval from First Service to Conception

The mean interval from first service to conception was 8.5 ± 0.7 days (Table 4.12). There were no differences in the mean intervals between each age group (9.3 ± 1.2 , 6.3 ± 1.0 , 9.0 ± 1.1 and 10.4 ± 3.7 days for the 2, 3, 4-8 and 8+ year old cows, respectively) and between years.

Induced calving cows had the longest interval (13.6 ± 2.0 days), compared with cows without abnormalities (7.7 ± 0.7 days) or assisted calving cows (6.8 ± 3.4 days, $p < 0.0001$). Cows which had calved < 40 days at PSM tended to have a longer interval (14.3 ± 3.8 days) than those which had calved ≥ 40 days at PSM (8.3 ± 0.7 days, $p = 0.06$).

The average first service conception rates in Friesian, Jersey and crossbred cows were not different (61.2, 60.3 and 62.8%, respectively).

5. Total Return to Service Interval

The total return to service intervals of cows in the No1 herd were divided into short (1-17 days), normal (18-24 days) and long return intervals (≥ 25 days). Short return intervals (1-17 days) were distributed from 2 to 17 days (Figure 4.1), and comprised 46.7% of all return intervals (Table 4.13).

The 39-45 day return intervals were low (2.9%), compared with the figures for 18-24 day return intervals of 36.2% (Table 4.14). The high number of normal return intervals (18-24 days) and the small number of 39-45 day return intervals showed a high oestrus detection efficiency of the herd. The ratio of single to double cycle lengths was between 13 and 24 in four of the five years, and 4.7 in the fifth year, when there were few cycles of 18-24 days (Table 4.6). This supports the overall high oestrus detection efficiency in the herd. The 1-7 day, 8-12 day and 13-17 day short return intervals were 36.5, 31.1 and 32.4%, respectively (Table 4.13) of total short

returns.

The long return to service intervals were also divided into 25-38 day and 39-45 day intervals, and comprised 12.0 and 2.9% of all intervals, respectively(Table 4.14).

6. Milkfat Production at PSM

There was a positive relationship between milkfat/cow/day at PSM and age and with years($r = 0.3$ and 0.7 , respectively, $p < 0.0001$). The mean milkfat/cow/day at PSM for each age group were 0.49, 0.54, 0.71 and 0.36 kg for the 2, 3, 4-8 and 8+ year old cows, respectively($p < 0.0001$). Milkfat production per cow per day at PSM did not affect the intervals from PSM to first service, to conception and first service to conception.

Table 4.9. The mean interval from calving to first oestrus in each age group from 1984 to 1988 in the Ruakura Dairy Farm No1.

Years	Ages				Means
	2yr	3yr	4-8yr	8+ yr	
1984	33.0 ± 2.9 ^{a,b2,o} (36)	36.2 ± 4.2 ^b (24)	39.2 ± 3.1 ^o (31)	24.4 ± 8.4 (5)	35.3 ± 1.9 ^{a,d,d1,d2} (96)
1985	39.3 ± 3.8 ^b (32)	40.7 ± 2.4 ^b (34)	44.9 ± 2.4 ^b (34)	43.5 ± 6.0 (8)	41.8 ± 1.6 ^{a2,a3,d2} (108)
1986	44.4 ± 3.9 ^{b2,d} (34)	33.9 ± 3.5 ^{a,b,o1,f,e} (20)	43.0 ± 2.6 ^{b1,b2,a} (48)	45.5 ± 15.5 (2)	41.8 ± 1.9 ^{a2,d} (104)
1987	51.3 ± 2.8 ^{a,b} (58)	54.7 ± 4.3 ^{a,b} (26)	53.5 ± 3.0 ^{a,b,b1,b2,c} (28)	-	52.6 ± 2.0 ^{a,a1,a2,a3} (110)
1988	46.2 ± 3.2 ^o (41)	44.2 ± 3.4 ^{o1} (26)	39.0 ± 2.4 ^a (38)	-	43.1 ± 1.8 ^{a1,d1} (105)
All years	43.9 ± 1.5 (201)	42.1 ± 1.7 (128)	43.5 ± 1.3 (179)	37.4 ± 5.0 (15)	43.1 ± 0.8 (523)

^a = value in the same superscripts and in the same column ($p < 0.001$).

^{b,o} = values in the same superscripts and in the same column ($p < 0.05$).

^d = value in the same superscripts and in the same column ($p < 0.01$).

^{a,f} = values in the same superscripts and in the same row ($p < 0.05$).

Table 4.10. The mean interval from Planned Start of Mating(PSM) to first service in each age group from 1982 to 1988.

Years	Ages				Means
	2yr	3yr	4-8yr	8+yr	
1984	10.3 ± 1.2 (36)	6.9 ± 1.2 (20)	9.8 ± 1.2 (29)	7.6 ± 2.5 (5)	9.2 ± 0.7 (90)
1985	9.4 ± 1.4 (32)	10.3 ± 1.0 (34)	11.0 ± 1.1 (34)	10.9 ± 2.0 (8)	10.3 ± 0.6 (108)
1986	7.3 ± 0.9 (34)	9.2 ± 1.2 (20)	10.7 ± 0.9 (48)	10.0 ± 7.0 (2)	9.3 ± 0.6 (104)
1987	10.3 ± 1.0 (57)	9.7 ± 1.2 (24)	10.0 ± 1.4 (28)	-	10.1 ± 0.7 (109)
1988	8.8 ± 0.7 (45)	9.1 ± 1.0 (38)	9.9 ± 1.0 (26)	-	9.2 ± 0.5 (109)
Means of all years	9.4 ± 0.5 (204)	9.4 ± 0.5 (124)	10.1 ± 0.5 (177)	9.7 ± 1.5 (15)	9.6 ± 0.3 (520)

Table 4.11. The mean interval from Planned Start of Mating(PSM) to conception of cows in each age group in the No1 herd from 1984 to 1988.

Years	Ages				Means
	2yr	3yr	4-8yr	8+yr	
1984	19.5 ± 2.5 (35)	13.1 ± 2.2 (20)	16.1 ± 2.8 (25)	13.2 ± 5.8 (5)	16.6 ± 1.5 (85)
1985	17.5 ± 2.8 (27)	15.8 ± 2.0 (32)	22.2 ± 2.9 (33)	24.2 ± 5.2 (8)	19.1 ± 1.4 (100)
1986	13.2 ± 1.5 (24)	13.9 ± 2.3 (8)	18.9 ± 2.4 (32)	-	16.1 ± 1.4 (64)
1987	20.8 ± 3.1 (27)	14.9 ± 2.6 (14)	19.4 ± 2.6 (24)	-	19.0 ± 1.7 (65)
1988	19.9 ± 2.8 (43)	17.3 ± 2.4 (26)	18.6 ± 3.1 (32)	-	18.8 ± 1.6 (101)
Means of all years	18.5 ± 1.2 (156)	15.4 ± 1.1 (100)	19.2 ± 1.2 (146)	20.0 ± 4.0 (13)	18.0 ± 0.7 (415)

Table 4.12. The interval from first service to conception in each age group of cows from the No1 herd from 1984 to 1988.

Years	Ages				Means
	2yr	3yr	4-8yr	8 + yr	
1984	9.5 ± 2.3 (35)	6.2 ± 2.0 (20)	5.5 ± 2.4 (25)	5.6 ± 3.5 (5)	7.3 ± 1.3 (85)
1985	9.2 ± 2.7 (27)	5.8 ± 1.8 (32)	11.0 ± 2.6 (33)	13.4 ± 5.5 (8)	9.0 ± 1.3 (100)
1986	5.2 ± 1.5 (24)	5.5 ± 3.1 (8)	8.0 ± 2.4 (32)	-	6.6 ± 1.4 (64)
1987	10.6 ± 2.8 (27)	5.9 ± 2.6 (14)	9.9 ± 2.6 (24)	-	9.3 ± 1.6 (65)
1988	10.8 ± 2.8 (43)	7.4 ± 2.4 (26)	10.2 ± 2.7 (32)	-	9.7 ± 1.6 (101)
Means of all years	9.3 ± 1.2 (156)	6.3 ± 1.0 (100)	9.0 ± 1.1 (146)	10.4 ± 3.7 (13)	8.5 ± 0.7 (415)

Table 4.13. The percentage of cows in each age group in the No1 and No2 herds which had total short return to service intervals of 1-17 days.

Short returns	Age groups				Total(%)
	2yr	3yr	4-8yr	8 + yr	
No1 herd					46.7
1-7 days	34.4 (22)	30.3 (10)	41.3 (19)	-	36.5
8-12 days	32.8 (21)	39.4 (13)	21.7 (10)	-	31.1
13-17 days	32.8 (21)	30.3 (10)	36.9 (17)	-	32.4
No2 herd					15.1
1-7 days	45.8 (11)	28.6 (6)	39.1 (18)	55.5 (5)	40
8-12 days	29.2 (7)	42.8 (9)	34.8 (16)	33.3 (3)	35
13-17 days	25(6)	28.6 (6)	26.1 (12)	11.1 (1)	25

() = number of cows

Table 4.14. The number of cows in each age group in the No1 herd which had various length of return to service intervals

Total return intervals	2yr	3yr	4-8yr	8 + yr	Total cycles	%
1-7 days	22	10	19	3	54	17.5
8-12 days	21	13	10	2	46	14.9
13-17 days	21	10	17	-	48	15.5
18-24 days	45	23	39	5	112	36.2
25-38 days	14	7	16	-	37	12.0
39-45 days	5	-	4	-	9	2.9
46-48 days	1	1	1	-	3	1.0
Total	129	64	106	10	309	

THE RUAKURA DAIRY HERD No2

DAIRYMAN PERFORMANCE ANALYSIS

In order to evaluate the reproductive performance of cows in the Ruakura Dairy Herd No2 over the period from 1982 to 1988, results from the analysis reports produced by the DairyMAN Programme were compared across the series of years.

1. Reproductive Performance Summary

The reproductive performance of cows in the Dairy Herd No2 over the period from 1982 to 1988 is summarised in Table 4.15. There were no differences in the patterns of the four and eight week calving rates, except in 1986, when the four week-calving rate was high(88%), compared with those in the other years. Most cows in each year calved within 8 weeks after PSC. In 1984 and 1985, there was a high induced calving rate(16 and 17%, respectively).

The 3 week and 4 week submission rates were between 88 and 100%, values which were close to the target values of 90 and 92%, respectively.

The first service PRs were high in 1986 and 1987(71% and 64%, respectively), while those in the other years were between 43% to 56%.

The four week herd-in-calf rates were lowest in 1983 and 1985(49 and 50%, respectively), compared with other years. The eight week herd-in-calf rates were also lowest in 1983, 1984 and 1985.

In 1985, the empty rate was high(22%) compared with other years(5% to 14%) and the target value of 7%.

The reproductive performance of cows in the No2 herd was the highest in 1986(Table 4.15). There was a high four week-calving rate with the lowest induced calving and empty rates. The first service PR and the four week herd-in-calf rate were also the highest. In contrast, the reproductive performance of cows was lowest in 1985. The herd in 1985 had a low herd-in-calf rate at four weeks after PSM(50%) and the highest empty rate(22%). The herd also had a high induced calving rate(17%) in 1985, reflecting suboptimal reproductive performance in the previous year.

Table 4.15. Summary of the reproductive performance of cows in the No2 herd reported by the DairyMAN Programme from 1982 to 1988.

Reproductive performance monitor	1982	1983	1984	1985	1986	1987	1988	Target values(%)
1. 4 week calving rate(%)	78	72	74	75	88	73	75	66
8 week calving rate(%)	100	100	97	100	99	100	99	90
2. Induced calving rate(%)	12	11	16	17	6	5	11	11
3. 3 week Submission rate(%)	91	91	88	89	94	94	91	90
4 week Submission rate(%)	96	94	95	95	100	96	96	92
4. First service PR(%)	56	50	55	43	71	64	54	59
Total service PR(%)	66	64	69	68	81	73	68	59
5. 4 week Herd-in-calf rate(%)	59	49	61	50	69	65	61	57
8 week Herd-in-calf rate(%)	84	70	78	67	89	81	83	86
6. 4 week Predicted calving rate(%)	62	57	68	64	73	73	67	66
8 week Predicted calving rate(%)	88	81	88	86	93	92	93	90
7. Empty rate(%)	5	14	12	22	5	11	9	7

PR = Pregnancy Rate

2. Comparison of Herd Sub-groups for Reproductive indices.

2.1. Calving Rate

There were approximately 190 cows/year in the analysis. It is obvious that adult cows and heifers calved over the period from 1982 to 1988 with a concentrated calving pattern, which were above the target values for the first 8 weeks after PSC (Table 4.16). However, a high percentage of prematurely induced calvings were recorded in 1984 and 1985 (16% and 17%, respectively).

The calving rates at four and eight weeks after PSC in 1986 were high (88 and 99%, respectively), compared with other years, ranging from 72 to 75% and 97 to 100%, respectively (Table 4.16). The calving rates at four weeks after PSC in the 3 and 8+ year old cows were slightly lower than those in other age groups in the herd.

2.2. Premating Heat (PMH)

The occurrence of premating heats (+PMH), the first service PR in cows which had records of PMH (+PMH cows) and without PMH (-PMH cows) are shown in Table 4.17. The occurrence of +PMH cows in 1985 was the lowest (61%), compared with 90% in 1986 and intermediate values in the rest of the years. In fact, the occurrence of +PMH in the 2, 3 and 8+ year old cows was low (59, 54 and 50%, respectively), compared with 65% in the 4-8 year old cows. However, the occurrence of +PMH in the 4-8 year old cows in 1985 was also low, compared with those in the other years and the target values. The occurrence of +PMH in the 2 year old cows in 1984 was the highest (90%), compared with the rest of the herd. This resulted from the tightened calving rate at 4 weeks after PSC in this age group, allowing the 2 year old cows to have enough time to return to cycle before PSM. A similar pattern was also observed in this age group in 1986.

The occurrence of +PMH was high in cows which had calved ≥ 40 days at PSM, compared with that in cows which had calved < 40 days at PSM. The pattern of this index in +PMH cows which had calved ≥ 40 days at PSM was also low in 1985, while the highest pattern was observed in 1986. The percentage of +PMH cows which had calved < 40 days at PSM was the lowest in 1984.

The first service PRs in +PMH cows were high, compared with those in -PMH cows. In 1986 and 1987, the values of the first service PRs in +PMH cows were high (76% and 74%, respectively), compared with those in -PMH cows (65% and 71%). The higher percentages were also observed in different age groups (Table 4.17).

However, the first service PR in +PMH cows was not always higher than that in -PMH cows. In 1983, the first service PRs in +PMH cows and -PMH cows averaged 61% and 68%, respectively (Table 4.17). Similar patterns were also observed in each age group and in post-partum interval to PSM in 1983. The first service PR in +PMH cows which had calved < 40 days at PSM was also low in 1987 and 1988, compared with -PMH cows.

Table 4.16. Summary of the calving rates at 4 and 8 weeks after Planned Start of Calving in each age group of cows from the No2 herd from 1982 to 1988.

Calving rates(%)	1982	1983	1984	1985	1986	1987	1988
Summary	78,100	72,100	74,97	75,100	88,99	73,100	75,99
Age groups							
2 year old	88,100	80,100	94,98	95,100	98,100	88,100	80,98
3 year old	63,100	69,100	71,97	69,100	86,100	79,100	81,100
4-8 year old	80,100	72,100	69,97	68,100	81,100	66,100	71,100
8+ year old	79,100	64,100	44,100	80,100	57,100	57,100	50,100

First and second values in each column represent 4 and 8 week calving rates, respectively.

Table 4.17. Summary of the occurrence of Premating Heat(PMH) and the first service Pregnancy Rate(PR) of cows with and without PMH(\pm PMH) in each age group, and in relation to the post-partum interval(\pm 40 days at PSM) from 1982 to 1988.

Premating Heat	Years							Target
	82	83	84	85	86	87	88	
Summary								
Prevalence of +PMH(%)	88	78	77	61	90	82	79	85
1 st service PR(+PMH)	63	61	69	69	76	74	68	59
1 st service PR(-PMH)	50	68	60	58	65	71	49	59
Age groups								
2yr: Prevalence of +PMH	75	73	90	59	90	83	78	75
1 st serv.PR(+PMH)	70	55	65	65	75	83	78	59
1 st serv.PR(-PMH)	40	64	80	75	75	71	40	59
3yr: Prevalence of +PMH	83	77	65	54	86	84	75	80
1 st serv.PR(+PMH)	72	53	80	76	81	72	63	59
1 st serv.PR(-PMH)	33	63	82	61	60	50	44	59
4-8yr: Prevalence of +PMH	95	80	76	65	92	81	79	90
1 st serv.PR(+PMH)	62	63	71	67	74	70	67	59
1 st serv.PR(-PMH)	80	80	46	54	63	79	55	59
8 + yr: Prevalence of +PMH	93	86	67	50	100	71	99	90
1 st serv.PR(+PMH)	31	75	33	80	86	80	-	59
1 st serv.PR(-PMH)	99	-	67	20	-	50	50	59
Post-partum interval								
>40 days at PSM:								
Prevalence of +PMH	91	82	88	61	92	85	85	85
1 st serv.PR(+PMH)	63	61	69	69	76	74	72	59
1 st serv.PR(-PMH)	57	63	67	58	71	65	52	59
<40 days at PSM:								
Prevalence of +PMH	67	52	29	50	57	53	43	85
1 st serv.PR(+PMH)	63	62	70	-	50	67	17	59
1 st serv.PR(-PMH)	38	82	56	100	33	88	44	59

2.3. Submission Rate(SR)

The submission rates at three and four weeks after PSM from 1982 to 1988 were within the target range, only those at three weeks after PSM in 1984 and 1985 were slightly lower than the target values(Table 4.18).

The 3 and 8+ year old cows were observed to have lower SR at three weeks after PSM, particularly in 1982, 1983, 1984 and 1985. After oestrus synchronisation had been used in this herd in 1985, the SRs at three and four weeks after PSM were well above the target values in these age groups. The 2 year old cows were observed to have a slightly lower percentage for the SR in 1983. The 4-8 year old cows had a high SR throughout the period studied.

The SRs at three and four weeks after PSM in cows which had calved ≥ 40 days at PSM(89 to 95% and 95 to 100%, respectively) were within the range of the target values over the period, while most cows had calved < 40 days at PSM had lower SRs(Table 4.18).

2.4. Return Interval Analysis

The summary of the total return to service intervals of cows in this herd over the period from 1982 to 1988 is shown in Table 4.19. The total return to service intervals are divided into short(1-17 days), normal(18-24 days) and long return intervals(≥ 25 days). The long return intervals were also divided into 25-38 days, 39-45 days and more than 45 days. The return interval of 25-38 days was assumed to be associated with either errors in oestrus detection at the first service or to early embryonic death, while the ratio of the return intervals of 18-24 days and 39-45 days is used to assess oestrus detection efficiency in the herd.

The total ratio of 18-24 to 39-45 day intervals in all years except 1986(7.2 to 12) showed a high oestrus detection efficiency in this herd. In 1985 and 1987, the percentage of short return intervals of 1-17 days was high(22%), compared with the target value of 15%. In 1986 the ratio of 18-24 to 39-45 day intervals(2.2, compared with the target value of > 10.0) showed a low oestrus detection efficiency. This indicates that an unusually large number of oestrous cows were not detected when they returned to oestrus at 18-24 days, but were detected at the subsequent return to service interval of 39-45 days.

2.5. First and Second Service Pregnancy Rate

The first and second service PR of cows in each age group and the post-partum interval in this herd are shown in Table 4.20. The pattern of the first service PR of cows in this herd was high in 1986, while the pattern was lowest in 1985. This index in 1985 was also observed to be lower than the target value of 59%. The first service PRs in 1986 were also high in every age group. In contrast to those in 1986, it appeared that the first service PRs in 1985 were also low in every age group. The 2 and 3 year old cows had lower first service PR than in 4-8 year cows. This was also apparent in the period from 1982 to 1985. There must be some specific causes which affected the first service PR in the whole herd.

Cows which had calved ≥ 40 days at PSM had higher first service PR than

those which had calved <40 days at PSM. The patterns of the first service PR in cows which had calved ≥ 40 days at PSM over the period from 1982 to 1988 were similar to those summarised in the whole herd (Table 4.20). Cows which had calved <40 days at PSM had a low first service PR, ranging from 14 to 47%.

2.6. Herd in-calf Rate

The herd in-calf rates at four and eight weeks after PSM of cows in this herd over the period from 1982 to 1988 are summarised in Table 4.21. The herd in-calf rates at four and eight weeks in 1983 and 1985 were the lowest compared with the target value of 57 and 86%, respectively, and the rest of the years. The lower percentages of this index were also observed in each age group in those years.

In 1986, the herd in-calf rates at four and eight weeks after PSM were high (69 and 89%), compared with the rest of the years. These were also found to be high in each age group. The patterns of this index were similar in 1987 and 1988, but slightly lower than in 1986. The patterns of this index were lower in cows which had calved <40 days, compared with those which had calved ≥ 40 days at PSM.

2.7. Predicted Calving Spread Next Season

The predicted calving spread next season at 4 and 8 weeks after PSC in the No2 herd are shown in the Table 4.22. The predicted calving spread at 4 and 8 weeks after PSC were below the target values in 1983. These indices at 4 and 8 weeks were also low in every age group (55 and 79%, 55 and 76%, 58 and 84%, and 57 and 79%, for the 2, 3, 4-8 and 8+ year old cows, respectively).

The summary of these indices were slightly low in 1985. The values at 4 weeks after PSC were high above the target in the 2 and 3 year old cows (70 and 69%, respectively), while the 4-8 year and 8+ year old cows had the values below the target (61 and 44%, respectively). The 8+ year old cows had the lower values than other age groups.

The predicted calving spread next season at 4 and 8 weeks after PSC in cows which had calved ≥ 40 days at PSM from 1984 to 1988 were slightly higher than summarised values in Table 4.22.

Table 4.18. Summary of 3 and 4 week submission rates(SR) of cows in each age group in the No2 herd from 1982 to 1988.

Submission rates	Years						
	1982	1983	1984	1985	1986	1987	1988
Summary:							
3 and 4 week SR	91,96	91,94	88,95	89,95	94,99	94,96	91,96
Age groups:							
2yr	93,98	85,90	94,96	90,92	93,99	98,99	89,99
3yr	71,90	87,92	74,87	87,99	94,99	92,92	94,94
4-8yr	97,98	95,97	90,97	91,96	94,99	94,96	91,94
8 + yr	86,93	86,86	89,99	70,70	99,99	86,86	99,99
Post-partum interval:							
≥40 days at PSM	91,97	93,96	91,96	89,95	94,99	95,96	93,98
<40 days at PSM	92,92	76,80	77,91	50,99	99,99	88,88	82,86

First and second values in each column represent the 3 and 4 weeks SRs, respectively.

Table 4.19. Summary of the percentage of the return intervals which were short(1-17 days), normal(18-24 days) and long(25-38, 39-45 and ≥ 45 days) in cows which had the post-partum intervals(± 40 days at PSM) in the No2 herd from 1982 to 1988.

Return interval	82	83	84	85	86	87	88	Target
Summary:								
Return interval of								
1-17 days	11	6	8	22	8	22	14	15
18-24 days	63	68	69	56	47	61	64	69
25-38 days	14	14	14	12	13	6	9	8
39-45 days	7	6	6	5	22	9	7	7
>45 days	6	6	2	6	10	1	3	2
Ratio of 18-24 and 39-45 days intervals	9.1	10	12	12	2.2	7.2	9.2	> 10
Post-partum interval:								
≥ 40 days								
1-17 days	7	6	5	23	8	24	13	15
18-24 days	69	69	70	56	48	62	68	69
25-38 days	11	16	9	11	12	6	6	8
39-45 days	7	4	5	5	22	8	10	7
>45 days	6	5	2	6	12	0	4	2
Ratio of 18-24 and 39-45 days intervals	10	16	17	11	2.2	7.6	7	> 10
< 40 days								
1-17 days	30		19					
18-24 days	30	67	38	50	50	72		
25-38 days	29		29	50	25			
39-45 days	6	25	10		25	14		
>45 days	6	8	5			14		
Ratio of 18-24 and 39-45 days interval	6	8	5			14		> 10

Table 4.20. Summary of the first and second service Pregnancy Rates(PR) of cows in each age group, and in relation to the post-partum intervals(± 40 days at PSM) in the No2 herd from 1982 to 1988.

Pregnancy Rates	Years						
	1982	1983	1984	1985	1986	1987	1988
Summary:							
1 st &2 nd serv. PR	56,68	50,59	55,70	43,67	71,100	64,73	54,77
Age groups:							
2yr	52,88	40,74	58,69	38,83	68,100	76,78	59,87
3yr	60,83	42,53	52,67	44,79	75,100	63,67	47,81
4-8yr	60,58	55,54	57,78	45,61	69,100	59,72	55,73
8+ yr	36,56	64,67	33,20	40,40	86,100	57,100	50,-
Post-partum interval:							
≥ 40 days at PSM	58,71	51,59	61,70	43,68	72,100	65,71	61,79
< 40 days at PSM	46,50	42,64	31,71	-	43,100	47,83	14,70

First and second values in each column represent the first and second service PRs, respectively.

Table 4.21. Summary of 4 and 8 week Herd-in-calf rates of cows in each age group and in relation to the post-partum intervals(± 40 days at PSM) in the No2 herd from 1982 to 1988.

4 and 8 week Herd-in-calf rates	Years							Target
	1982	1983	1984	1985	1986	1987	1988	
Summary	59,84	49,70	61,78	50,67	69,89	65,81	61,83	57,86
Age groups: 2yr	60,80	45,65	65,83	49,69	75,90	74,80	65,89	57,86
3yr	60,83	46,64	52,65	51,69	67,83	68,84	56,81	57,86
4-8yr	62,86	51,73	64,80	51,64	67,89	61,77	61,81	57,86
8 + yr	36,86	57,79	33,67	40,80	71,100	57,86	50,50	57,86
Post-partum intervals:								
≥ 40 days at PSM	60,87	53,74	68,85	51,68	70,89	68,84	69,86	57,86
<40 days at PSM	50,67	24,40	26,46		43,86	41,53	14,64	57,86

First and second values in each column represent the 4 and 8 week herd in-calf rates, respectively.

Table4.22. Summary of the 4 and 8 week predicted calving spread in the next season of cows in the No2 herd in each age group, and in relation to the post-partum intervals(± 40 days at PSM).

Predicted Calving Spread	1982	1983	1984	1985	1986	1987	1988	Target values
Summary	62,88	57,81	68,88	64,86	73,93	73,92	67,93	66,90
Age groups								
: 2yr	67,89	55,79	70,91	70,100	81,97	82,97	71,94	66,90
: 3yr	64,88	55,76	73,91	69,93	71,88	74,91	65,93	66,90
: 4-8yr	64,89	58,84	69,87	61,81	70,93	70,89	69,91	66,91
: 8 + yr	36,86	57,79	38,75	44,89	71,100	67,100	50,50	66,90
Post-partum intervals								
≥ 40 days at PSM	63,90	59,83	74,92	65,86	74,93	76,91	75,96	66,96
< 40 days at PSM	55,73	35,59	36,64	-	50,100	47,64	22,74	66,90

First and second values in each column represent the 4 and 8 week predicted calving spread next season, respectively.

MEASUREMENT OF REPRODUCTIVE EFFICIENCY(in the No2 herd)

1. Interval from Calving to First Oestrus

The mean interval from calving to first oestrus in the No2 herd over the period from 1982 to 1988 was 43.8 days (Table 4.23). There was a significant difference in the mean interval from calving to first oestrus between each age groups (51.7, 47.8, 39.6 and 37.3 days for the 2, 3, 4-8 and 8+ year old cows, respectively, $p < 0.0001$) of all cows in this herd from 1982 to 1988. The first calving heifers had the longest interval, compared with the 3 year old cows ($p < 0.05$) and the 4-8 year old cows ($p < 0.001$). There was a small negative relationship between the interval from calving to first oestrus and age (the correlation coefficient (r) = -0.22, $p < 0.0001$).

Body condition score (BCS) at calving affected the interval from calving to first oestrus, so that cows which had a high BCS at calving (≥ 4) had a shorter interval than those with a low BCS (≤ 3.5) [40.3 days vs 59.9 days, $p < 0.005$]. This showed that the higher the BCS at calving, the shorter the interval from calving to first oestrus. Younger cows (2 and 3 year olds) which had a BCS at calving of ≤ 3.5 also had the longest interval, compared with the older cows in the herd (68.2 days vs 40.3 days, $p < 0.001$).

Parturient conditions such as retained foetal membranes, assisted calving and induced calving affected the interval. Cows with calving difficulty and those which were assisted to calve had the longest interval (51.7 days), compared with those calved without abnormalities (43.1 days, $p < 0.001$) and induced calving cows (41.2 days, $p < 0.001$). There was a high proportion of first calving heifers (2 year old) which were assisted to calve (50.4%), and this was associated with intervals longer than the older cows. Cows which had been induced to calve prematurely with BCS of ≥ 4.5 had a significantly shorter interval than those with BCS of ≤ 4 (39.0 days vs 54.0 days, $p < 0.005$).

There were significant differences in the interval from calving to first oestrus between age groups ($p < 0.01$, Table 4.23). It can be seen in 1985 that adverse results were obtained in every age group of cows and the 2 year old cows were affected the most having the longest intervals (63.5 days).

There was a negative correlation between the interval, age and BCS at calving ($r = -0.22$ and -0.27 , respectively, $p < 0.0001$). There was also a correlation between age and BCS at calving of cows in this herd ($r = 0.16$, $p < 0.0001$).

Cows which had an average daily milkfat production of ≤ 0.6 kg/cow/day during the mating period had significantly longer intervals (53.2 ± 1.5 days) than cows which had average milkfat production of 0.7-0.9 and ≥ 1.0 kg/cow/day (42.8 ± 0.8 and 39.0 ± 0.9 days, respectively, $p < 0.0001$). About half of the 2 year old cows (50.2%) represented those which had milkfat production of ≤ 0.6 kg/cow/day, while the remaining cows of this age group had milkfat production between 0.7-0.9 kg/cow/day. About 42.2% of the 4-8 year old cows had milkfat production ≥ 1.0 kg/cow/day and 49.8% of these cows had milkfat production of 0.7-0.9 kg/cow/day. The 3 year old cows (76%) had milkfat production of 0.7-0.9 kg/cow/day. The long interval average of 53.2 days in the lowest milkfat production (≤ 0.6 kg/cow/day) involved the 2 year old cows which

Table 4.23. The mean intervals from calving to first oestrus in each age group of cows from the No2 herd from 1982 to 1988.

Years	Age groups				Means
	2yr	3yr	4-8yr	8 + yr	
1982	52.7 ± 4.2 ^{a,o,F} (40)	41.7 ± 3.7 ^{a,b,F} (35)	32.8 ± 1.5 ^{b,E1,E2,G} (99)	32.1 ± 4.4 ^{o,E} (14)	38.6 ± 1.5 ^{E2,G1} (188)
1983	55.4 ± 4.0 ^{a,o,o1} (40)	44.8 ± 3.8 ^{a,E} (38)	38.4 ± 2.0 ^{o,F1} (99)	32.6 ± 4.5 ^{o1} (14)	42.8 ± 1.6 (191)
1984	44.6 ± 2.7 ^{b,E,F} (48)	60.3 ± 4.3 ^{bb1oEE1FF1} (31)	43.1 ± 1.5 ^{E2} (102)	38.0 ± 5.9 ^o (9)	46.1 ± 1.4 ^{E,E2} (190)
1985	63.5 ± 4.1 ^{bcE,E1,E2} (39)	54.6 ± 3.5 ^o (35)	47.2 ± 2.0 ^{b,EF,F1,G} (101)	60.5 ± 9.4 ^E (10)	52.8 ± 1.7 ^{E,E1,G,G1} (189)
1986	46.2 ± 3.4 ^{o,o2,E1} (40)	42.6 ± 3.3 ^{a1,o1,E1} (36)	34.8 ± 1.7 ^{a1,a2,o,E} (95)	22.0 ± 4.2 ^{a2,o1,o2} (7)	38.5 ± 1.4 ^G (178)
1987	53.3 ± 3.6 ^{a,o} (42)	42.5 ± 4.2 ^{a,F1} (36)	38.8 ± 1.9 ^{o,F} (100)	43.0 ± 9.4 (7)	42.9 ± 1.6 (187)
1988	48.1 ± 3.9 ^{a,a1,E2} (46)	49.7 ± 4.1 ^{a2,a3} (36)	41.3 ± 1.7 ^{a,a2,E1} (107)	21.5 ± 10.5 ^{a1,a3} (2)	44.3 ± 1.6 ^{E1} (191)
Means of all years	51.7 ± 1.4 ^{d,d1} (295)	47.8 ± 1.5 ^{a,d2} (253)	39.6 ± 0.7 ^{d1,d2} (703)	37.3 ± 2.8 ^{a,d} (63)	43.8 (1314)

^{a,b,c,d} = Significant levels of values in the same superscripts and in the same rows (a = p < 0.05, b = p < 0.001, c = p < 0.01, d = p < 0.0001).

^{E,F,G} = Significant levels of values in the same superscripts and in the same columns (E = p < 0.001, F = p < 0.05, G = p < 0.0001).

also had the longest interval from calving to first oestrus(Table 4.23).

2. Interval from Planned Start of Mating(PSM) to First Service

The mean interval from PSM to first service of cows in this herd from 1982 to 1988 was 12.1 days(Table 4.24). There were no significant differences in the mean interval among age groups. There were no relationships between the interval and age groups, years and BCS at calving.

There was a significant difference in the mean interval from PSM to first service in cows which had BCS at mating of ≤ 3.5 and BCS of ≥ 4 (13.9 days vs 11.4 days, $p < 0.0001$).

Cows which were induced to calve prematurely had the longest interval, compared with those assisted to calve or calved with or without retained foetal membranes(15.3 days, compared with 12.2, 11.7 or 10.2 days, respectively, $p < 0.005$).

Cows which had records of a Premating Heat(PMH) before PSM(at least once) had a significantly shorter interval than those with no recorded PMH(11.1 days vs 16.0 days, $p < 0.0001$). Cows which had calved ≥ 40 days at PSM had significantly shorter intervals than those which had calved < 40 days at PSM(11.8 days vs 15.6 days, $p < 0.0001$).

Live weight change between calving and mating did not significantly affect the interval.

3. Interval from Planned Start of Mating to Conception

The mean interval from PSM to conception of this herd was 22.3 days(Table 4.25). There were significant differences in the mean interval from PSM to conception between young cows(2 years) and older cows(8+ years)[20.5 days vs 27.9 days, $p < 0.05$].

The interval was the shortest in 1987(18.9 days), compared with the other years($p < 0.05$). BCS at calving did not have any effect on the interval from PSM to conception, while BCS at mating affected the interval. Cows which had BCS at mating of ≥ 4 , had a significantly shorter interval than cows which had BCS at mating of ≤ 3.5 (21.3 ± 0.6 days vs 25.2 ± 1.1 days, $p < 0.005$). Cows which were induced to calve prematurely had a significant longer interval than those assisted to calve, calved with or without retained foetal membranes(31.3 days, compared with 24.0, 21.2 and 18.0 days, respectively, $p < 0.05$).

Cows which had calved ≥ 40 days at PSM had significantly shorter interval than those had calved < 40 days at PSM(21.6 days vs 30.2 days, $p < 0.0005$). Cows which had records of a PMH had a highly significantly shorter interval than those without a PMH recorded before PSM(21.1 days vs 27.2 days, respectively, $p < 0.005$).

Table 4.24. The mean intervals from Planned Start of Mating(PSM) to first service in each age group of cows in the No2 herd from 1982 to 1988.

Years	Ages				Means
	2yr	3yr	4-8yr	8+yr	
1982	12.0 ± 1.9 (40)	13.9 ± 1.8 (35)	9.7 ± 0.6 (99)	13.6 ± 1.9 (14)	11.2 ± 0.6 (188)
1983	12.0 ± 1.9 (40)	10.6 ± 1.6 (38)	10.9 ± 0.9 (99)	12.1 ± 3.4 (14)	11.2 ± 0.7 (191)
1984	13.4 ± 1.4 (48)	19.1 ± 2.9 (31)	13.0 ± 0.7 (102)	12.8 ± 2.4 (9)	14.1 ± 0.7 (190)
1985	11.3 ± 1.4 (39)	11.1 ± 1.1 (39)	12.1 ± 0.8 (101)	20.2 ± 6.5 (10)	12.2 ± 0.7 (189)
1986	11.3 ± 1.0 (40)	10.8 ± 1.1 (36)	11.3 ± 0.6 (95)	11.0 ± 2.2 (7)	11.2 ± 0.5 (178)
1987	9.8 ± 0.8 (42)	13.8 ± 2.4 (38)	11.5 ± 1.0 (100)	13.0 ± 4.5 (7)	11.6 ± 0.7 (187)
1988	13.0 ± 1.1 (46)	13.9 ± 2.0 (36)	12.9 ± 0.8 (107)	11.0 ± 8.0 (191)	13.1 ± 0.6 (191)
Means of all years	11.9 ± 0.5 (295)	13.1 ± 0.7 (253)	11.7 ± 0.3 (703)	13.8 ± 1.5 (63)	12.1 (1314)

Table 4.25. The mean intervals from Planned Start of Mating(PSM) to conception in each age group of cows in the No2 herd from 1982 to 1988.

Years	Ages				Means
	2yr	3yr	4-8yr	8+ yr	
1982	23.5 ± 3.4 (39)	20.9 ± 3.1 (33)	23.5 ± 2.2 (96)	32.6 ± 5.5 (13)	23.7 ± 1.5 (181)
1983	25.9 ± 3.7 (37)	26.4 ± 4.0 (37)	24.2 ± 2.2 (37)	22.3 ± 6.4 (13)	24.9 ± 1.6 (177)
1984	23.6 ± 2.7 (48)	25.1 ± 3.6 (31)	23.3 ± 1.8 (96)	29.5 ± 7.6 (6)	23.9 ± 1.4 (181)
1985	17.5 ± 2.4 (39)	19.6 ± 2.8 (36)	22.5 ± 1.9 (92)	35.6 ± 7.3 (9)	21.5 ± 1.3 (176)
1986	16.9 ± 2.2 (39)	21.9 ± 3.5 (35)	21.8 ± 1.8 (92)	23.0 ± 6.8 (7)	20.8 ± 1.3 (173)
1987	16.4 ± 2.4 (40)	21.1 ± 3.3 (36)	19.0 ± 1.9 (94)	19.0 ± 5.5 (7)	18.9 ± 1.3 (177)
1988	19.3 ± 2.0 (45)	25.4 ± 3.3 (35)	22.7 ± 1.6 (99)	43.5 ± 40 (2)	22.6 ± 1.2 (181)
Means of all years	20.5 ± 1.0 (287)	22.9 ± 1.3 (243)	22.4 ± 0.7 (659)	27.9 ± 2.8 (57)	22.3 (1246)

There was a positive correlation between age and milk fat production (MF/cow/day) at PSM ($r = 0.51$, $p < 0.0001$), indicating that milk fat production (kg/cow/day) at PSM increased when age increased. There were also positive correlations between MF/cow/day at PSM, Production Index and years ($r = 0.29$ and 0.29 , respectively, $p < 0.01$).

4. Interval from First Service to Conception

The mean interval from first service to conception of cows in this herd was 10.6 days (Table 4.26). There were no significant differences in the mean intervals between age groups ($p = 0.12$), although the interval increased with age. The intervals were significantly different between years ($p < 0.05$) being longest in 1982 and 1983.

BCS at calving and mating did not affect the interval from first service to conception. Cows which had calved < 40 days at PSM had a longer interval than cows which had calved ≥ 40 days at PSM (14.1 days vs 11.2 days, $p < 0.05$). Induced calving cows had the longest interval (15.6 ± 2.4 days), compared with assisted calving cows (12.1 ± 1.8 days), cows calved with and without abnormalities (8.0 ± 2.1 or 9.8 ± 0.5 days, $p < 0.005$).

Milk fat/cow/day at PSM was the lowest in the 2 year old cows with the average of 0.69 kg/cow/day, compared with 0.83, 0.95 and 0.91 kg/cow/day for the 3, 4-8 and 8+ year old cows, respectively ($p < 0.0001$). These differences in each age group were also significantly different in each year from 1982 to 1988 ($p < 0.0001$), but not significantly different between years.

5. Total Return to Service Interval

The total return to service intervals of cows in the No2 herd were also divided into short (1-17 days), normal (18-24 days) and long return intervals (≥ 25 days). It can be seen from Figure 4.2 that a high proportion of total return intervals were around 18-22 days. The percentage of short return intervals was 15.1% of all return intervals (Table 4.13). The percentages of 18-24 day and 39-45 day return intervals were 62.9 and 6.9%, respectively. The ratio of single (18-24 days) to double (39-45 days) cycles was 9.0, which indicates that few cows with normal cycle lengths were missed by the oestrus detection methods used in the herd.

The percentages of short return intervals of 1-7 days, 8-12 days and 13-17 days were 40, 35 and 25% of all short return intervals, respectively (Table 4.13). The high percentage of 1-7 day return intervals was due to the high number of 1 day return (consecutive inseminations). As in the No 1 herd, 3 year old cows in the No2 herd also had a high percentage of 8-12 day return intervals (42.8%).

Table 4.26. The mean intervals from first service to conception in each age group of cows in the No2 herd from 1982 to 1988.

Years	Ages				Means
	2yr	3yr	4-8yr	8+yr	
1982	11.6 ± 3.0 (39)	8.1 ± 2.6 (33)	13.9 ± 2.2 (96)	19.0 ± 5.9 (13)	12.7 ± 1.5 (181)
1983	14.5 ± 3.5 (37)	16.2 ± 3.7 (37)	13.5 ± 2.2 (90)	10.5 ± 4.7 (13)	14.1 ± 1.6 (177)
1984	10.2 ± 2.6 (48)	6.0 ± 2.5 (31)	10.7 ± 1.7 (96)	15.0 ± 9.6 (6)	9.9 ± 1.2 (181)
1985	6.2 ± 1.7 (39)	8.7 ± 2.8 (36)	10.7 ± 1.8 (92)	13.1 ± 5.7 (9)	9.4 ± 1.2 (176)
1986	6.8 ± 2.1 (40)	11.2 ± 3.3 (35)	10.4 ± 1.7 (93)	12.0 ± 7.8 (7)	9.8 ± 1.2 (175)
1987	6.3 ± 2.1 (42)	9.2 ± 2.6 (37)	9.9 ± 1.9 (95)	6.0 ± 3.9 (7)	8.8 ± 1.2 (181)
1988	6.3 ± 1.6 (45)	11.3 ± 2.6 (35)	9.6 ± 1.6 (99)	32.5 ± 32 (2)	9.4 ± 1.1 (181)
Means of all years	8.8 ± 0.9 (290)	10.2 ± 1.1 (244)	11.2 ± 0.7 (661)	13.7 ± 2.5 (57)	10.6 (1252)

Table 4.27. The number of cows in each age group in the No2 herd which had various length of return to service intervals of less than 49 days.

Total return intervals	2yr	3yr	4-8yr	8 + yr	Total cycles	%
1-7 days	11	6	18	5	40	6.3
8-12 days	7	9	16	3	35	5.5
13-17 days	6	6	12	1	25	3.9
18-24 days	72	76	234	26	408	63.8
25-38 days	17	12	46	7	81	12.7
39-45 days	6	8	29	2	45	7.0
46-48 days	2	-	3	-	5	0.8

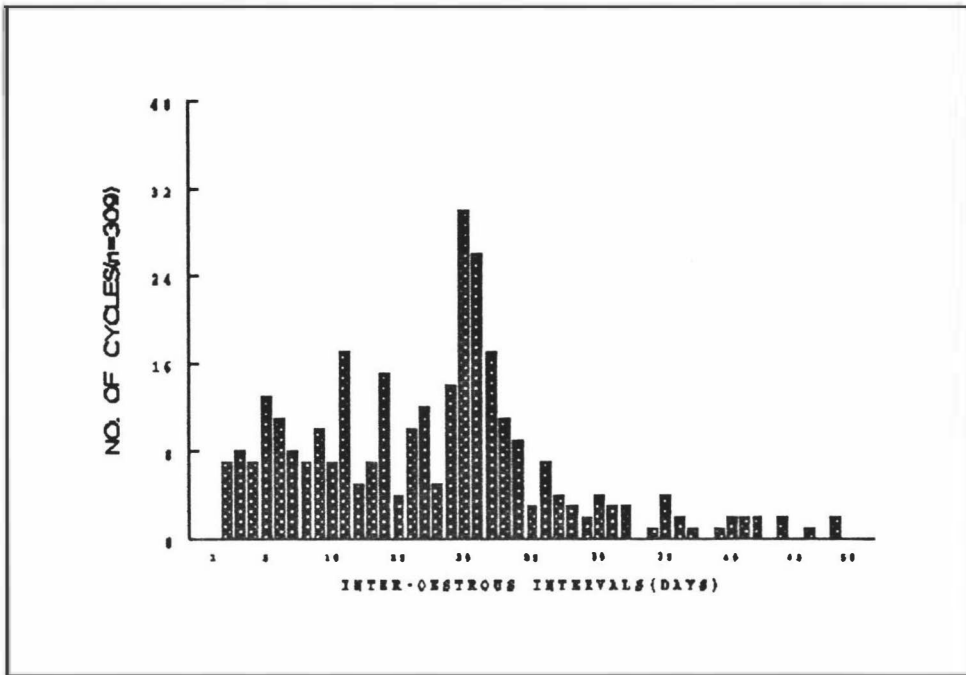


Figure 4.1. The distribution of all return to service intervals of cows in the No1 herd from 1984 to 1988.

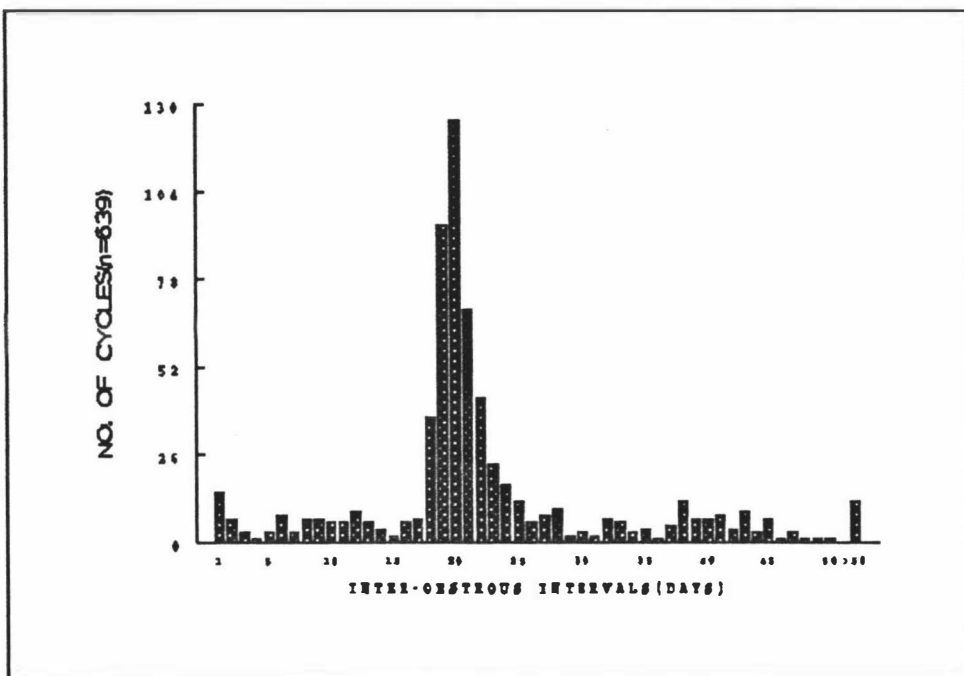


Figure 4.2. The distribution of all return to service intervals of cows in the No2 herd from 1982 to 1988.

DISCUSSION

The DairyMAN Programme has been designed and developed for a reproduction, health and production recording and analysis system for seasonal dairy herds (McKay, 1988). It can analyse herd and farm performance quickly and effectively and monitor the change in the performance in order to identify the target problem. Once the problem has been defined, recommendations for improvements are made (Radostits and Blood, 1985). In the present study, only reproductive data from the Ruakura No1 and No2 herds were analysed.

CALVING RATE

The high percentage of 4 and 8 week calving rates were achieved above the target range in both No1 and No2 herds. Macmillan *et al.* (1984) showed that 68% of cows (excluding 2 year old animals) studied in 1982 calved within 4 weeks from PSC. Calving rates derived using the DairyMAN Programme in this present study were high, ranging from 77 to 98% and 72 to 88% for the No1 and No2 herds, respectively (Table 4.1 and Table 4.15). This might be due to the use of calving induction and of oestrus synchronisation in these herds.

The actual calving rates were quite high when compared with the predicted calving spread from mating records in the previous season (Table 4.1 and Table 4.15). This is probably because the induction of premature parturition could shorten the pregnancies of late calving cows and produce the concentrated calving pattern of cows in these two herds. In the No1 herd, when one of the pair of identical twins was culled for either voluntary or involuntary causes, the other one would no longer be suitable and would be culled.

SUBMISSION RATE

The 3 and 4 week SRs were high overall in both herds, except that the SRs were slightly low in 1984 and 1985 in the No2 herd, and in 1984 in the No1 herd. There are many factors such as inadequate nutrition, age distribution of the herd, parturient diseases and oestrus detection efficiency which affect the SR. The first three factors influence the SR by prolonging the interval from calving to first oestrus (Butler *et al.*, 1981; Butler and Smith, 1989; McGowan, 1981; Fielden *et al.*, 1976; Eddy, 1980; Sandals *et al.*, 1979; Moller and MacDiarmid, 1981a; Macmillan and Clayton, 1980). Cows which had calved ≥ 40 days at PSM are likely to return to cycle before PSM and possibly during the early part of the breeding programme since the interval from calving to first oestrus in New Zealand dairy herds has been reported as 47 to 50 days (Macmillan and Clayton, 1980) and that reported in this thesis by the author is 40.7 days (Chapter 1). Those cows which were influenced by these three mentioned factors, may not return to oestrus during the first 3 and 4 weeks of the breeding programme and hence may reduce the SR below the target range.

The thoroughness and accuracy of detection of oestrus is the most important factor reducing reproductive efficiency in dairy herds (Esslemont and

Ellis, 1974; Morris, 1976; de Kruif and Brand, 1978; Macmillan, 1985b; Jansen *et al.*, 1987). Bulls were used to run with cows in the No1 herd. The bulls' fertility and their ability to detect oestrous cows and mate with them are also important factors influencing the SR and CR (Macmillan and Watson, 1973). Oestrous cows in the No1 herd were commonly mated by bulls before they were detected in oestrus by herdsmen during milking. If the ability of the bulls to detect oestrous cows was 100%, cows which had no record of a PMH before PSM should be in true anoestrus. Therefore, the SR of this herd is influenced by the ability of the bulls to detect and mate oestrous cows, and the ability of herdsmen to detect mated cows during milking.

The slightly low SR in 1984 in the No1 herd (Table 4.4) might be the result of a low oestrus detection rate since the occurrence of +PMH cows in 1984 was well above the target range in each age group and those which had calved ≥ 40 days at PSM (Table 4.3). In contrast, the SRs in 1985 were well above the target range and the occurrence of +PMH cows in 1985 was below the target in every age group, except the 3 year old cows. This means that there would have been some factors which caused the prolonged interval from calving to first oestrus in 1985. Inadequate nutrition before and after calving might be the cause, and could result in a high proportion of anoestrous cows before PSM. Since no treatment of anoestrus had been performed in 1985 or earlier, the increased nutritional supply after calving and during lactation may result in the high SR in 1985. Anoestrous cows might have been in oestrus and then mated at the first oestrus during the first 3 and 4 weeks after PSM.

In the No2 herd, artificial insemination was used, and the accuracy of detecting oestrous cows and presenting them at the right time for insemination was also important. The widespread use of tailpainting in New Zealand dairy herds increased the number of cows detected in oestrus and was associated with high conception rates (Macmillan and Curnow, 1977; Macmillan *et al.*, 1984). The 3 and 8+ year old cows had the lowest SRs, compared with other age groups. This might be due to the late return to first oestrus after calving (Fielden *et al.*, 1976; Macmillan and Clayton, 1980; Moller, 1970).

The occurrence of +PMH cows in the No2 herd was lowest in 1985. This was also found in every age group and those which had calved ≥ 40 days at PSM. The reason might be the same as those mentioned above in the No1 herd, by nutritional insufficiency. In addition, the effect of nutritional insufficiency may result in prolonging the mean interval from calving to first oestrus to 52.8 days in 1985 (Table 4.23). This mean interval was significantly higher than other years studied, and this interval was also high in every age group, compared with other years. The mean interval from calving to first oestrus in the No2 herd over the period from 1982 to 1988 was 43.8 days which was shorter than that reported by Macmillan and Clayton (1980). This might be the result of the increased oestrus detection efficiency. This is by the use of tailpainting as an aid in the detection of oestrus in the herd. The error in identifying and diagnosing oestrous animals in a herd were also reduced (Macmillan and Watson, 1976).

PREGNANCY RATE

The first service PR in the No2 herd was lowest in 1985 and highest in 1986. This low first service PR was also found in every age group and cows

which had calved ≥ 40 days at PSM (Table 4.20). The cause of the low first service PRs in 1985 might be due to inadequate nutrition before and after calving, resulting in a prolonged interval from calving to first oestrus and low fertility (Butler *et al.*, 1981; Morris, 1976; Williamson, 1987). In addition, the mean condition score at mating of cows in 1985 was low (3.75, compared with the mean BCS at calving of 4.57), which was associated with inadequate nutrition during lactation and after calving. Macmillan (1985a) showed that the CRs were affected by condition score at calving which were out of the range of condition score of 4.0 and 6.5. However, cows in this herd had only low first service PR in 1985, but the total service PRs were well above the target range. If nutrition insufficiency was the actual cause of the low first service PR, the conditions of the cows might be corrected by increased feed supply, by either hay or silage supplements. The cows then returned in good condition and should conceive in the subsequent inseminations.

+PMH cows had higher first service PR than -PMH cows (Macmillan and Clayton, 1980). The first service PRs in +PMH cows in both herds were higher than -PMH cows. These were also found in each age group and cows which had calved ≥ 40 days at PSM. It is therefore suggested that target values for PR in +PMH cows should be higher than in -PMH cows.

Some of -PMH cows were late calving cows which were induced to calve prematurely. Moller and MacDiarmid (1981) showed that 16.7% of cows induced to calve prematurely were non-pregnant and the calving rate after first mating was 44.9%. Macmillan *et al.* (1987) also showed that induced cows have lower fertility than normally calving herdmates.

INTERVAL FROM CALVING TO FIRST OESTRUS

The intervals from calving to first oestrus in the No1 and No2 herds in the present study were 43.1 and 43.8 days, respectively. This mean interval in the two herds was slightly shorter than that reported by Macmillan and Clayton (1980). This is due to the increased oestrus detection efficiency of the herd. In addition, the increased use of hormonal treatment such as prostaglandin $F_{2\alpha}$ in post-partum cows (Macmillan *et al.*, 1987) may partly increase oestrus detection efficiency in groups of treated animals after synchronisation, by tailpainting as an aid in detection of oestrus (Macmillan and Curnow, 1977).

Age groups have an influence on the interval from calving to first oestrus. Young cows usually have longer intervals than older cows in the herd (Macmillan and Clayton, 1980). This is associated with the stage of physical maturity, with nutrition and with social stress within the herd (Fielden *et al.*, 1976). In the present study, it is apparent that in the No2 herd that young cows had significantly longer intervals than older cows. These young animals were adversely affected when inadequate nutrition was the problem in the herd in some years (in 1985, Table 4.10).

Breed of cows in the No1 herd had a significant effect on the interval as crossbred cows had a shorter interval than Friesian or Jersey herdmates and Jersey cows had the longest interval. This is in contrast to results reported by Macmillan and Clayton (1980) which showed that Jersey's had shorter intervals than Friesian x Jersey crossbred cows.

Parturient conditions such as retained foetal membranes, assisted calving and induced calving prolonged the interval from calving to first oestrus (Eddy, 1980; Morant, 1984; Reid, 1984; Moller and MacDiarmid, 1981a; Morrow *et al.*, 1966; Sandals *et al.*, 1979). In the present study, cows with calving difficulty which were assisted to calve, and induced calving cows had significantly longer intervals than those calved normally. Cows which were assisted to calve had the longest interval in the No2 herd and the high proportion of the 2 year old cows were observed (50.4%). Assisted calving is associated with uterine infection post-partum and is depended on the degree of injury to the uterus and uterine infection.

Cows which had poor body condition at calving had a longer interval than those with high body condition (McGowan, 1981; Butler *et al.*, 1981; Macmillan, 1985a). Cows which had a high BCS at calving of ≥ 4.0 had a shorter interval than those with BCS of ≤ 3.5 (40.3 days vs 59.9 days, $p < 0.005$).

PSM TO FIRST SERVICE AND TO CONCEPTION

Results reported in the present study in the No2 herd over the period from 1982 to 1988 for the average intervals from PSM to MFID and MConD were 12.1 and 22.3 days, respectively. These intervals were shorter than those reported by Macmillan (1985a) in the same herd over the period from 1968 to 1976 of 17 and 28 days for the intervals from PSM to MFID and MConD, respectively. The shorter intervals of the two indices than those in the previous years mentioned might be due to the increased use of hormonal treatment such as prostaglandin $F_{2\alpha}$, which was shown to reduce the interval from PSM to MFID and high SRs (Macmillan, 1983) and increased incidence of oestrus in non-cycling cows treated within 7 days of CIDR removal, but with normal fertility (Macmillan and Day, 1987). The high SR was also associated with high CR (Macmillan, 1970). The average intervals of the two indices in the No2 herd were close to the ideal targets of 12 and 21 days for the intervals from PSM to MFID and MConD, respectively (Macmillan, 1985a).

In the No1 herd, the average intervals from PSM to MFID and to MConD over the period from 1984 to 1988 in the present study were 9.6 and 18.0 days, respectively. This shows that most cows were mated and conceived within the first 3 and 4 weeks after PSM. The two intervals were even shorter than the ideal targets reported by Macmillan (1985a).

TOTAL RETURN TO SERVICE INTERVAL

The two herds in this study appeared to have return intervals which did not fit the typical pattern seen in commercial herds. The proportion of short cycles is exceptionally high in the No1 herd (Table 4.6) which is naturally mated. However, this did not affect the conception rates of the herd. This might indicate that these short oestrous cycles were genuine and were physiologically fertile, and cows in the herd might conceive after these short cycles. In addition, the high proportion of short return intervals was most likely due to oestrus detection errors, associated with the misinterpretation of chin-ball harness marks. Non-oestrous cows might have been recorded to be mated by bulls, and these cows subsequently might have been mated and conceived to service by bulls when they were in oestrus within 17 days after they were recorded. It is noteworthy that the spread of

intervals across the days does not show any strong pattern.

There was a high percentage of cows in the No2 herd which had short return intervals in 1985 and 1987(22% and 22%, respectively). The short return intervals in the No2 herd were clustered around 8-13 days in 1985, while a substantial proportion of cows were inseminated on consecutive days(Figure 4.2). Macmillan and Watson(1971) showed that return intervals of 8 to 12 days were due to genuine short oestrous cycles, and also Macmillan *et al*/(1984) reported the unadjusted incidence of short return intervals in New Zealand dairy herds was 19 to 20% of all return intervals of <50 days. In the present study, the average incidence of short return to service intervals in the No2 herd was 15.1%. The slightly high level of short return intervals is due to the overmating of cows in this herd during the first 3 weeks after PSM. In fact, cows were presented for insemination when they had tailpaint scores of ≤ 4 . These cows might have been in oestrus within 17 days after insemination with tailpaint scores of ≤ 1 . The high proportion of cows presented for insemination during the first 3 weeks after PSM produced a high SR in all 7 years of the herd, and relatively short interval from PSM to MFID.

In both herds, the ratio of single(18-24 day) to double(39-45 day) cycles was high in most years, supporting the view that oestrus detection was of a high standard. Occasionally, there were periods when there were few cycles 18-24 days, associated with unusually high numbers of short cycles.

In both herds, a high proportion of 3 year old cows had short return intervals of 8-12 days. It was reported that short oestrous cycles were mostly found in young cows in large herds(Macmillan and Shannon, 1973; Macmillan and Watson, 1971).

CONCLUSION

The DairyMAN Programme is capable of analysing not only breeding records, but also production and health data. In the present study, only breeding records and their relationships to other factors were used. In normal use of DairyMAN, results from analyses produced by the programme are reported for a particular farm. These results are used to monitor and compare against standard or target values. A failure to achieve targets can be used as a cue to investigate and define problems. If performance targets are not being met, diagnostic reports should be generated to investigate the decrease in performance. Once the problem has been defined, decisions should be made and changes in management should be assessed economically to optimise production efficiency of the herd.

The analysis of breeding records from the No1 and No2 herds showed that the reproductive performance in the two herds from the start of the period of study until 1988 were well above the target values. The increase of use of hormonal treatments such as prostaglandins and progesterone devices (CIDR) to synchronise oestrus and/or to increase fertility of the herd might be one of the reasons why most reproductive indices improved concomitantly with the increase in submission rates and NRR during the last two decades. In addition, a number of research reports have emphasised the importance of oestrus detection efficiency, resulting in high submission rates and also high conception rates in the herd. The ratio of return to service intervals of 18-24 days and 39-45 days intervals of more than 10.0 in the No1 herd which had bulls run with the herd, showed the high oestrus detection efficiency achieved. This herd also had a high percentage of short return to service intervals, while the No2 herd which used artificial insemination had an optimum percentage of these intervals.

Another management factor which can reduce the reproductive performance of a herd is nutritional status before and after calving. Relatively low reproductive performances were obtained in both herds during seasons in which pasture growth was known to be badly affected by climatic conditions. In the present study, it is obvious that in 1985 when the reproductive performance summary produced by the DairyMAN Programme was lowest in both herds, there were adverse conditions for pasture growth. Inadequate feed supply after calving and during lactation affect firstly the occurrence of +PMH cows before PSM and the prolonged interval from calving to first oestrus in every age group and the post-partum intervals (± 40 days) at PSM, resulting in low submission rate. Secondly, the conception of the herd was also affected. This is shown by the low percentage of first service PR of cows in every age group in the No2 herd in 1985.

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