Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

A STUDY OF SOME FACTORS AFFECTING THE POST-PARTUM OESTROUS INTERVAL IN SUCKLED ANGUS COWS

A thesis presented in partial fulfilment
of the requirements for the degree of
Master of Agricultural Science
in Animal Science at
Massey University

Stephen Todd Morris
1976

ABSTRACT

The objectives of this study were to determine the length of interval from parturition to first oestrus and investigate factors that might influence this interval. Sixty-one records were collected in 1975 from the breeding herd at Massey University's No. 3 sheep farm Tuapaka, another 207 records covering the years 1971 to 1973 and 1975 were obtained from the herd of the Whatawhata Hill Country Research Station, Ministry of Agriculture and Fisheries, Hamilton. The Massey herd consisted of Angus cows aged 4-years and older while the Whatawhata Angus herd consisted of cows aged 2-years and older.

Oestrus was detected at each location by the use of chin-ball mating harnesses attached to entire or vasectomised bulls. Management of the cows followed normal New Zealand hill country practices with the exception that in the Massey herd post-calving treatments were imposed. These treatments were:

(i) On the hill throughout the trial (H)
(ii) Removed from the pad at birth (PB)
(iii) Removed from the pad at 20 days (P20)
(iv) Removed from the pad at 40 days (P40)

After calving, cows and calves were grouped into three blocks according to calf age with treatments nested within blocks.

The analysis consisted of a study of the relationships between the length of the interval from calving to first oestrus and the nutritional treatments, milk production, cow liveweight changes, and calf variables.

The least squares means for post-partum interval to first oestrus were 79.2 days and 74.5 days for the Massey and Whatawhata herds, respectively. The regression of

calving date significantly ($P < 0.01$) influenced the post-partum interval in the Massey herd, but the effects of block, treatment, age of dam and sex of calf were non-significant. For the Whatawhata herd, year of record ($P < 0.001$), age of dam ($P < 0.01$) and the regression of calving date ($P < 0.001$) all influenced the post-partum interval. The sire of calf at foot and sex of calf were non-significant while the regression of cow liveweight change post-calving to mating approached significance ($0.05 < P < 0.10$).

Milk production of the dam for the Massey data was assessed by the weigh-nurse-weigh method. Twenty-day milk production was significantly correlated ($r = 0.25$, for 59 df, $P < 0.05$) with post-partum interval to first oestrus, but 40- and 60-day milk production was not related to this interval. Calf pre-weaning gain was correlated ($r = 0.28$, for 205 df, $P < 0.05$) with this interval in the Whatawhata data.

Post-calving liveweights of the cows were influenced by treatments with the P20 and P40 cows being lighter than the H or PB cows. These differences in cow liveweight did not influence the length of the post-partum interval. This result indicated that pre-calving nutrition was more important than post-calving nutrition.

The calving interval for the Massey herd was 367.6 days compared with 365.1 days for the Whatawhata herd. Calving interval was positively and significantly correlated with post-partum interval to first oestrus ($r = 0.29$, for 49 df, $P < 0.05$, and $r = 0.54$, for 82 df, $P < 0.01$, for the Massey and Whatawhata herds, respectively).

It was concluded from this study that if the interval to first post-partum oestrus in Angus cows was 80 days, then mating should commence 70 days after calving and continue for 42 days. Young heifers experience a longer post-partum anoestrus and consequently should be mated 21 days before the mature herd. Particular attention needs to be given to pre-calving nutrition, while for the first 40-days post-partum cows can be fed to maintain liveweight.

Adoption of these practices should lead to a substantial improvement in the reproductive status of a beef breeding herd.

ACKNOWLEDGEMENTS

The author is specially indebted to his supervisor Mr R.A. Barton, for his invaluable guidance and assistance in all aspects of the study.

Gratitude is also expressed to Professor A.L. Rae for his advice on statistical matters and to Mr A.B. Pleasants who generously gave his instruction and help in the statistical analysis and computer operation.

Thanks are extended to Mr D.R. Patterson who assisted in the collection of most of the Massey University data and made many helpful comments on the behaviour of the animals; the Tuapaka farm staff, Mr W.M. Deighton and Mr A.L. Harwood who handled the day-to-day management of the stock.

Mr G.K. Hight, Director, Whatawhata Hill Country Research Station, generously provided the author with data. Special thanks to Dr T.W. Knight and Mr G.B. Nicoll for assistance in compiling these data, and to the technicians at the Whatawhata Hill Country Research Station for collecting these records.

The staff at the Massey University Computer Unit were particularly helpful, as was Mr C.J. Dodd who assisted with computer programming.

Sincere thanks are due to Mrs Hilde Godenho for the skilful and efficient manner in which she typed the manuscript.

The author would also like to thank his many colleagues and friends who helped make this study more enjoyable than it otherwise might have been.

The Combined Beef Breeders' Research Committee provided financial support to Mr R.A. Barton which included a grant for this study. This contribution is appreciated.

The author held the Helen E. Akers Scholarship and the Henry Marfell Scholarship during the course of this study. This assistance is acknowledged with gratitude.

Grateful appreciation is also expressed to the author's mother for her encouragement throughout this and earlier studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

The basis of a profitable beef cattle breeding enterprise rests largely on the reproductive rate of the cow, i.e., her ability to produce a viable calf or calves within 12-monthly intervals. Low calving percentages mean fewer stock for sale and less culling of low producers and inferior animals.

Selection for traits associated with fertility is generally unsuccessful, since these characters are of low heritability. Hence management practices tend to play a major role in improving reproductive performance.

An early return to service after calving is necessary if a cow is to have a calving interval of 12 months or less, i.e., she must calve, resume oestrous cycles, be mated and conceive within a maximum period of 90 days. Consequently the period between parturition, first oestrus, and conception is of considerable economic significance in the beef-breeding herd. The length of the post-partum anoestrous interval (period during which cows do not show oestrus) and the variables controlling this must be known in order to regulate the breeding season and manage the herd for maximum fertility and production.

Research into dairy cattle reproduction has provided a foundation for research in beef cattle reproduction. However, the basic differences in production goals, management, nutrition and environmental stresses between beef cows and dairy cows, prevents direct incorporation of dairy cattle results into a management system for the beef cow herd. Hill country conditions under which beef cattle production often takes place make record keeping difficult and consequently information on beef cattle reproduction has been accumulated slowly.

The bulk of the information available on this subject consists of data from experimental herds in the United States of America. However, these herds have been managed differently to those in New Zealand. There is virtually no information on beef cattle reproduction relating to the New Zealand situation.

More data are needed on calving intervals and the period between parturition and first oestrus. In view of this the present study was designed to obtain information on these intervals, in a single-suckled Angus beef cow herd run under typical New Zealand hill country conditions. The data used came from two locations: Massey University's No. 3 sheep farm, Tuapaka and Whatawhata Hill Country Research Station, Ministry of Agriculture and Fisheries, Hamilton.

The analysis consisted of a study of the relative effects of various factors controlling the lengths of these post-partum intervals. Factors considered include various nutritional treatments imposed, milk production, cow live-weight changes and calf variables.

CHAPTER TWO

REVIEW OF LITERATURE

A. The Physiological Changes that Occur in the Post-Partum Cow

Parturition is accompanied by a marked alteration in the pituitary-ovarian relationship. The reproductive system undergoes great changes from the time of pregnancy termination to a condition capable of initiating and maintaining a new pregnancy. In mares, there is an oestrous cycle which may be fertile within one to three weeks following parturition. However, parturition in the cow, ewe and goat is not followed by resumption of oestrous cycles (Hafez, 1974) as soon as is the case for the mare.

Immediately following calving a cow's ovaries remain quiescent, containing only the corpus luteum of pregnancy. While the uterus is involuting, the corpus luteum from the previous pregnancy is regressing and ovarian follicular growth is initiated. Follicular growth is usually limited at the time of parturition and increases until ovulation occurs and oestrous cycles are resumed.

The time period required after calving for re-adjustment by individuals is variable and appears to be influenced by a variety of environmental and genetic factors. The literature on changes in the post-partum cow will be reviewed in three sections: involution of the uterus; initiation of cycle activity; and the relationship of these to subsequent fertility.

1. Involution of the uterus

Following expulsion of the foetus and placenta, the return of the uterus to its normal non-pregnant size is termed uterine involution. Rasbech (1950) has indicated that uterine involution has two components. One is the decrease in size due to muscular contractions and the other is the regressive tissue changes that occur following parturition. This means that neither gross size nor histologic criteria are completely reliable indicators of the process of involution. Research workers studying involution of the uterus do so either by rectal palpation of cows from the time of calving, or they may make histological studies on reproductive tracts from cows slaughtered at predetermined intervals from calving.

Involutionary processes in the genital tract commence immediately after calving. Gier and Marion (1968) studied changes in the uteri of 57 clinically normal post-partum dairy cows to determine at what stage the uterus can be considered to have returned to "normal". They state that in the cow immediately after parturition, the uterus is a large flabby sac, nearly a metre long and weighing 9 kg.

Drastic reduction in size and re-organisation of tissues is necessary before another pregnancy can be maintained. Gier and Marion (1968) indicated that these changes may be considered as three overlapping processes: reduction in size; loss of tissue; and repair of tissue.

During the first few days after parturition, there was a rapid decrease in the dimensions of the post-gravid horn due to vasoconstriction and muscular constriction. The length of the post-gravid horn was reduced to a half of the parturition size at 15 days and to a third at 30 days. Fifty days after parturition the normal involution processes were complete. The weight of the average uterus decreased from 9.0 kg at parturition to 1.0 kg at 30 days and 0.75 kg at 50 days. The carnuncles in the gravid horn at parturition averaged 70 mm in length, 35 mm in width, and 25 mm in height. Each carnuncle consisted of a crumpled mass of septums and blood vessels. Five days after parturition, necrosis, due to vasoconstriction resulted in complete septal disorganisation. At 12 days the carnuncular system had sloughed, leaving a raw surface with protruding remnants of blood vessels. Under normal conditions, the carnuncular surface was covered again by epithelium at 25 days after parturition. Shrinkage of the vascular system and muscular contraction continued to reduce the size of the post-gravid uterus until it reached near pre-gravid size within 40 to 50 days after parturition (Gier and Marion, 1968).

Morrow et al. (1966) obtained data by examining 204 dairy cows per rectum twice weekly. They concluded, like Gier and Marion, that the size of uterus decreased slowly during the first 4 to 9 days post-partum. From 10 to 14 days post-partum there was a marked decrease in uterine size. Involution was associated with uterine lochial discharge. The involuting uterus was approaching its former non-pregnant size at day 25.

Riesen (1968), weighing uteri from 75 primiparous cows, found that the uterine weight of cattle slaughtered 10 days post-partum was one third of that found in cows slaughtered immediately after parturition. Twenty days after parturition the uterine weight was only one-ninth. After 30 days post-partum, few changes were observed in the uterus. Tennant et al. (1967) observed from 2,388 rectal examinations that decreases in uterine volume occurred rapidly between 10 and 30 days with only minor reductions thereafter. Similar results came from the study of Wagner and Hansel (1969). They observed that the uterine mucosal epithelium was re-established in most cows within 30 days post-partum.

It is probable that the majority of involution changes have occurred before day 30 post-partum, but, there is no doubt other changes may continue to occur after this period. This is probably why Buch et al. (1955) reported a period of 50 days for the involution process to be completed. Gier and Marion (1968) stated that histological involution had occurred by 25 days post-partum although shrinkage of the vascular system and muscular contractions caused further reductions in size until 40 to 50 days post-partum.

An integral part of the involution process is the uterine contractions which increase to one contraction every three minutes during the first few days post-partum. During the next three or four days they gradually diminish to one every 10 to 12 minutes. These contractions cause shortening of the elongated uterine muscle cells (Hafez, 1974). Another integral part is the uterine discharge which normally occurs during the post-partum period. This is composed of mucus, blood, shreds of foetal membranes, and carnuncular tissue. For the first two or three days this discharge is blood stained; it then becomes paler in colour; then between the seventh and fourteenth day it is mixed with an increased quantity of blood due to haemorrhage from carnuncular tissue sloughing (Hafez, 1974). Wagner and Hansel (1969) report that the surface of the bovine carnuncular, which is devoid of epithelium immediately after parturition begins to regenerate within 12- to 14-days post-partum by proliferation from surrounding tissue and is normally completely re-established within 30-days post-partum.

While the uterus is involuting, the size of the cervix is gradually decreasing, as assessed by rectal palpation. Morrow et al. (1966) observed that these changes to the cervix are largely completed at day 30. Moller (1970b) concluded that changes in the diameter of the uterine horns can be observed for some time after maximum reduction in the diameter of the cervix and they probably bear a closer relationship with the involutionary process than do cervical changes.

The involution of the uterus and cervix can be detected by rectal palpation. The entire uterus is definable by rectal palpation within 8 to 10 days post-partum according to Rasbeck (1950). He reported that the complete uterus can be palpated at this stage, its surface is smooth and soft with fluctuations frequently noticeable in the post-gravid horn, and the carnuncles detectable as hazel-nut shaped processes. The cervix has become hard. Later, i.e., 10- to 18-days post-partum, the uterus is a soft plastic body.

The cervix continues to diminish in size to a diameter similar to that of the post-gravid uterine horn. During the final stages, 18 to 25 days post-partum, uterine tone increases and the post-gravid horn becomes very similar to the non-gravid horn. Hafez (1974) indicated that the non-gravid horn regressed almost completely whereas the pregnant horn (post-gravid) and cervix remained larger than before even after involution was completed. This is supported by Wagner and Hansel (1969) who found that at day 30 the non-gravid horn was approximately 1 cm smaller in diameter and weighed 100 g less than the gravid horn. In his review, Moller (1970a) came to the same conclusion; i.e., the post-gravid uterus rarely returned to its pre-gravid size.

Because of the complexity of the process of involution, a precise definition embracing uterine, cervical and vaginal changes is not feasible. Perhaps Buch et al. (1955) proposed the best set of criteria to determine when involution was completed. These were:

(i) Return of uterus to a normal location in the pelvic or near pelvic region

(ii) Normal and approximately equal size of the uterine horns with little further reduction in their size

(iii) Attainment of the normal uterine tone and consistency

It is clear that the aim of these various processes is to prepare the reproductive tract so that conception is again possible.

2. Initiation of cyclic activity

Naturally, the objective mentioned above can be achieved only if a normal ovum is released at ovulation in association with overt symptoms of oestrus; this being the initiation of post-parturient ovarian activity. It is reasonable to assume that for oestrus to occur after parturition, the pattern of synthesis and release of pituitary gonadotrophins that typifies a normal breeding season must be resumed. Hormonial imbalances established to support pregnancy and its subsequent termination are gradually re-adjusted after calving to re-establish normal oestrous cycles. Most research workers seem to agree that follicular growth and ovulation occur sooner after parturition than is commonly supposed. It must be remembered that the majority of these workers have used dairy cows as experimental animals and these are more often than not being milked, and hence do not have a calf at foot, like the beef cow.

Re-establishment of oestrous activity following parturition is preceded by resumption of follicular development. The expression of oestrus may follow quickly or there may be a period of follicular atresia, or even one or more ovulations, before there is normal oestrus. The cow at the time of parturition shows as little follicular development in the ovaries as at any other time in her adult life (Casida et al., 1968). Follicular size at this time is minimal, (Labhsetwar et al., 1964). There is a decrease in follicular size during the course of pregnancy, which presumably is due to inhibition of anterior pituitary gonadotrophin hormone secretion by high levels of oestrogen during the latter part of pregnancy. After pregnancy the development of follicles to approximately mature size was noted at 21-days post-partum by Labhsetwar et al. (1964), and Saiduddin et al. (1968) showed that there was an increased follicular fluid weight as early as 10-days post-partum.

Morrow et al. (1966) could detect ovarian follicles within 5 to 7 days post-partum with first ovulation occurring at 15 days. Other workers found that follicles large enough to mature and ovulate were present 1 to 2 weeks post-partum in lactating dairy cows (Wagner and Oxenreider, 1971; Wagner and Hansel, 1969). Suckling tended to increase the post-partum interval to the occurrence of a follicle greater than 10 mm diameter (Wagner and Oxenreider, 1971). The interval was 16 days for suckled dairy cows, 9 days for non-lactating and 13 days for milked dairy cows. However, Saiduddin et al. (1968) found no differences in follicular development between suckled and non-suckled animals at 10-, 20- and 30-days post-partum.

Hafez (1974) suggested that the post-partum anoestrus may be due to inadequate pituitary gonadotrophic release and low ovarian sensitivity. The pituitary lutenising hormone (L.H.) activity is low at calving and increases throughout anoestrus until ovulation occurs and a cyclic pattern is re-established. Follicle stimulating hormone (F.S.H.) activity in the pituitary gland appears to be inverse to this, suggesting that this hormone is being released, causing increased follicular development until L.H. is released and oestrus and ovulation occur, ending anoestrus. This theory is backed by the work of Labhsetwar et al. (1964) in which it was found that a decline in pituitary levels of F.S.H. occurred between parturition and 21 days later. Saiduddin et al. (1968) noted a decrease by 10 days with a further decrease by 20 days while Riesen et al. (1968) and Foote (1971) suggested that there is a continual gradual release of F.S.H. to stimulate ovarian follicular development in preparation for ovulation. Wagner and Oxenreider (1971) also observed the pituitary level of F.S.H. hormone to be at a peak at parturition declining over the first 20 or so days post-partum and L.H. levels gradually rose after parturition (Wagner and Oxenreider, 1971; Riesen et al., 1968; Labhsetwar et al., 1964; and Saiduddin et al., 1968). Arije et al. (1974) studied the levels of various hormones in blood, of three multiparous beef cows from 3- to 4-weeks post-partum. L.H. levels were low pre-partum, with periodic increases after 2 weeks post-partum until oestrus, when a peak occurred some 27 hours before ovulation. The level then declined until a peak at the subsequent oestrus. These results can be interpreted as a pituitary accumulation of L.H. preparatory for ovulation.

First ovulation occurred more frequently on the ovary opposite the previously gravid uterine horn, (Britt et al., 1974; Morrow, 1969). This tendency decreased as the interval to ovulation increased. Similarly Marion and Gier (1968) noted that 90% of first ovulations before 15 days after parturition occurred from the ovary opposite the previously gravid horn, while 60% of the ovulations between 15 and 20 days occurred in the ovary opposite the gravid horn. Subsequent frequency of first ovulation from each ovary was normal. There is a suggestion, (Menge et al., 1962), that there is a relationship between the length of the interval from parturition to first oestrus and the length of the first post-partum oestrous cycle. Thus cows exhibiting oestrus early after calving had a higher frequency of short cycles and cows exhibiting oestrus later had a higher percentage of long cycles among the 229 Friesian dairy cows in their investigation.

Numerous studies have indicated that the interval from parturition to first oestrus was longer than the interval from parturition to ovulation. This is due to "silent oestrus" (quiet ovulation) or the occurrence of ovulation without the overt symptoms of oestrus. The first post-partum ovulation is not always accompanied by oestrus, although the incidence of quiet ovulations decreases as oestrous detection is improved. The occurrence of ovulation without oestrus as one form of early post-partum ovarian activity has been recognised in a number of studies. Saiduddin et al. (1968) found first ovulation was not preceded immediately by oestrus in 46.5% of calving intervals studied. Morrow et al. (1966, 1969b) studied occurrence of silent or unobserved oestrus and ovulation and noted it decreased in frequency with each succeeding oestrous cycle. The 79.0% frequency of silent oestrus at first oestrus decreased to 55.0% at the second oestrous period and was further decreased to 35.0% at the third oestrous period. Furthermore, Whitmore et al. (1974) noted that of 386 first ovulations studied in dairy cows, 165 or 43% occurred without detected oestrus. These workers also noted that cows on a high plane of nutrition compared with those on a low plane, showed a higher incidence of quiet ovulations, namely, 49% and 36% respectively. Similar results were reported by Saiduddin et al. (1967b) where it was observed that oestrus was not detected at first ovulation in 33% of cows fed a medium level of concentrates during the calving interval while of those fed a high level 49% did not show oestrus at first ovulation.

Graves et al. (1968) found a difference between suckled and non-suckled beef cows in the incidence of quiet ovulations. In the non-suckled group, 42.4% of the first ovulations were quiet while in the suckled group, 70.6% of the first ovulations were quiet. There was also a difference at the second ovulation, suckled cows showing 50% quiet ovulation, whereas, non-suckled cows showed 26.1% as quiet ovulations.

Early workers, Casida and Wisnicky (1950), estimated that 68% of cows showed at least one quiet ovulation without manifest oestrus before the first oestrus. In a most comprehensive study by Mylrea (1962) involving a total of 870 post-partum heat periods of Australian Illawarra Milking Shorthorn cows, it was shown that quiet ovulations were highest at the first post-calving ovulation (46.9%), were progressively lower for the second and third ovulations and then settled at an incidence of 20% for the fourth and subsequent ovulations. In terms of cows, 53.6% had no silent ovulations before first detected heat, 28.1% experienced one silent ovulation, 11.7% had two, and 6.6% had three or more silent ovulations before first observed heat. Other reports quote levels of silent heats of 18.6% (Trimberger and Fincher, 1956), 23.7% from 3,076 ovulations, (Labhsetwar et al., 1964) and 62% of first ovulations being silent (Menge et al., 1962).

Two possible explanations of quiet ovulations are that normal signs of heat occur, but are not observed; and/or signs of heat are weak or of short duration. The first explanation is classed as a management factor and involves variations in the efficiency of the observer in detecting heat. This could account for the wide ranges in observations reported in the literature. The second explanation is more of a biological nature and it may or may not play a role in oestrus once normal oestrous cycles are established. In this connection, it must be remembered that in most beef herds, cows at all stages from late pregnancy through to having calves at foot are run together. Mylrea (1962) has looked at the effect of silent heats on the length of the post-partum anoestrous period. In this study, the portion of cows which had not shown heat at 60-days post-calving was 25.5%, while at 90 days it was 6.6%, yet the proportions which had not ovulated were only 7.1% and 1.5%, respectively. Mylrea concluded that the occurrence of a longer post-partum anoestrous period is more likely to be indicative of quiet ovulations than of ovarian inactivity.

It may be that these so-called quiet ovulations are just a matter of failing to detect heat, there being perhaps, no hard and fast line between an expressed oestrus and a sub-oestrus grading into a completely quiet oestrus. What the actual percentage of quiet oestrus would be very difficult to determine as its determination is related to the checking procedure employed.

One unusual phenomena is the expression of oestrus during pregnancy. Mylrea (1962) found that 4 cows from 198 (2.0%) had exhibited signs of oestrus during pregnancy. These were at 24-, 31-, 50- and 130- days post-conception, respectively. El Sheikh and El Fouly (1964) studied 1,231 pregnancies in Friesian cows and found 32.7% of the cows exhibited post-conception oestrus. Most occurred within 70 days of conception (90%) with the average interval to oestrus being 33.9 days after conception. If this phenomenon is important in beef cows, then it surely would influence heat detection programmes where first heat is actually occurring during the breeding season.

Periparturient disease has a marked effect on post-partum reproductive activity in the cow. Diseases such as dystocia, retained placenta, milk fever and ketosis all tend to prolong involution. Multiple births (not a disease in this sense, but associated with calving problems) fall into a similar category. Buch et al. (1955), Gier and Marion

(1968), and Marion et al. (1968) found in representative numbers of animals that these conditions will delay involution by 5 to 8 days. Gier and Marion (1968) put forward the hypothesis that such delays are due to a decrease in uterine motility immediately after parturition thus inhibiting the normally rapid regression of the uterus brought about by frequent muscular contractions of the myometrium in the initial 24- hours post-partum. Morrow et al. (1966, 1969b) found the mean interval to first ovulation was 15.0 days in normal calving cows and 34.4 for abnormally calving cows. Cows with periparturient diseases tend to have longer calving intervals, for example, 22 days longer in one study of 50 dairy cows over 123 lactations (Morrow, 1971).

3. Relation to subsequent fertility

Uterine involution in the cow involves extensive sloughing of carnuncular tissue and expulsion through the vagina. This provides a most unfavourable milieu for spermatozoa or for fertilised ova during the first 2 to 3 weeks post-partum. Buch et al. (1955) postulated that involution of the uterus may be necessary for a cow to conceive readily following parturition. Trimberger (1956) disagreed with this as his research on conception rates from service at various intervals after parturition, showed that very frequently a cow will conceive and carry to term even though the uterus is not involuted. Furthermore, Perkins and Kidder (1963) collected data on 255 service periods of Hereford and Angus cows and indicated that conception rate was not affected by the involutionary state of the uterus at the time of mating. The average number of days from first mating to conception being 31.0 days and 35.6 days for non-involuted and involuted groups, respectively. They also found that the conception rate of cows not conceiving when mated prior to involution of the uterus was not impaired at second mating. Thus it would appear that length of the interval from parturition to breeding may be of greater importance in achieving satisfactory conception rates than is the involutionary state of the uterus. This theory is supported by Menge et al. (1962) who stated that the process of uterine involution appears to be largely independent of ovarian activity as it was not significantly associated with the length of the interval to first oestrus.

Casida et al. (1968) also questions the necessity for the uterus to be completely involuted for conception to occur. An estimate from these workers on the proportion of cows at given post-partum intervals which had shown a heat period and also had involuted were: 30 days, 6%; 45 days, 44%; 60 days, 75%; 75 days, 87%; 90 days, 96%; 105 days, 99%; 120 days, 100%.

Fertility of cows mated at first oestrus was greater for the longer time intervals following parturition than for the shorter (Saiduddin et al., 1968). During the first 20-days post-partum fertility was very low and this appeared to be due mainly to absence of fertilisation and that this may have been related to the uterine changes during this period. Perkins and Kidder (1963) noted higher conception rates when cows were mated 79-days post-partum or later, than for cows mated at a shorter post-partum interval. Higher fertility was also noted at similar intervals from parturition, when ovulation occurred on the side of the formerly non-pregnant horn, compared to the pregnant horn.

The relative importance of the interval from parturition until first breeding and the interval to involution of the uterus and their effect on fertility has been assessed by Wiltbank and Cook (1955), Casida et al. (1968) and Foote et al. (1960a). Of the two, the interval from calving to first mating, was more important. The standard partial regression of fertility on interval to involution of the uterus and on interval to first service was found to be 0.02 and 0.40, respectively (Foote et al., 1960a).

Present assessment of the limitation of fertility during the post-partum period is that depressed fertility most obviously is brought about at first by absence of follicular development and then by absence of oestrus with accompanying ovulation. If oestrus occurs early then fertilisation rate is the limiting factor due to the state of the reproductive tract at that time.

B. The Post-Partum Interval

1. Interval to first oestrus

A review of the literature revealed a wide variation in post-partum ovarian activity and in the time from parturition to first oestrus. The experimental design, occurrence of silent oestrus, methods used to detect oestrus, and nutritional status were possible factors responsible for these reported differences. The diligence with which cows have been observed and the promptness with which observations have been started after parturition have undoubtedly varied in different studies. Some studies did not begin until 20- to 40-days post-partum and as a result many early post-partum ovulations may have been overlooked. Maternal instinct may override the normal oestrous expression, and so make it difficult to detect oestrus in cows nursing calves. Much of the early data on the length of this interval came from breeding herds in which observations of oestrus were made and recorded as an aid to breeding and health management. These observations were probably less exact than those made specifically to furnish experimental data. There is the impression that beef and dairy cows differ in the length of the interval, but there is a dearth of information regarding this interval in beef cattle under range or run conditions.

This may be partly due to the absence of a suitable method of easily identifying the oestrous animal. Continuous observations of cows provide reasonably accurate information, but this is often impracticable with large herds, or with cattle grazed under extensive conditions. A heat-mount detector attached to the cow and which changes from red to white when pressure is maintained for 4 or 5 seconds has been tested by Baker (1965) and at Whatawhata Hill

Country Research Station, Lang et al. (1968). Although better than visual methods for recording oestrus, some detectors were rubbed off, and the colour change in others was activated by cows mounting each other, according to Lang et al. (1968). Characteristics of cattle that must be considered in the design of equipment suitable for marking the oestrous cow, are the varied coat colours; accentuated hair shedding; mounting between females; mud, dust and dung contamination; a long mating period; and greater impact forces at copulation or when lying down or rubbing on objects when compared to sheep.

Lang et al. (1968) have come reasonably close to a device suitable for marking oestrous cows. This is the chin-ball mating harness, which is attached to the chin of a bull, either intact or vasectomised. When mounting a cow, the bull pulls his chin down the back and rump of a cow, so rubbing a ball-bearing and allowing a marking substance to streak the cow. Although reasonably successful, even this device has its limitations. If time and money permitted, there is no substitute for the eye of a skilled observer who checks his cows regularly for oestrus. Foote (1975) estimates that with good checks at dawn and dusk he can detect about 90% of the heats.

A classic example of how variation in time to first post-partum oestrus can occur simply by operating two methods of observation comes from King et al. (1976). They studied the onset of ovarian function in two groups of Holstein cows over the first 90-days post-partum. Group one consisted of 36 animals housed in a free-stall area and observed continuously for oestrus with closed circuit television and a time-lapse videorecorder. Group two consisted of 33 cows housed in tie stalls with oestrous detection done by a herdsman twice daily. A significant difference was observed between the two groups in days from parturition to first detected oestrus, 34.5 and 56.6 days for groups one and two, respectively.

Morrow et al. (1969a) reported that there was a wide variation in the reported interval from parturition to first observed oestrus. They reviewed 13 studies with dairy cattle and 5 studies with beef cattle. Ranges for each were 30 to 76.3 days for dairy, and 52.2 to 80.2 days for beef cows, respectively. In another comprehensive review, Casida et al. (1968) noted that the range for 21 different studies on dairy cows was of the order of 30 to 72 days. Comparable figures from the same review for 18 studies on beef cows were 46 to 104 days. From Table 2.1 the range for studies concerning dairy cows is 32.1 to 71.8 days while for beef cows it is 52.2 to 104.0 days.

However, it must be remembered that all these reported post-partum intervals are relative to the environment in which they were collected. An example is the report of Kohli and Suri (1960) working in India with Hariana cows, where it was found that the interval was 267 days from 576 calvings. This is an extremely long post-partum interval and is perhaps related to the harsh environment in which these cattle live. Dessouky and Rakha (1961) observed in Egypt 335 Friesian cows and reported a post-partum interval of 85 days which is considerably longer than most published data on this characteristic of dairy cattle.

The majority of the studies reported in Table 2.1 come from America. Noticeable in the literature is the complete lack of New Zealand data on this subject. Barton (1958) stated that cows do not usually experience their first post-partum heat period until 3 to 8 weeks following calving. Under run conditions the interval from calving to first heat may average nearly 11 weeks and indeed there may be some cows that will not experience their post-calving heat for 14 weeks or more. His statement was based on the views of cattlemen but not on any investigation into the post-partum interval in beef cows in New Zealand.

2. Interval to involution of the uterus

It has been mentioned in an earlier section that invo-

Table 2.1

Summary of some studies reporting the interval from parturition to first observed oestrus in various breeds of dairy and beef cattle

No. of parturitions	Breed	Mean interval to first oestrus (days)	Reference
29 S	Holstein	71.8	Clapp (1937)
80 M - 2x	Holstein	46.4	Clapp (1937)
180 m - 4x	Holstein	69.4	Clapp (1937)
322	Holstein	33.0	Buch *et al*. (1955)
1646 Herd 1	Holstein	55.4	Carmen (1955)
Herd 2	Holstein	71.0	Carmen (1955)
170	Holstein	69.3	Chapman and Casida (1937)
472	Dairy	32.1	Olds and Sheath (1953)
426	Holstein	32.4	Menge *et al*. (1962)
1398	Dairy	43.0	Thatcher and Wilcox (1973)
340	Holstein	39.0	Whitmore *et al*. (1974)
400	Holstein	50.2	Trimberger (1956)
968	Dairy	57.0	Herman and Edmondson (1950)
146	Dairy	40.1	Norwood (1963)
383	Jersey	40.4	Fallon (1958)
61	Hereford	58.6	Foote *et al*. (1960a)
711	Hereford	80.2	Lasley and Bogart (1943)
54	Angus	59.0	Warnick (1955)
97	Hereford	63.0	Warnick (1955)
255	Hereford and Angus	52.2	Perkins and Kidder (1963)
140	Bonsmara	66.6	Bosman and Harwin (1969)
139 M - 2x	Shorthorn	74.0	Wiltbank and Cook (1958)
266 S	Shorthorn	104.0	Wiltbank and Cook (1958)
35 M - 2x	Shorthorn	54.0	Wiltbank and Cook (1958)
34 S	Shorthorn	84.0	Wiltbank and Cook (1958)

M - 2x = milked twice daily
M - 4x = milked four times daily
S = suckled

lution of the uterus is difficult to define; the problem is one of determining the end-point. Morrow *et al*. (1969a) stated that most studies include one of the following criteria to determine whether involution has been completed.

(i) Return of the uterus to a normal location in the pelvic cavity

(ii) Normal and approximately equal size of the uterine horns

(iii) Normal uterine tone and consistency has been returned

Morrow *et al*. (1969a) has reviewed 6 studies with dairy cattle and showed that the interval to involution of the uterus ranged from 26.2 to 52.0 days. The 3 studies he reported with beef cattle indicated a range of 26 to 56 days. Casida *et al*. (1968) obtained average values in different studies ranging from 26 to 56 days. From Table 2.2 the 15 studies involving dairy cows showed ranges from 25.0 to 57.0 days. The 10 studies of beef cows ranged from 30.0 to 56.0 days. Perhaps it is possible to observe from these limited figures that the uteri of beef cows take longer to involute than those of dairy cows. It should be mentioned that the wide ranges reported in the interval to involution of the uterus could reflect the techniques used in which some studies used palpation of the uterus while others employed histological methods.

3. Interval to first breeding

Variation in the duration of this interval is in part due to the biological variation up to first post-partum oestrus and, in part, to the management practice of the breeding herd. There may be instances when cows are mated as soon as first heat occurs, especially in the case of beef cows suckling a claf (calf), or there may be a delay until a fixed time after calving.

Table 2.2

Interval from parturition to involution of the uterus

No. of parturitions	Breed	Interval to involution (days)	Reference
252	Holstein	47.0	Buch et al. (1955)
60	Holstein	29.4	Casida and Wisnicky (1950)
385	Dairy	39.0	Marion et al. (1968)
59 - M	Dairy	31.6	Moller (1970b)
76 - S	Dairy	31.6	Moller (1970b)
426	Holstein	42.3	Menge et al. (1962)
204	Dairy	25.0	Morrow et al. (1969c)
57	Dairy	57.0	Gier and Marion (1968)
35 - M	Shorthorn	44.0	Wiltbank and Cook (1958)
34 - S	Shorthorn	56.0	Wiltbank and Cook (1958)
2338	Dairy	40.0	Tennant et al. (1967)
44	Holstein	30.0	Wagner and Hansel (1969)
27	Holstein	42.0	Britt et al. (1974)
50	Holstein	26.2	Casida and Venzke (1936)
146	Dairy	42.2	Norwood (1963)
61	Hereford	43.7	Foote et al. (1960a)
118	Hereford	36.5	Perkins and Kidder (1963)
137	Angus	38.7	Perkins and Kidder (1963)
20	Hereford	47.0	Foote and Hunter (1964)
18	Hereford	46.0	Foote and Saiduddin (1964)
25	Angus	30.0	Oxenreider (1968)
22	Angus	40.9	Foote et al. (1960b)
9	Shorthorn	42.6	Foote et al. (1960b)
8	Jersey	27.0	Fosgate et al. (1962)
10	Holstein	27.8	Fosgate et al. (1962)

M = milked daily

S = suckled

Fallon (1958) indicated that fertility at first heat was related more to the length of the post-partum interval to first oestrus than to any other characteristic of first heat *per se*. Thatcher and Wilcox (1973) reported that in dairy cows as the number of oestrous periods before 60-days post-partum increases, services per conception decrease during the breeding season beginning at 60-days post-partum. Lasley and Bogart (1943) have observed that as the interval between calving and first observed oestrus increased, fertility also increased. In their experiment, only 48.6% of the cows mated 10 to 40 days after calving settled with one insemination, while 75% of those mated 161 to 190 days after calving settled with one insemination. These workers suggested that it would be advisable to mate cows 70 to 90 days after calving to make it possible for them to conceive and produce a calf at yearly intervals.

In his review, Britt (1975) indicated that dairy cows inseminated between 40- and 60-days post-partum had conception rates of about 50%; delayed first mating until 60-days post-partum increased conception rate by an additional 10%.

The effect of early mating on calving interval has been studied even less than the relationship between early mating and fertility. Whitmore *et al*. (1974) assigned cows before first calving to be mated early (first post-partum oestrus) or late (first oestrus after 74-days post-partum) during their subsequent lactation in the herd. The average calving interval for the early mated group was 11.2 months compared to 12.4 months for the late mated group. Thus it appears that calving interval in dairy cows can be reduced by shortening the interval from calving to first insemination, but this may not be the case with beef cows.

Morrow *et al*. (1969d) reviewed much of the work done on the interval from calving to first mating (see Table 2.3). From this table it appears that the conception rate, which varies from 57.8 to 88.9%, was highest during the period 90 to 110 days after calving than during any other period.

Table 2.3

Summary of studies reporting the optimum post-partum interval required for maximum breeding efficiency in dairy and beef cows

From: Morrow *et al*. (1969d)

No. of conceptions	Breed	Optimum interval (days)	Conception rate %	Reference
291	Hereford	70 - 90	62.9	Lasley and Bogart (1943)
11,685	Dairy	61 - 90	73.1	Edwards (1950)
1,674	Dairy	80 - 120	57.8	Van Demark and Salisbury (1950)
100	(Angus (Hereford	91 - 110	88.9	Warnick (1955)
255	(Hereford (Angus	80 - 99	75.0	Perkins and Kidder (1963)

Morrow et al. (1969d) concluded from these results that a 60-day post-partum non-gravid interval appears satisfactory which after a 280-day pregnancy allows 25 days in which a cow has to become pregnant if a yearly calving interval is to be maintained. Hence there is only time for one oestrous cycle. All cows would need to have experienced their first post-partum oestrus by the start of the mating season at 60-days post-partum. It is highly probable that beef cows suckling a calf will not have experienced their first oestrus by this time and indeed, some will experience this oestrus only towards the end of a mating season, lasting for 45 days.

C. Factors that may Influence the Post-Partum Interval

1. Genetic factors

There are breed differences in the length of the interval from calving to first oestrus. It has been stated earlier that differences in this characteristic exist between beef and dairy cows, due probably to the different management of these two types of cows together with the suckling effect in the case of the former.

In a survey of the literature, Casida et al. (1968) indicated that different groups of dairy cows had averages ranging from 30 to 72 days and for beef cows from 46 to 104 days in the length of the lactational anoestrous period. Hafez (1974) quoted average differences in post-partum intervals to uterine involution, first ovulation and first oestrus of 46 and 44 days; 49 and 26 days; 60 and 33 days, respectively for Hereford and Holstein cows with the lesser figure for each characteristic being that of the Holstein cows. Hafez concluded that differences between beef and dairy cows in endocrine function may be due to genetic factors, milk production level, method and frequency of milking, suckling effect and to nutritional influences.

Baker (1968) stated in his review that the mean post-partum oestrous interval in European breeds of cattle in the U.S.A. lies in the range of 46.9 to 80.2 days. He also stated that Bos indicus cattle and crosses of these with European breeds - show protracted periods of lactational anoestrus ranging from 116 to 467 days. Reynolds (1967, 1973) reported the average interval from calving to first heat as being 63 days for Angus cows, 79 days for Brahman, 74 days for Brangus and 80 days for Africander x Angus cows. These figures indicate a 16-day difference between the Angus and the Brahman cow. Baker (1968) observed no oestrus in Shorthorn and Zebu x Shorthorn cows when they suckled calves up to 4 months of age. Howes et al. (1960) reported from their study that Brahman cows may, in fact, deplete their body reserves to a greater extent to benefit the calf than will cows of the British breeds and that this resulted in their delayed oestrus.

Wiltbank et al. (1961) studied the records of Angus, Shorthorn, Hereford, Brahman x Angus and Africander x Angus cows of all ages. Angus cows had the shortest intervals from calving to first oestrus. These authors did not give specific times, but noted that considerably more of the Brahman x Angus and Africander x Angus cows did not show oestrus by 100-days post-partum compared to Angus, Hereford or Shorthorn cows.

A comprehensive breed evaluation programme is concurrently being conducted at Clay Center, Nebraska, (Anon., 1974, 1975). Sire breeds used for crossing with Angus and Hereford cows to form a crossbred cow population have included Jersey, South Devon, Limousin, Simmental, Charolais together with straightbred Angus and Hereford and crosses between them. Straightbred Angus and Hereford 2-year heifers had intervals to first post-partum oestrus of 90 and 83 days, while for 3-year-olds the interval was 58 and 67 days for Angus and Hereford heifers, respectively. The shortest interval recorded in the 2-year-old group came from the Limousin x Hereford heifers taking 71 days, while the group taking the longest time to return to oestrus post-partum was the Angus x

Hereford heifer at 90 days. At 3-years-of-age, the South Devon crossed with either the Angus or Hereford cow produced a crossbred cow that returned to post-partum oestrus faster than most other breeds and crosses. Results from this study are only preliminary, with perhaps the greatest single factor emerging, being the wide variation within breeds and crosses as well as between breeds and crosses.

Warnick (1955) obtained an average post-partum interval to first oestrus of 62.7 days for Hereford cows, which was considerably shorter than the 80.2 days reported by Lasley and Bogart (1943) for range cows of this breed. These differences in findings more than likely arise because of different nutritional, management, or climatic factors, or an interaction among these factors. In the same study, Warnick observed a 59.2 days post-partum interval in Angus cows, this being considerably shorter than the 69.3 days reported by Chapman and Casida (1937).

Perkins and Kidder (1963) reported that the average interval to uterine involution was 36.5 days for Hereford cows and 38.7 days for Angus cows, but these differences were not statistically different. Ustinov (1973) observed in 124 Angus cows, an interval from parturition to first oestrus of 67.1 days while in 111 Shorthorns the interval was 90.7 days. Laster et al. (1973) noted Brown Swiss cows had longer intervals than any of the following cows, in their investigation: Red Poll, Hereford, Angus, Charolais x Angus, and Charolais x Hereford. This difference was considered to be due to the greater milk-producing ability of the Brown Swiss cow.

Cundiff et al. (1974) have compared the effects of heterosis on reproduction in an experiment involving straightbred Hereford, Angus and Shorthorn females and the reciprocal crosses of these breeds. Analysis of the 570 matings of straightbred cows and the 687 matings of crossbred cows revealed that the interval from parturition to first oestrus was significantly ($P < 0.05$) reduced by 2.7 days due to heterosis. This heterosis effect was greater in the Angus x Shorthorn than in the Angus x Hereford crosses due probably to the Shorthorn having a longer interval to post-partum oestrus, namely 63.2 days compared to 50.6 and 55.1 days than for Hereford and Angus, respectively.

Menge *et al*. (1962) noted that inbred animals involuted significantly earlier than outbred animals (39.6 days *versus* 45.0 days). Olds and Sheath (1953) found significantly more variation between daughters of different bulls than between daughters of the same bull. Brown *et al*. (1954), however, showed that calving intervals were not influenced by sire breed of dam. The literature is not very clear on this subject, but it is obvious that large animal variation exists in the interval to first oestrus with some of this being genetic in origin.

Koger *et al*. (1962) and England *et al*. (1973) have indicated that a significant interaction between breed and lactational status occurs because non-lactating cows of all breeds perform at nearly the same level while lactating cows show wide breed differences. Deutscher and Whiteman (1971) observed that suckling was confounded with breed differences. They compared Angus and Angus x Holstein heifers and found that the crossbreds had poorer rebreeding performance while nursing calves, with only 13% of these rebreeding compared to 65% of the straightbred Angus heifers. These authors suggested that feeding level was too low to support the increased milk production from the crossbred heifers. Similar results were noted by Morgan *et al*. (1974), who found that the fertility of 2-year-old Friesian heifers was reduced more than that of 2-year-old Hereford heifers when they suckled their first calf. This is probably due to the higher milk production and greater weight loss in the Friesian heifers.

In their study, Dunn *et al*. (1969) observed breed-by-nutrition interactions. Their data indicated breed-by-post-calving nutrition interactions at 100- and 200-days post-partum. A higher proportion of Hereford compared to Angus cows exhibited oestrus at 100-days post-partum when the energy level fed was increased from a low level, to a moderate, and then to a high level, respective percentages of Hereford cows showing oestrus were 70, 90 and 100 at the low, moderate and high energy levels while for the Angus cows the proportions were 91, 94 and 95%, respectively. It can be concluded therefore, that breeds will differ in reproductive performance under any given environmental conditions.

2. Age and parity of cow

The age of the cow is a factor influencing the interval from calving to first oestrus. It must be remembered when reviewing published results on the influence of age that in well-managed herds there is continuous selection for reproductive efficiency. This favours older cows, for those that survive to an advanced age have demonstrated their higher fertility.

The interval from calving to first oestrus in cows suckling calves was longer in the younger than in the older cows in the study of Wiltbank et al. (1961). Cows with one calving had longest intervals in the work of Flores (1971) and in the study of Wilson and Willis (1974). Wiltbank (1970) reported that younger cows have a longer interval than older cows. In one breeding season the average interval from calving to first oestrus was 53.4 days in cows which were 5-years-old or older, 60.2 days in 4-year-old cows, 66.8 days in 3-year-old cows and 91.6 days in 2-year-old cows. Wiltbank further stated that at 80-days post-partum, 80% of the cows 5-years-old or older had shown oestrus compared with only 68% of the 3-year-old cows. Consequently the interval from calving to first oestrus was too long to permit a calving interval of 12-months in 32% of the young cows and in 11% of the older cows.

Bosman and Harwin (1969), working in South Africa, found post-partum intervals for 2-, 3-, 4-, 5-, 6-, 9- and

10-year-old and older cows of 82.6, 66.0, 64.9, 65.0, 67.9 and 65.6 days, respectively. These differences were not statistically significant but there was a tendency for the younger age group to have longer post-partum intervals. Similar trends were found in the results of the extensive research being carried out at the U.S. Meat and Animal Research Center, Nebraska (Anon., 1975). It was found that the average over all breeds for the interval to first post-partum oestrus was 84.9 days for 635 2-year-olds. For 427 3-year-olds it was 62.8 days and for 230 4-year-olds it was 57.4 days.

In terms of calving interval, Brown et al. (1954) noted that this trait tends to decrease as calving sequence increases, being 15.4 months from first to second calving, 14.2 months for the next calving interval and 12-months for the third interval. In their study, age accounted for 17.5% of the total variance in time to first post-partum oestrus. In New Zealand, Fielden et al. (1973) examined 370 cows, out of a population of 2,576, because they had not been seen in oestrus; the incidence of suspected anoestrus being highest in the youngest age group (21% of the 2-year-old heifers) decreasing to 10% in the mature age group. Ninety-two percent of the 2-year-old heifers were classified as having inactive ovaries; the comparable figures for 3-year-old and mature cows were 82% and 52%, respectively.

In all of the literature reviewed there is a clear indication that heifers are prone to experience longer intervals to first post-partum oestrus than older cows. There have, however, been some reports where parity and age have had no influence on this interval. In his study, Warnick (1955) found the average interval to first oestrus following calving among various age groups varied from 55.0 days in 6-year-old cows to 76.5 days in 5-year-old cows. There was no apparent trend associated with age and mean differences were not statistically significant. Others to find no effect of age were Clapp (1937); Buch et al. (1955); and Foote et al. (1960b).

The other phenomena associated with age is the decline in reproductive efficiency with age. Herman and Edmondson (1950) noted the interval was longest, about 75 days for first-calf heifers aged 1½- to 2½-years; shortest, (that is, 50 to 60 days) for cows from 2½- to 7-years, and increased again to between 60 and 90 days for cows older than 7-years. Other authors who noted a decrease with increasing age include Wiltbank and Cook (1958) and Lindley et al. (1958). These latter authors found that calving interval increased in cows greater than 10-years-of-age with the regression of cow age on calving interval being curvilinear indicating a decline with advancing age. Similar results were obtained by Schalles (1967) whose study involved 769 Angus cows calving over a 11-year period.

Belling (1963) observed the most efficient period of reproduction to be between the ages of 3- to 7-years. He found that cows older than 8-years-of-age had longer calving intervals. Plasse et al. (1968) working with B. indicus cattle in Florida, have noted that calving intervals decreased in length with increasing age. This may have been due to the adverse environment affecting younger cows more than older cows which may have become more adapted to the stresses of lactation under the conditions prevailing in Florida.

Mahadevan et al. (1972) have considered that as the cow ages, there is an increased production of milk with each successive calving. If feed supply is inadequate to meet this increase there then becomes less nutrients available for the reproductive processes. Consequently these workers consider calving interval increases with age.

Age and parity were shown to have an effect on the involution rate in the work of Morrow et al. (1966); Casida and Wisnicky (1950); Buch et al. (1955) and Marion et al. (1968). All these workers found primiparous cows involuted faster than pluriparous cows. Norwood (1963) observed in his study that pluriparous cows involuted in 40.3 days while primiparous cows took 35.3 days. Tennant et al. (1967) and

Moller (1970b) considered age had no influence on the involution rate of the uterus. These authors suggest other factors such as disease, nutrition and the suckling stimilus may be more important and hence make interpretations of age effects difficult.

3. Milk production and suckling status of cow

Milk production of the dam accounts for a significant proportion of the variation in growth rate of beef calves, (Neville, 1962, Barton, 1970). Correlations between milk yield and average daily gain of calves range from 0.58 to 0.85 in the studies of Furr and Nelson (1964); Melton et al. (1967); Jeffery et al. (1971) and Neville (1962). The question is whether level of milk production will influence reproductive performance. There is an opinion held by many authors that high milk production is antagonistic to efficient reproduction.

The effect of suckling and/or lactation on reproductive activity has been ably demonstrated by many workers. It has been shown that the interval to first oestrus is significantly longer in cows being suckled than in cows from which calves were removed at birth. Clapp (1937) was one of the first to demonstrate this effect. In his experiment, cows milked four times daily appeared to have a prolonged anoestrous period (69 days) compared to suckled cows (72 days) while those milked only twice daily had an interval to first post-partum oestrus of 46 days. Wiltbank and Cook (1958) reported that Shorthorn cows had their first post-partum oestrus 54 days after parturition when milked twice daily, while oestrus did not appear in those that nursed calves until 84 days post-partum. This difference of 30 days was highly significant ($P < 0.01$).

Graves et al. (1968) working with beef cows found over a series of experiments, that interval from parturition to first oestrus was 35 to 54 days shorter for non-suckled than for suckled cows. These data, together with those of

Saiduddin *et al*. (1968) show a greater difference between dairy and beef cattle when they were suckled than when they were not suckled. Beef cows are delayed more by suckling a single calf than dairy cows, due perhaps to a breed-by-suckling and/or lactation interaction. Saiduddin *et al*. (1967a) found that dairy cows suckling a calf were detected in oestrus 15 days later than cows dried off soon after calving (45 *versus* 30 days) while Wagner and Hansel (1969) saw none of their 11 suckled cows in oestrus prior to slaughter at 30 days, although 2 had ovulated. In a more recent study of 45 Angus cows, England *et al*. (1973), noted that suckling lengthened the post-partum interval to first ovulation (43 *versus* 23 days) and to first post-partum oestrus (65 *versus* 38 days).

In an experiment conducted by Randel *et al*. (1976) a total of 28 Hereford and Hereford x Angus cows from 3- to 9-years-of-age was equally allotted at calving to be non-suckled or suckled. The non-suckled cows had their calves removed 12 hours after calving. Both groups were fed to maintain post-calving liveweight. Return to oestrus after parturition took 50.1 days in the suckled group and 16.1 days in the non-suckled group. Conner *et al*. (1974) noted intervals to first post-partum oestrus of 47 days for non-suckled heifers and 76 days for suckled heifers. De Alba (1960) has studied the effect of suckling on calving interval in Crillio cows in tropical Latin America. Suckled cows returned to oestrus 108 days post-partum and had a calving interval of 418 days. The corresponding figures for non-suckled cows were 64 and 389 days, respectively.

Lactation and/or milk removal does have a definite influence on post-partum reproduction. The complete suckling-ovarian inactivity system is not clearly understood. Wagner and Oxenreider (1971) have suggested that elevated blood levels of progesterone and cortisol from the adrenals in response to milk removal may be the limiting factor. Suckling depressed serum lutenising hormone in the study of Randel *et al*. (1976). Moller (1970b) indicated that follicle stimulating hormone is circulating at satisfactory levels giving rise to the formation of follicles on the ovaries, but the main inhibiting factor is insufficiency of lutenising hormone. It has been reported by Oxenreider and Wagner (1971), that cows suckling calves are subject to more frequent mammary stimulation than cows milked twice daily and that this may contribute to hormonial differences in suckled and milked cows.

Lactating cows require more nutrients than non-lactating cows because of the additional nutrients required for milk production. Dunn et al. (1969) and Wiltbank et al. (1964) have shown that increasing energy intake following calving will shorten the post-partum interval. In most of the reported experiments involving the effect of lactation on post-partum interval, the nutrient intake may not have been completely adjusted for lactational status. Therefore, it may be argued that if the nutrient intake of non-lactating or lower-producing cows was not reduced sufficiently, then they may come into oestrus earlier because they had more nutrients available for reproductive activity.

When a cow is not suckled or milked following parturition, a considerable amount of milk remains in the udder until she is "dried off". This residual milk can affect neural stimuli arising from the mammary gland and consequently have an inhibitory influence on oestrual activity similar to that of milking or suckling. A technique to test this theory is by mastectomy involving the removal of all mammary tissue and the teats.

Short et al. (1972) used this technique to test for the effect of suckling stimulus. In their experiment, 34 Angus cows were assigned as follows: 12 cows were suckled intact; 13 were non-suckled intact; and 9 were non-suckled and mastectomised. The interval to first post-partum oestrus for the 3 groups was 65 days, 25 days and 12 days, respectively. Non-suckling and non-suckling plus mastectomy progressively shortened the interval from calving to first oestrus. The mastectomy group further reduced the interval compared to the non-suckled group. The mechanism whereby mastectomy shortens the post-partum interval is presumably via magnification of the effect of non-suckling by completely removing any inhibitory effect of lactation and/or nursing. Not only is all milk production eliminated, but also the major neural connections with this area are severed.

Perhaps one way of removing the suckling effect when raising beef calves from the dairy herd came from the work of Ugarte and Preston (1975). They studied 120 Holstein cows and assigned them to one of two groups, namely, one group of cows suckled their own calves twice a day just after milking, and the other group of cows acted as a control with their calves separated at birth. Weaning occurred at 10 weeks in the suckled group. An unexpected finding was that the interval and manifestation of first oestrus did not differ between control and suckled cows. Interval to first oestrus being 89.6 days in the restricted suckling groups and 88.5 days in the milked control group. The reason for this difference may be in the management system adopted, since in the method used the calves were in physical contact with their dams for at the most 1 hour daily, whereas in traditional beef cattle management, calves are with their dams virtually continuously.

Suckling of calves has been found to have a beneficial effect on uterine involution (Lauderdale et al., 1968, Riesen et al., 1968 and Riesen, 1968). In contrast, Wiltbank and Cook (1958) found that suckling had the opposite effect. In their experiment suckled Shorthorn cows had completed involution by 56 days while milked cows took only 44 days. Wagner and Hansel (1969) after weighing uteri reported that nursing did not affect the speed of the involutionary process. Similar conclusions were drawn by Oxenreider and Wagner (1971), Conner et al. (1974) and Oxenreider (1968). Working with dairy cattle in New Zealand, Moller (1970b) has compared uterine involution in milked and nurse cows suckling 3 or 4 calves. His results indicated no significant differences in the speed of involution between milked and suckled cows, the time for the two groups being 31.6 days and 31.7 days, respectively.

Nurse cows experienced more quiet ovulations than milked cows (Wiltbank and Cook, 1958), with nurse cows having an average of 1.6 more quiet ovulations as against 0.9 by milked cows. Graves et al. (1968) working with beef cows noted that the percentage of first ovulations classified as quiet was 42.4% and 70.6% for non-suckled and suckled cows, respectively. Suckled cows also had a higher percentage of second ovulations that were quiet as compared to non-suckled cows (50.0% versus 26.1%). England et al. (1973) found the same trend. The incidence of quiet ovulations before first manifest oestrus in their study was 1.26 for suckled cows and 0.64 for milked cows. Moller (1970b) noted 57% of ovulations in the first 60 days were silent in milked cows while the corresponding figure in nurse cows suckling 3 or 4 calves was 100%.

Moller (1970b) stated that multiple suckling, while not influencing the speed of uterine involution, does delay ovulation and supress oestrus. Everitt et al. (1968) found in a New Zealand dairy herd that multiple suckling delayed oestrus, with these cows completely failing to show signs of oestrus until 5 to 7 days after weaning at 10 weeks. In a second experiment, the same workers found that weaning at 7 weeks improved reproductive efficiency as this allowed more time for the cow to return to heat. Moller (1970b) noted multiple suckling delayed first ovulation significantly compared to milking twice daily (42.3 versus 64.9 days). The multiple-suckled cows were suckled by 3 or 4 calves, but of these cows those that were suckled only twice daily experienced better ovarian growth than those suckled continuously, but not as good as those milked twice daily. Results for time to first post-partum ovulation for cows suckling 4 calves continuously, 3 calves continuously, suckling 3 calves twice daily and for cows milked were: 71.0, 61.8, 60.6 and 35.7 days, respectively.

Wetteman *et al.* (1976a, b) have also studied the influence of suckling intensity on the length of the post-partum anoestrous interval. In their trial, 44 Hereford x Holstein cows were assigned at calving to one of three suckling intensities namely, own single calf, a single foster calf or a foster calf and their own calf. The cows were maintained under range conditions and supplemented so liveweight loss during October to April was similar for all treatments. The first post-partum oestrus occurred earlier after calving in cows nursing their own (67 days) or foster calves (62 days) than in cows nursing two calves (95 days). Only 42.8% had shown oestrus by 90 days post-partum compared to 88.8% of those suckling foster calves and 71.4% of those nursing their own calves. Note here that in no group were all of the cows ready to re-mate by 90-days post-partum. Data obtained in that study indicated that increasing the suckling intensity increased the interval from calving until the time when the ovary becomes functional. Since this effect is independent of the nutritional status of the cows, it suggests that suckling probably inhibits secretion of gonadotrophic hormones by the anterior pituitary.

Kaiser (1975) carried out a series of experiments to study the effect of multiple suckling (2, 3 or 4 calves, respectively) during early lactation on the interval to first post-partum oestrus. Multiple suckling significantly inhibited the onset of the first post-partum oestrus. Only 3 of 57 suckled cows were observed in oestrus before weaning. Suckled cows did not lose more liveweight than milked cows, but suckling inhibited oestrus (93 days *versus* 24 days). Both suckled and milked cows received the same nutritional treatment, and therefore the above results indicate that suckling *per se* rather than nutritional effects, was the likely factor responsible for the delay in first post-partum oestrus in multiple-suckled cows. This interval is more strongly related to the duration of the suckling period, rather than to the actual strength of suckling stimulus, as controlled by the number of calves being suckled.

It is often stated that an increase in beef production could be achieved by increasing the incidence of multiple births. However, if this were the case, and calves born as twins or triplets were left with their mothers, success could be limited by the inadequacy of milk production of the dam and of the suckling effect in delaying post-partum reproductive activity. Bellows et al. (1974) studied this problem in beef cows treated with follicle stimulating hormone (F.S.H.) to induce multiple births. The incidence of retained placenta increased in dams producing multiple births. These authors concluded that prolonged post-partum intervals noted in dams which nursed more than one calf, were a result of milk production or the suckling stimulus, associated with nursing more than one calf and not the influence of multiple births per se. Similar results came from Turman et al. (1971) who found 25% of the cows nursing twins after F.S.H. treatment, did not re-mate while lactating, but did conceive within 6 weeks after the calves were weaned.

One way of overcoming the suckling effect is by early weaning. Weaning at 3 days in the experiment of Bellows et al. (1974) resulted in an average post-partum interval of 19.6 days compared to an interval of 39.0 days for cows which were weaned at 35 days. This occurred irrespective of whether the cows were nursing a single calf or twin calves.

Biswal and Rao (1960) studied the fertility rate in cows whose calves were weaned at birth compared with those weaned at the normal time and found that 80.3% of weaned cows came into oestrus within 120 days of calving compared with 62.8% of the non-weaned cows. Laster et al. (1973) have investigated the effects of weaning 1 week before the start of the mating period. Their results indicated that weaning increased the percentage of cows exhibiting oestrus before the end of this mating period by 29% in 2-year-olds, 26.7% in 3-year-olds and by 16.2% in mature cows.

Schottler and Williams (1975) confirmed this suggestion that early weaning will advance the date of subsequent calving.

They reduced age at weaning from 7 months to 4 months and advanced date of subsequent calving by 39 days. It remains to be seen if this conveys any overall advantage in terms of calf growth, and cow reproductive performance. Certainly present management systems would need to be reviewed in New Zealand if early weaning was to be practised, especially in terms of feeding of the young weaned calf.

There have been few studies done on the effect of level of milk production and time to first oestrus in beef cattle. This is most probably a reflection of the difficulty of obtaining reliable milk production data from the suckled beef cow, especially under run or open range conditions. There is some information on this topic from studies with dairy cows. Olds and Sheath (1953) reported a very small correlation of 0.09 between interval to first oestrus and milk production ($P < 0.05$). They showed that for each additional 1,000 lb of 4% fat-corrected milk produced during the first 120 days of lactation, there was a period of about 1.5 days more between calving and first oestrus. Whitmore *et al.* (1974) noted intervals to first post-partum ovulation and to oestrus were higher on average, from genetically high-producing than for genetically low-producing cows (31 *versus* 29 days for time to first ovulation and 42 *versus* 36 days for time to first oestrus, respectively). Actual 60-day milk production showed a significant and positive correlation with post-partum interval to first ovulation ($r = 0.13$, for 276 df, $P < 0.05$) and to first oestrus ($r = 0.16$, for 276 df, $P < 0.05$).

Further experiments on the influence of milk production on reproductive activity post-calving were carried out by Marion and Gier (1968). They divided a total of 250 dairy cows after parturition into 3 production groups based on levels of daily milk production, namely, under 22 kg, 22 to 30 kg, over 30 kg. Average daily interval from parturition to first ovulation and first oestrus for the three groups were respectively; low, 13.1 and 28.4, medium, 14.0 and 33.1, high, 15.5 and 36.9, with differences between low and high producers being significant. Saiduddin *et al.* (1968) found the interval to first oestrus after parturition was 9 days longer in genetically high-milk producers compared to genetically low producers. Similarly, Dumitrescu (1969) studied 44 high-producing Brown Alpine (5900 litres/day) cows and 40 medium producing (3200 litres/day) cows of the same breed and noted the percentage in oestrus within 60 days of calving. They were for winter and summer calvings respectively, 65 and 90% for high producers and 80 and 100% for the low producers.

There is one report indicating milk production does not influence the interval from parturition to first oestrus (Herman and Edmondson, 1950). Apart from this study most of the literature agrees that genetically high milk-producing cows have longer post-partum intervals to first oestrus than genetically lower milk-producing cows. This is the case in dairy-bred cows, but for beef-bred cows few studies have been conducted on this subject and the situation is largely unknown. Traditional beef-bred cows may not have a high enough milk production to inhibit ovarian activity. There is an increasing use of dual-purpose breeds, such as the Friesian and Simmental, in single-suckled beef herds and these breeds may, however, have a milk production high enough to inhibit post-partum oestrous activity. Further studies are required in this area before any definite answers can be given.

4. Sex of calf

The results in the literature are variable as to a sex of calf effect on interval to first post-partum oestrus. Barton (1970) from his review of the literature suggested that male calves tend to nurse more frequently due largely to their greater size and that this may stimulate greater milk production of those dams nursing male calves. Bosman and Harwin (1969) have found in their work that the sex of calf effect approached significance at the 5% level. Their cows nursing female calves exhibited oestrus 6 days earlier than those nursing male calves. Similar results were presented by Tomar and Arneja (1972) working in India on 446 Hariana cows. They found that cows nursing male calves return to post-partum oestrus on average in 228.7 days while those nursing female calves took 195.4 days.

Belling (1963) has noted that sex of calf influences calving intervals. In his study of 406 Hereford cows those nursing female calves had a calving interval of 355 days compared to 367 days for those nursing male calves, the difference being highly significant ($P < 0.01$). Plasse et al. (1968) also found that sex of calf influenced the calving interval with cows nursing male calves having an average interval of 415.1 days, while those nursing female calves had an average interval of 404.7 days. These authors suggested that this may be due to a longer gestation period for male calves. Preston and Willis (1974) noted from a review of the literature that female calves were generally carried for a shorter period than male calves although not all workers found significant differences in gestation length according to sex of the foetus.

Numerous reports indicate that there is no influence of sex on post-partum interval. Notable among these is the study of Warnick (1955) who observed that the average interval to post-partum oestrus in cows that gave birth to male calves was 61.5 days and 61.0 days for cows which gave birth to female calves. Lasley et al. (1961) have indicated that sex of suckling calf had no influence on calving interval. Wilson and Willis (1974) found only small differences in calving interval due to sex of calf influence. In Santa Gertrudis cows it was 3 days while in Brahman cows it was 5.6 days. Other workers who found no consistent sex influence were Acharya et al. (1971) and Choudhury et al. (1974), the latter authors also found no sex influence on the rate of uterine involution.

5. Nutrition of dam

The reproductive and milk production of beef cattle is closely associated with their nutritional status. Throughout the literature there is a clear inference that a great deal of variation in reproductive performance was related to the level of nutrition. Inadequate nutrition will suppress oestrus in young, growing females more than in adults. Low levels of energy lead to ovarian inactivity and anoestrus in suckled beef cows. The number of cows wintered on hill country will usually determine the number carried throughout the year and it is in the winter months when a beef cow is normally in the late stages of pregnancy. Nutrient requirements of the pregnant cow are elevated substantially during the last trimester of pregnancy.

The importance of adequate nutrition before and after calving in order to decrease the duration of the post-partum oestrous interval has been demonstrated by various authors. Foremost among these has been the work of Wiltbank et al. (1962). Their study was aimed at determining the effects of two levels of energy on reproductive performance of mature beef cows. Eighty-eight mature, pregnant Hereford cows were fed prior to calving on two different levels of energy, namely, 9 lb of total digestible nutrients, (T.D.N.) per head daily (high) and 4.5 lb of T.D.N. per head daily (low). Following calving one-half of the cows on each of the high and low rations received 16.0 lb of T.D.N. per head daily (high-high and low-high, respectively). The remainder received 8.0 lb T.D.N. per head daily (high-low and low-low, respectively).

The results indicated that the energy level fed can markedly influence reproductive performance in the mature, suckled beef cow. Prior to calving cows in the high-high and high-low groups gained weight, while cows in the low-high and low-low groups lost weight. The level of energy fed following calving also influenced liveweight. Treatment, while not significantly affecting the interval from calving to involution of the uterus, did affect the occurrence of oestrus. The intervals from calving to first oestrus for the low-low, low-high, high-low and high-high groups were 52, 65, 43 and 48 days, respectively. The low-high group was significantly higher than the other 3 groups ($P < 0.01$). Oestrus was exhibited sooner after calving in the group of cows fed the high-energy ration prior to calving. This group also had a high proportion of cows cycling by 90-days post-partum.

Although pre- and post- calving energy levels influenced onset of oestrus, the level of energy provided before parturition appeared to be relatively more important. The response of the cows to the level of energy offered them after calving appeared to be conditioned by their pre-calving energy level. The post-calving energy level had little effect on cows that had received a high level of energy prior to calving. A large number of cows fed on a low plane continuously failed to show oestrus by 90 days post-partum compared to those on the low-high feed level.

Thus it appears that a low level of energy prior to calving exerted an effect on the time to first post-partum oestrus which was not readily overcome, even by feeding a high level post-calving.

In another experiment, Wiltbank et al. (1964) studied the influence of feeding different levels of energy after calving on the reproductive performance of beef cows. This experiment involved 69 mature Hereford cows, all fed the same ration, namely, 4.7 lb T.D.N. daily (i.e., one-half of recommended allowance) over the last 140 days of pregnancy. Post-calving nutrition was either increased immediately after parturition or delayed for 28 days. Cows were allotted to one of the following treatments:

(a) 12.5 lb T.D.N. daily
(b) 16.5 lb T.D.N. daily
(c) 25.0 lb T.D.N. daily
(d) 8.5 lb T.D.N. for 28 days and thereafter 16.5 lb T.D.N. daily

(e) 8.5 lb T.D.N. for 28 days and thereafter 25.0 lb T.D.N. daily.

Cows weighed 500 kg at the start of the experiment, 24 hours post-calving they weighed 389 kg. The respective treatment group average liveweights at 84 days post-calving were 383 kg, 403 kg, 510 kg, 397 kg and 465 kg for treatments (a) to (e), respectively.

According to N.R.C. (1958) treatment (b) was considered to be 100% of the recommended energy level. The post-partum intervals to first heat for the 5 respective treatments were 73, 49, 72, 78 and 82 days. Treatment (b) was significantly shorter than the other treatments ($P < 0.01$). The feeding of 75% (treatment (a)) or 150% (treatment (c)) of the recommended level significantly delayed the first post-partum heat as did feeding 50% for the first 4 weeks post-partum and then increasing the level to 100 and 150%, respectively (treatments (d) and (e)).

It is clear from the study, that cows on inadequate levels of energy post-calving do not show oestrus during the breeding season. Wiltbank (1970) reported on cows which calved at 2-years-of-age and had been fed 8 lb of T.D.N. daily prior to calving, while at calving they were assigned to a low level (7 lb T.D.N.), a medium level (13 lb T.D.N.), or a high level (22 lb T.D.N.) of energy. Only 81% of the heifers fed the low level of energy had shown oestrus by 100-days post-partum compared with 97% and 98% of the medium- and high- energy groups. It should be noted that there is little difference between the medium- and high- energy level groups.

Turman et al. (1964) in their study of 80 yearling Hereford heifers, allotted these heifers to 4 levels of winter supplement: low-low, low-high, high-low and high-high, indicating respective feed levels pre- and post-calving. The low level females lost 20% of their autumn liveweight through to calving while the heifers in the high level maintained their autumn liveweight. Comparing the extremes in treatment, the low-low group of heifers exhibited their first post-partum heat 92.6 days post-partum while the high-high group returned to heat 55.6 days post-partum. This highlights the observation that the level of feeding before calving is the important factor compared to the level of nutrition post-calving. This is shown by the post-partum interval to first heat for the high-low group being 63.6 days as against 70.4 days for the low-high group.

Dunn et al. (1969) also found that the level of pre-calving energy caused a greater effect than post-calving energy levels. In their study, 203 2-year-old heifers were assigned to 5 groups, these being low-moderate, low-high, high-low, high-moderate and high-high, each representing pre- and post-calving energy levels, respectively. By 40-days post-calving 25% of the cows fed the high pre-calving level had shown oestrus compared with 6% of those fed the low level. By 60-days post-partum, 69% of high level group and 44% of the low pre-calving group had shown oestrus, while at 80-days, 88% of those on the high level and 80% on the low level of energy prior to calving had shown oestrus. The effect of the pre-calving energy level had disappeared at 100-days post-partum.

These findings indicate that feeding low post-calving energy levels inhibited the occurrence of oestrus late in the post-partum period. Furthermore, the detrimental effect of feeding low levels of energy in late gestation are not completely overcome by feeding high levels post-calving.

In a more recent study, Falk et al. (1975) obtained intervals from parturition to first oestrus of 63, 67 and 78 days respectively, for 73 heifers in groups of high, medium or low energy levels for 150-days pre-partum. These findings agree with those of Zimmerman et al. (1961) where protein, as well as energy intakes, were restricted before calving. Their results indicated that adequate energy intake was more critical than protein intake for maintaining optimum reproductive function.

Contrary to the above findings, Corah et al. (1975) found pre-partum nutrition did not significantly influence the interval to first post-partum oestrus in either heifers or cows. According to these authors, this may be explained at least in the case of the heifers by the excellent condition (as measured by fat cover) they were in at the commencement of the treatment period.

In New Zealand, Hight (1966, 1968 a, b) has studied the feeding level of suckled beef cows over the late stages of pregnancy and during early lactation. A significant result from this series of experiments was that cows in the group fed a low level of nutrition in late pregnancy and between calving and weaning contained a higher proportion of dry cows. This group also had a 19-day delay in mean onset of calving the following season, due to a delay in the onset of oestrus following calving. In contrast, no differences in subsequent fertility were observed between the high-high, high-low or low-high groups (each representing pre- and post-calving nutritional history) suggesting that fertility responses of cows to level of nutrition given after calving are influenced by the pre-calving level of nutrition.

Pleasants (1974) found that 2-year-old in-calf heifers wintered on a sawdust pad had only a 64% positive pregnancy diagnosis following their second mating while the comparable figure for the heifers wintered on the hill was 93.3%. This was despite any significant differences in the liveweight of these heifers on removal from the pad. There were no differences in the percentage of mature cows diagnosed pregnant that calved on the pad compared with those cows which calved on the hill.

Calving intervals of 18 months or more are not uncommon in Queensland beef herds (Lamond, 1969). One reason for this is that Queensland herds calve during the wet summer season. As a consequence late pregnancy and frequently early lactation occur during the dry season. Supplementation of cows over this period has been proposed. Little (1975) found that protein supplementation plus phosphorus significantly reduced the interval from calving to first post-partum oestrus by 46%, with all animals exhibiting oestrus within 2 months of calving. Three months after calving, only 50% of the controls and 70% of those given phosphorus alone had shown oestrus. Cows under limited feed conditions over late pregnancy and early lactation will need some supplementation to maintain satisfactory reproductive performance.

There is a possible relationship between nutritional intake and the lactational status of suckled beef cows. The marked depression of fertility in first-calf beef heifers may be due to a combination of lactational stress, suckling of calves, a need for continued body growth and to marginal nutritional intake. The results of Oxenreider and Wagner (1971) showed that a wide variation in energy intake did not alter the time to first ovulation in animals not subjected to the stress of lactation. However, none of the suckled cows on the low or medium energy diet ovulated prior to slaughter at 56 days. This strongly supports the importance of a high energy diet for young cows during the lactation period. These effects occurred even though all animals were fed a normal maintenance prior to parturition. Such effects are more pronounced if the animals are fed inadequate levels during late pregnancy as illustrated by Wiltbank et al. (1964).

The detrimental effects of low levels of feeding are clear, but there is also a suggestion in the literature that high levels of feeding may be just as detrimental. Pinney et al. (1972) have shown that high levels of winter feeding reduce the life span, impair the milking ability of beef females, and are excessively costly. Wiltbank et al. (1964) found feeding higher levels than those recommended post-calving, did not decrease the interval from calving to oestrus; also that higher levels of feeding after calving did not overcome the effects of a low level of nutrition before calving.

Working in Zambia, Symington et al. (1967) found that post-partum oestrus was retarded by a plane of nutrition which failed to support liveweight during early lactation. They also noted that there was no evidence that the onset of post-partum oestrus was hastened by a plane of nutrition which allowed liveweight to increase during the early stages of lactation compared with a plane of nutrition which maintained almost constant liveweight during this period.

Body condition at calving may be one characteristic which is important in the manifestation of an early post-partum oestrus. Whitman et al. (1975) found body condition at calving accounted for a significant portion of the variation in the likelihood of oestrus 30- to 90-days post-partum ($P < 0.01$). Acharya et al. (1971) also noted each additional 10 kg increase in liveweight at calving decreased calving interval by 2.3 days. Manipulation of nutrition can have a marked effect on the time to first post-partum oestrus. Cows need to be fed to gain liveweight over the last 8 weeks of pregnancy and thereafter they should be offered a moderate level of feeding to maintain liveweight to give best results during the early stages of lactation, both in terms of milk production and in reproductive performance.

6. Season and year of calving

The season of calving has been observed by Buch et al. (1955) to have a significant effect on the length of the post-partum interval. The longest intervals followed winter calvings, the shortest intervals followed summer calvings while spring and autumn calvings were intermediate between these extremes. Similar results were obtained by Dessouky and Rakha (1961) but Self and Burrell (1975) noted autumn-calving cows had shorter intervals than spring-calving cows. Herman and Edmondson (1950) and Wiltbank and Cook (1958), however, did not observe any relationship between season of the year and length of the period from calving to first oestrus.

Warnick (1955) found the average interval to first post-partum oestrus for cows which calved in the first half of the season compared to those which calved during the last half of the season was 28.3 days longer for Hereford cows and 25.5 days longer for Angus cows. Covariance analysis produced a significant negative relationship between date of calving and interval from calving to the post-partum oestrus. There were negative regressions of -0.51 for the Angus and -0.64 for the Hereford cows. This phenomenon should contribute to a more uniform calving interval from 1 year to the next.

Laster et al. (1973) found in their study that calving date affected ($P < 0.05$) the interval to first oestrus in cows 4-years and older, but not in the 2- and 3-year-olds. Cows calving earlier in the season returned to oestrus in a shorter period of time. This finding is at variance with the work of Warnick (1955) but the herd calved in the autumn and consequently there may have been a seasonal effect involved.

Ben-David (1964) working in Israel, noted that the amount of daylight occurring monthly was significantly correlated with the average number of days to first oestrus after calving ($r = 0.52$). This, together with other environmental factors such as quality and quantity of feed supply, temperature changes and an interaction of these factors could be possible reasons for seasonal differences.

Season also affected uterine involution rate in the studies of Norwood (1963), Buch et al. (1955) and Marion et al. (1968), with involution being longest in the winter months and shortest in summer. Contrary to the findings of these workers, Morrow et al. (1966) found no significant differences in rate of uterine involution attributable to seasonal differences. Labhsetwar et al. (1963) found a higher incidence of quiet ovulations in the warmer months of the year compared to the cooler months.

Year differences are likely to affect the post-partum interval to first oestrus. Brown et al. (1954) found year of calving contributed to 6.7% of the total variance in this interval. Flores (1971) noted in his investigations conducted at two locations, yearly variation in the interval from calving to first oestrus. At one location the interval was 88.3 days and 99.9 days, for two consecutive years while with cows at the other location he recorded intervals of 74.0 days and 91.6 days for the two years, respectively. Similarly, Warnick (1955) observed a highly significant difference in post-partum interval due to years. The average intervals for cows in his study was 50.2 days in 1951, 59.8 days in 1952 and 71.2 days in 1953. Others also found year differences (Acharya et al., 1971 and Self and Burrell, 1975).

Calving interval was influenced by year in the studies of Lasley et al. (1961) and Wilson and Willis (1974) while Schalles (1967) noted cows which calved early in the spring had shorter calving intervals. Climatic effects, especially on pasture production, are likely to account for the major part of this yearly variation.

CHAPTER THREE

MATERIALS AND METHODS

A. Source of Data

1. Massey University Data

The experimental herd was located at Tuapaka, which is the University's No. 3 sheep farm of 462 ha of which some 400 ha is steep, wet and exposed hill country of poor soil fertility. It is situated on the Tararua range, west of the Manawatu Gorge. The highest point on the property is 300 m above sea-level at its back boundary.

Because of the nature of this type of country, together with the carrying capacity of Tuapaka, a sawdust pad was installed to enable a larger number of beef cows to be wintered. For a detailed description of the pad the reader is referred to Pleasants (1974) and Pleasants and Barton (1974). Treatments were applied in this present study to suit the use of the sawdust pad.

Angus cows aged 4- to 11-years were used in the experiment. For purposes of analysis they were grouped into 4 age classes: 4-year-olds, 5- and 6-year-olds, 7-year-olds, and 8-year-olds and older cows.

The management of the herd after weaning followed typical hill country beef breeding herd practice. The herd was set stocked over the whole farm throughout the autumn, early-winter period. During this period the cows lost up to 15% of their autumn liveweight. For the remaining 8 weeks of gestation the cows were fed to gain liveweight so as to recover any earlier losses that may have occurred.

All cows had the same pre-calving treatment to 17 July 1975, after which 4 treatment groups were established as follows:

(i) On the hill throughout the trial (H)
(ii) Removed from the pad at birth (PB)
(iii) Removed from the pad at 20 days (P20)
(iv) Removed from the pad at 40 days (P40) (end of pad treatment).

In Block B, treatment P20 was identical to treatment P40 because of a negligible liveweight difference between the two. For the purposes of analysis, however, they were considered as 2 treatments.

After calving, cows and calves were grouped into three blocks according to calf age. Blocks consisted of cows from each treatment group and each block was run as a separate mob.

The cows on the pad received a daily ration of 4.5 kg of hay, 2.3 kg of barley straw and 1.4 kg of barley meal per animal. Those cows wintered on the hill received no supplement, but grazed winter-saved pasture.

Calving commenced on 1 August and any cows calving after 15 September were excluded from the experiment. From 1 April the cows were weighed at 2-weekly intervals up to 17 July. Post-partum cow liveweights were taken at 20-day intervals to 100-days post-partum. At birth, or soon thereafter, the calves were weighed and tagged.

Milk production data were obtained by the weigh-nurse-weigh method. The calf was separated from the cow overnight, weighed next morning, allowed to nurse, then immediately weighed. The difference between the two weights was assumed to be the amount of milk consumed by the calf, but is regarded here as that produced by the cow. The figure obtained is really only an estimate of the calf's appetite (Barton, 1970), but does serve to indicate relative differences between treatments.

After calving, vasectomised yearling Angus bulls, each equipped with a chin-ball mating harness (Lang et al., 1968), were run with the cows to determine the interval from calving to first oestrus. The bulls were rotated between mobs, had their harnesses checked and the marker dye changed at 3-weekly intervals. Matings were recorded in the field every third day. Entire bulls, also fitted with chin-ball mating harnesses, were introduced on 20 October. Matings continued to be recorded until removal of the entire bulls on 20 December. Any cows not marked were excluded from the analysis.

A new method for the detection of oestrus proposed by Dr K.L. MacMillan of the New Zealand Dairy Board's Artificial Breeding Centre, Awahuri, was evaluated and compared with the chin-ball mating harness. This technique involved applying a white strip of paint to the cow's rump. When the cow was mounted the paint flaked off, making the detection of oestrus clearly perceptible.

The 1976 calving dates were also recorded for use in a study of calving intervals.

2. Ministry of Agriculture and Fisheries' Data

The second part of this study is based on data from 207 Angus cows at the Whatawhata Hill Country Research Station, Ministry of Agriculture and Fisheries, Hamilton. Data were collected over the years 1971 to 1975; the 1974 data were excluded due to oestrous synchronisation experiments being conducted with the cows in that year. For purposes of analysis cows were grouped into 5 age classes; namely, 2-year-old, 3-year-old, 4-year-old, 5-year-old and 6-year-old and older.

Calving in the earlier years extended from August to November, but was gradually condensed to August and September only, by the 1975 calving. Vasectomised bulls each fitted with chin-ball mating harnesses were run with the cows from calving onwards. Mating to Angus bulls commenced on approximately 1 November each year. The mating period extended from the beginning of November to January in the earlier years, but for the 1975 mating season it was of 9 week's duration.

Matings were recorded every 7 days, but classified into 14-day intervals, when the colour of the marker ink was changed. Prior to mating, cows within each age class were randomly assigned to mating groups. Each group was then run separately until the end of mating when they were regrouped into one mob.

Post-weaning management followed normal hill-country management practices. This consisted of roughage grazing (i.e., fern, rank grass, plus some hay) to assist in pasture development. During this period, cows may lose up to 10% of their autumn liveweight. If cows do lose weight they are fed to increase their weight over the last 8 weeks of gestation. All cows were grazed rotationally over the winter with the aim of increasing herbage utilisation and liveweight gain.

Calf weights (birth-weights) were recorded while the cows were weighed within 48 hours of calving. The cows were weighed at mating and weaning, then at monthly intervals through to calving.

A study of calving intervals were carried out within the 1971/72 and 1972/73 years.

B. Method of Analysis

The data used in this study were analysed using the method of least squares as described by Harvey (1975). Only linear "fixed" effects were considered.

1. Massey University Data

(i) Interval to first post-partum oestrus (days), milk production of the dam (kg), and calving interval (days)

The mathematical model chosen to describe these traits was:

$$Y_{ijklm} = \mu + b_i + t_{ij} + a_k + s_l + p(x_{ijklm} - \bar{x}) + e_{ijklm} \quad ...(3.1)$$

where: Y_{ijklm} = the record of the m^{th} individual specified by the subscripts i, j, k and l,

μ = the population mean when equal frequencies exist in all subclasses,

b_i = the effect of the i^{th} block (i = 1 to 3),

t_{ij} = the effect of the j^{th} treatment nested within the i^{th} block (j = 1 to 4, denoting the respective treatments, H, PB, P20 and P40),

a_k = the effect of the k^{th} age of dam class (k = 1 to 4, denoting 4-, 5- and 6-, 7- or 8-year-old and older dams, respectively),

s_l = the effect of the l^{th} sex of calf born (l = 1 or 2, denoting male or female respectively),

x_{ijklm} = date of birth of the m^{th} calf specified by subscripts i, j, k and l,

$\bar{x}$ = the mean date of birth,

p = the regression coefficient measuring the change in Y_{ijklm} for a difference of 1 day in age,

e_{ijklm} = the error peculiar to each Y_{ijklm}.

(ii) Post-partum cow liveweight

The mathematical model chosen to represent this trait was:

$$Y_{ijklm} = \mu + b_i + t_{ij} + a_k + s_l + p(x_{ijklm} - \bar{x}) + q(z_{ijklm} - \bar{z}) + e_{ijklm} \quad \ldots(3.2)$$

where: Y_{ijklm} = the record of the m^{th} individual specified by the subscripts i, j, k and l,

The other effects are as in Model (3.1) except that,

z_{ijklm} = the autumn liveweight of the m^{th} cow specified by subscripts i, j, k, and 1,

$\bar{z}$ = the mean autumn cow liveweight,

q = the regression coefficient measuring the change in Y_{ijklm} for a difference of 1 kg in autumn cow liveweight,

e_{ijklm} = the error peculiar to each Y_{ijklm}.

2. Ministry of Agriculture and Fisheries' Data

(i) Interval to first post-partum oestrus

The mathematical model chosen to describe this trait was:

$$Y_{ijklmn} = \mu + t_i + s_{ij} + m_{ik} + a_l + s_m + p(x_{ijklmn} - \bar{x}) + q(z_{ijklmn} - \bar{z}) + e_{ijklmn} \quad ...(3.3)$$

where: Y_{ijklmn} = the record of the n^{th} individual specified by the subscripts i, j, k, l and m,

μ = the population mean when equal frequencies exist in all subclasses,

t_i = the effect of the i^{th} year (i = 1 to 4),

s_{ij} = the effect of the j^{th} sire nested within the i^{th} year (j = 1 to 5),

m_{ik} = the effect of the k^{th} mating group nested within the i^{th} year (k = 1 to 4),

a_l = the effect of the l^{th} age of dam class (l = 1 to 5, denoting 2-, 3-, 4-, 5- or 6-year-old and older dams, respectively),

s_m = the effect of the m^{th} sex of calf born (m = 1 or 2, denoting male or female, respectively),

x_{ijklmn} = the date of birth of the n^{th} calf specified by subscripts i, j, k, l and m,

$\bar{x}$ = the mean date of birth,

p = the regression coefficient measuring the change of Y_{ijklmn} for a difference of 1 day in age,

z_{ijklmn} = the cow liveweight change from post-calving to pre-mating of the n^{th} cow specified by subscripts i, j, k, l and m,

$\bar{z}$ = the mean cow liveweight change,

q = the regression coefficient measuring the change in Y_{ijklmn} for a difference of 1 kg in cow liveweight change,

e_{ijklmn} = the error peculiar to each Y_{ijklmn}.

(ii) Calving interval

The mathematical model chosen to describe this trait was:

$$Y_{ijklmn} = \mu + t_i + s_{ij} + m_{ik} + a_l + s_m + p(x_{ijklmn} - \bar{x}) + e_{ijklmn} \quad \ldots(3.4)$$

where: Y_{ijklmn} = the record of the n^{th} individual specified by the subscripts i, j, k, l and m,

The other effects are as in Model (3.3) except that there is only one covariate.

x_{ijklm} = the date of birth of the n^{th} calf specified by subscripts i, j, k, l and m,

$\bar{x}$ = the mean date of birth,

p = the regression coefficient measuring the change in Y_{ijklmn} for a difference of 1 day in age.

In each of the models the e's were assumed to be normally and independently distributed, with mean zero and variance σe^2. If tests of significance are to be made then it is assumed the errors are also normally distributed, with mean zero and variance σe^2.

The first-order interactions among block, age of dam and sex effects for the Massey University data were tested by individual application of Models (3.1) and (3.2). The same procedure was applied to the first-order interactions among year, age of dam and sex of calf for the Ministry of Agriculture and Fisheries' data, i.e., Models (3.3) and (3.4). These tests indicated that the first-order interactions were non-significant; consequently they were excluded from the models.

The models may be written in matrix terms as:

$$y = Xb + e$$

where:

y = a known $(n \times 1)$ vector of observations where n is the total number of records,

X = a known $(n \times p)$ matrix of effects defined in the models, where p is the total number of effects,

b = an unknown $(p \times 1)$ vector of parameters being estimated,

e = an unknown $(n \times 1)$ vector of random error effects in which the elements are assumed to be normally and independently distributed with an expected value of zero and a variance-covariance matrix of $\sigma^2 I$, where I is an $(n \times n)$ identity matrix.

The method of least squares used to estimate the b's involves minimising the sums of squares of the deviations of the y's from their expected values (Searle, 1966, 1971).

Since $y = Xb + e$
and $E(e) = 0$
hence $E(y) = Xb$
and $e'e = (y - Xb)'\ (y - Xb)$
$= y'y - 2b'X'y + b'X'Xb$

Choosing as the estimator of $\hat{b}$ those values of b that minimise e'e involves differentiating e'e with respect to the elements of b and then equating to zero. This leads to the following equations:

$$X'X\hat{b} = X'y$$

These are the normal equations. Provided $(X'X)^{-1}$ exists they have the unique solution:

$$\hat{b} = (X'X)^{-1} X'y$$

where $\hat{b}$ is the estimated value of b which minimises e'e. The equations making up the X'X matrix in this study were not of full rank; i.e., linear dependencies existed among the equations. Therefore $(X'X)^{-1}$ does not exist and to solve the normal equations, restrictions must be imposed to reduce the X'X matrix to a full rank matrix. The restrictions applied were that the estimates within a given group sum to zero.

In term of Model (3.1) this would be:

$$\sum_i \hat{b}_i = \sum_j \hat{t}_{ij} = \sum_k \hat{a}_k = \sum_l \hat{s}_l = 0$$

The individual sums of squares for each effect were calculated by the direct method (Harvey, 1975)

$$\text{Sums of squares} = \hat{B}'Z^{-1}\hat{B}$$

where: $\hat{B}'$ = a row vector of the constant estimates for a given set,

Z^{-1} = the inverse of the segment of the inverse of the variance-covariance matrix corresponding, by row and column, to this set of constants,

$\hat{B}$ = a column vector of least squares estimates obtained from the full model.

The estimation of standard errors followed the procedure outlined in Harvey (1975). Here the standard error of a least squares mean $\hat{a}_i$ is defined as:

$$s_{\hat{u} + \hat{a}_i} = \sqrt{(c^{ii} + c^{ll} + 2c^{li})\,\hat{\sigma}e^2}$$

where: c = the inverse of the reduced (X'X) matrix, with superscripts denoting the appropriate row and column,

$\hat{\sigma}e^2$ = the error mean square.

With the restriction imposed that the sum of a group of effects equals zero the inverse elements for the last effect in each group are computed from the dependencies which cause the inverse elements within a set to sum to zero by rows and columns.

Where the analysis of variance showed the means to be significantly different, Duncan's multiple range test as outlined by Harvey (1975) was used to make comparisons among least squares means.

Product-moment correlations (Snedecor and Cochran, 1967) were determined for all these data. The following variables were correlated with time to first post-partum oestrus: cow liveweight, calf birth-weight, milk production of the dam and calving interval.

CHAPTER FOUR

RESULTS AND DISCUSSION

A. Massey University Data

1. Post-partum oestrous interval

The analysis of variance of main effects for the interval to first post-partum oestrus (Model 3.1) is presented in Table 4.1.

It will be noted in Table 4.1 that the only significant source of variation is the regression of calving date on time to first oestrus. Blocks, treatments, age of dam and sex of calf all had non-significant F ratios. The first-order interactions for the main non-nested effects namely, blocks x age, blocks x sex and sex x age were tested, but failed to reach significance and were therefore not considered part of Model 3.1.

The least squares estimates and means for each of the main effects are presented in Table 4.2.

(i) Blocks - Cows were grouped into blocks after calving according to calving date. This assisted in the management of the herd and removed the application of treatments across cows in varying stages of late pregnancy and early lactation.

Least squares means for each block are shown in Table 4.2. Average calving dates for the blocks were, day 223, day 230, and day 246 (Day 1 = 1 January) for Blocks A, B and C, respectively. These differences between blocks were, however, not statistically different.

(ii) Treatments - Table 4.3 gives the least squares means for the effect of treatments on post-partum interval. The effect of treatments did not account for any significant variation in this trait. No clear trends are recognisable from these data. Due to depressed nutritional levels it was considered that those treatments involving removal of cows from the pad at 20- or 40-days post-partum, would result in a delayed interval to first post-partum oestrus compared with those cows remaining on higher nutritional levels either on the hill throughout or removed from the pad at birth.

From the review of literature (Chapter Two) it is clear that the effect of nutritional level post-calving on time to first oestrus is conditioned by pre-calving nutritional levels. The cows in this experiment more than likely received high enough nutriment prior to calving to carry them over the lower levels of feed intake while on the pad for either 20- or 40-days post-calving.

The later calving groups (Block B and Block C) were on the pad for a longer period prior to calving compared to the early-calving group (Block A). This could have influenced their oestrual activity after calving. Block C cows removed from the pad at 20 and 40 days, recommenced post-calving oestrous activity at 94.6 and 93.1 days, respectively. For Block B the respective intervals for these two treatments were 87.4 and 82.3 days, while for Block A they were 72.8 and 65.8 days for cows removed at 20- and 40-days post-partum, respectively. These differences are not statistically significant and in part may be explained by the variation in cow weights between the treatment groups.

(iii) Age of dam - The least squares means for the influence of age of dam on post-partum interval are presented in Table 4.2.

It will be noted that the average interval to first oestrus following calving among the various age groups varied from 77.4 days in 5- and 6-year-old cows to 82.8 days in 8-year-old and older cows. Thus there was an apparent trend associated with ageing, but mean differences between ages were

Table 4.1

Analysis of variance of the main effects for interval to first post-partum oestrus

Source of variation	df	Mean square
Blocks	2	228.33
Treatments	9	307.84
Age of dam	3	30.28
Sex of calf	1	132.38
Regression on calving date	1	1747.17**
Error	44	212.86

** $P < 0.01$

Table 4.2 Least squares means and standard errors for post-partum interval to first oestrus

Source	No. of records	Mean (days)
General mean	61	79.2 ±2.9[2]
Blocks		
A	18	72.6 ±5.8
B	21	80.8 ±4.6
C	22	84.3 ±5.8
Block A		
H[1]	7	66.0 ±6.4
PB[1]	6	85.9 ±5.9
P20[1]	2	72.8 ±9.3
P40[1]	3	65.8 ±8.4
Block B		
H	7	81.8 ±5.6
PB	3	71.7 ±7.9
P20	5	87.4 ±6.5
P40	6	82.3 ±6.5
Block C		
H	5	81.2 ±7.4
PB	2	68.2 ±10.1
P20	8	94.6 ±5.4
P40	7	93.1 ±5.6
Age of dam		
4 years	7	78.1 ±6.2
5 + 6 years	13	77.4 ±4.2
7 years	36	78.6 ±2.7
8 + years	5	82.8 ±8.1
Sex of calf		
Male	34	80.9 ±3.7
Female	27	77.5 ±3.6
Regression on calving date (days/day)		-1.05 ±0.36

Note: [1]H - on hill throughout; PB - off pad at birth; P20 - off pad at 20 days; P40 - off pad at 40 days

[2] - standard error

This notation will be used throughout this thesis.

Table 4.3

Least squares means and standard errors for the effect of treatments on post-partum interval

	Means and standard errors (days)	Treatments H	PB	P20	P40
Block A	72.6 ± 5.8	66.0 ± 6.4	85.9 ± 5.9	72.8 ± 9.3	65.8 ± 8.4
Block B	80.8 ± 4.6	81.8 ± 5.6	71.7 ± 7.9	87.4 ± 6.5	82.3 ± 6.5
Block C	84.3 ± 5.8	81.2 ± 7.4	68.2 ± 10.1	94.6 ± 5.4	93.1 ± 5.6

not significant. Warnick (1955) also noted no mean differences between different age classes in his study involving Angus and Hereford cows. Reports in the literature generally agree that older cows take longer to return to oestrus after calving. This is consistent with the findings of the present study that 8-year-old and older cows have the longest post-partum interval. The effect is somewhat masked by selection within the herd for cows that conceive regularly within the 8-week mating season. This places some bias on data from the older age classes. It should be mentioned in this connection that no data on 2- or 3-year-old cows were included in this part of the study.

(iv) Sex of calf - The average interval to the first post-partum oestrus in cows that gave birth to male calves was 80.9 days and to female calves 77.5 days (Table 4.2). This difference of 3.4 days was not statistically different (Table 4.1) and so sex appeared to have no effect on interval to first oestrus in this study.

The literature on this subject is somewhat confusing. Some authors mention there are differences in favour of male calves, others suggest female calves have shorter intervals, while Warnick (1955), Bosman and Harwin (1969) have found no significant effect of sex of calf on the length of this interval. Insufficient numbers in those investigations and in the present study are perhaps the reason for the inconsistent results being obtained. No real conclusive statement can be made as to the influence of sex of calf on the post-partum interval except perhaps that there is a slight increase in the interval in cows that suckle male calves.

(v) Calving date - The regression of calving date on interval to first post-partum oestrus was -1.05 days, this being highly significant ($P < 0.01$). For each day later in the season that a cow calved, the period from calving to first oestrus was reduced by 1.05 days. This is difficult to reconcile with the later-calving group (Block C) having a longer interval to first oestrus, that is, 84.3 days, compared with the two early-calving groups (Block A and B) taking 72.6 and 80.8 days, respectively. The size of the regression coefficient is somewhat greater than that reported in other studies. Bosman and Harwin (1969) calculated a regression coefficient of -0.42 while Warnick (1955) found regression coefficients of -0.51 for Angus and -0.64 for Hereford cows.

(vi) Frequency of oestrous activity - Table 4.4 presents the percentage of the total cows over all treatments that had exhibited an observed oestrus and could have been remated. From the table it is seen that at 50-days post-partum only 3.3% of the cows had exhibited oestrus, while at 70 days the proportion was 18.0. At 90 days only 80.3% of the herd had exhibited oestrus, while at 110 days post-partum the proportion was 95.1. All the cows had shown oestrus within 125 days post-partum.

Various factors are probably related to the high incidence of cows (19.7%) not experiencing their first heat before 90-days post-partum. These would include the suckling stimulus of the calf, inadequate nutrition, or the cows may have simply had a silent heat or have missed being detected in oestrus.

2. Milk production of dam

Analysis of variance for milk production of the dam at 20-, 40- and 60-days a post-partum are presented in Table 4.5. Main effects only are given as the interactions between the main effects were tested independently and found to be non-significant and so consequently were disregarded from further analysis in Model 3.1.

(i) Blocks - Least squares means for the effect of blocks on milk production of the dam together with the general mean are shown in Table 4.6. Mean differences between blocks were significantly different ($P < 0.05$) at

Table 4.4

Cumulative frequency of post-partum oestrual activity

Days post-partum	Cumulative frequency (%)
50	3.3
70	18.0
90	80.3
110	95.1
125	100.0

Table 4.5

Analysis of variance of the main effects for 20-day, 40-day and 60-day milk production

Source of variation	df	20-day mean square	40-day mean square	60-day mean square
Blocks	2	4.12^{*}	6.88^{*}	5.72^{ns}
Treatments	9	2.31^{ns}	2.73	1.79
Age of dam	3	2.72^{ns}	11.32^{**}	2.54
Sex of calf	1	4.68^{*}	0.64	2.14
Regression on calving date	1	0.36	4.71	3.47
Error	44	1.14	1.90	2.38

ns $0.05 < P < 0.10$
* $P < 0.05$
** $P < 0.01$

Table 4.6

Least squares means and standard errors for the effect of blocks on milk production of the dam

	Milk production (kg)		
	20-day	40-day	60-day
General mean	4.9 ± 0.2	5.0 ± 0.3	4.7 ± 0.3
Block A	4.6 ± 0.4	6.2 ± 0.5[a]	5.8 ± 0.6
Block B	5.5 ± 0.3[a]	4.8 ± 0.4	4.6 ± 0.5
Block C	4.6 ± 0.4	4.1 ± 0.5	3.7 ± 0.6

Note: Superscripted values are significantly different from unsuperscripted or differently superscripted values at the 5% level of significance.

20- and 40-days post-partum while at 60 days the mean differences approached significance ($0.05 < P < 0.10$). The general trend is for milk production to increase up to approximately 40-days post-partum and then to decline.

The earliest-calving group followed this pattern (Block A), but Blocks B and C had their highest milk production at 20-days post-partum. This more than likely reflected the calving time in relation to feed supplies. The earlier calving group was on a somewhat restricted diet for a shorter period prior to calving than the other two groups, but also those on the hill went on to less pasture than latter calving groups. These two factors probably accounted for the prolonged high production measured from cows in Block A.

Blocks B and C reach a peak at 20-days post-partum. This is too early to allow the calf to utilise the increased milk produced at this stage, and so consequently the cow may dry off. This then leads to a situation developing some weeks later, whereby the calf's appetite has increased, but the cow cannot meet its increased demand for milk.

Block C produced the least amount of milk at 20-, 40- and 60-days post-partum. Thus it would appear that calving as early as possible, even during late winter, will result in best results in terms of milk production of the cow. This would allow the milk production of the cow to match the needs of the calf as it ages.

(ii) Treatments - Treatment effects on milk production were non-significant at 40- and 60-days post-partum and only approached significance at 20 days ($0.05 < P < 0.10$). The least squares means for this effect are shown in Table 4.7. It was thought that removal of the cows from the pad at 20- or 40-days post-partum would result in a surge of milk production similar to that noted by Pleasants (1974). One possible reason for this was that cows confined to the feeding pad (possibly under stressful conditions) would increase their milk production when they were transferred from the

Table 4.7

Least squares means and standard errors for the effect of treatments on milk production of the dam

Treatment	Milk production (kg)		
	20-day	40-day	60-day
Block A			
H	5.4 ± 0.5	7.0 ± 0.6	5.6 ± 0.7
PB	4.3 ± 0.4	5.2 ± 0.6	5.6 ± 0.6
P20	4.3 ± 0.7	6.4 ± 0.9	5.8 ± 1.0
P40	4.5 ± 0.6	6.2 ± 0.8	6.2 ± 0.9
Block B			
H	6.4 ± 0.4	4.6 ± 0.5	5.1 ± 0.6
PB	5.7 ± 0.6	5.4 ± 0.8	4.2 ± 0.8
P20	5.7 ± 0.5	5.0 ± 0.6	5.6 ± 0.7
P40	4.4 ± 0.5	4.2 ± 0.6	3.6 ± 0.7
Block C			
H	4.4 ± 0.5	5.4 ± 0.7	4.3 ± 0.8
PB	5.4 ± 0.7	2.2 ± 1.0	2.9 ± 1.1
P20	4.3 ± 0.4	4.3 ± 0.5	3.9 ± 0.6
P40	4.3 ± 0.4	3.8 ± 0.5	3.7 ± 0.6

pad to hill pastures and allowed there to graze under more natural conditions. In this trial there was only a slight surge of milk production upon removal from the pad noticeable in the cows in Block A, but no such surge was observed in either Block B or C cows.

The lowered amount of milk produced by cows in Blocks B and C compared to Block A is difficult to explain. It may be that the longer period spent on the pad prior to calving by Block B and C cows could have been a factor in decreasing milk production. In this connection, Renbarger _et al._ (1964) have found that low feeding levels before calving are not recovered in terms of milk production by liberal feeding after calving.

(iii) _Age of dam_ - The least squares means for the effect of age of dam on milk production are shown in Table 4.8. The age of dam influence approached significance ($0.05 < P < 0.01$) at 20-days post-partum, was highly significant at 40 days ($P < 0.01$), but was non-significant at 60 days. The older cows 8-years and older, had the highest estimates at 20- and 40-days post-partum, but not at 60 days, when 7-year-old cows had the highest milk production estimate. Similar findings were obtained by Pleasants (1974). This result is likely to be due to the better temperament of older cows during measurements, thereby promoting a greater milk flow.

Four-year-olds produced less milk at 40- and 60-days post-partum, significantly so at 40 days, but the 5- and 6-year-olds produced the least amount of milk at 20-days post-partum. The reason for the low production in 4-year-old cows could be due to the excitability of young cows whilst measurements were being taken, thereby inhibiting milk let-down.

(iv) _Sex of calf_ - The results of the present study on the influence of sex of calf on milk consumption of the calf are conflicting. For instance at 20-days post-partum

Table 4.8

Least squares means and standard errors for the effect of age of dam, sex of calf, and the regression coefficient of calving date on milk production of the dam

	No. of records	Milk production (kg) 20-day	40-day	60-day
General mean	61	4.9 ± 0.2	5.0 ± 0.3	4.7 ± 0.3
Age of dam (years)				
4	7	4.7 ± 0.5	3.4 ± 0.6[a]	4.1 ± 0.7
5 + 6	13	4.3 ± 0.3	4.5 ± 0.4[ab]	5.0 ± 0.5
7	36	4.7 ± 0.2	5.5 ± 0.3[bc]	5.3 ± 0.3
8 +	5	5.9 ± 0.6	6.5 ± 0.8[c]	4.5 ± 0.8
Sex of calf				
Male	34	5.2 ± 0.3*	4.9 ± 0.4	4.7 ± 0.4
Female	27	4.6 ± 0.3	5.1 ± 0.4	4.9 ± 0.4
Regression on calving date (days/kg)	61	0.015 ± 0.026	0.054 ± 0.034	0.047 ± 0.038

Note: Superscripted values are significantly different from unsuperscripted or differently superscripted values at the 5% level of significance.

* $P < 0.05$

(Table 4.8) male calves consumed significantly ($P < 0.05$) more milk than female calves, but at 40- and 60-days this was reversed with female calves consuming more, although the mean differences were not statistically significant. These results are consistent with those of Pleasants (1974) who in one year found male calves consumed more milk, but in the next year the reverse was observed.

Male calves are heavier at birth than females. This was the case in all comparisons reviewed by Preston and Willis (1974). Pleasants (1974) working also with the Angus herd at Massey University observed that males were consistently heavier at birth than females, although results were only significant ($P < 0.05$) in two of the years of his study, probably due to the low number of animals involved. The larger size of the male calf implies that its demand for milk is greater at an earlier age than that of the smaller female calf. In response to this increased demand and increased suckling frequency the dam produces more milk. Pleasants (1974) considered that climatic conditions could affect the sexes differently, with male calves more suited to adverse climatic conditions.

(v) Calving date - The least squares regression coefficients are shown in Table 4.8. The values are low and positive indicating an increase of 0.01 to 0.05 kg of milk for each day later that a calf was born. These results are contrary to what is expected. As a calf ages it would be expected to consume more milk, but in the present work it may be that there was no more milk available to the calf later in the lactation period. Pleasants (1974) found small negative regression coefficients of the order of 0.02 to 0.03 kg of milk consumed for every day of age of the calf. He suggested that older calves finish suckling earlier and therefore have more time to defaecate and/or urinate before reaching the weighing scales. If this is the case, this could account for the positive regression coefficients found in the present study.

3. Cow liveweights

Post-calving cow liveweight changes were studied in the hope that they would explain the results of the oestrous observations reported earlier. The analysis of variance of cow liveweights (Model 3.2) taken at 20-, 40-, 60-, 80- and 100-days post-partum are presented in Table 4.9. It will be seen in the table that blocks, treatments and age of dam are all significant sources of variation at every measurement while sex of suckling calf influenced cow liveweights only at 100-days post-partum.

(i) Blocks - Least squares means for the effect of blocks on cow liveweight are shown in Table 4.10. The general mean indicates that cows in this experiment increased in liveweight by approximately 40 kg from 20-days post-partum to 100-days post-partum. The cows in Block A increased by some 50 kg but started from a comparatively low liveweight of 359.6 kg compared to the mean starting liveweight of 382 kg. Block B cows increased by 15 kg over this period while Block C increased by 50 kg up to 441 kg or 20 kg above the mean at 100-days post-partum.

These liveweight changes, within each of the blocks, are also represented in Fig. 4.1 where cow liveweights are plotted against days post-partum. The weights of the cows in Block A show a gradual increase with time. Block B cows, however, experienced a considerable liveweight loss between 20- and 40-days post-partum, but thereafter they recovered to the same level as Block A cows. The likely explanation of this would be the fact that full rations were withheld from Block B cows for 2 to 3 weeks following calving. Block C cows had a similar liveweight loss over this period, but not as severe, and then subsequently recovered to the highest 100-day liveweight of any of the three blocks.

Block A cows were the lightest at 20-days post-partum, yet they recovered to nearly reach the general mean liveweight of 421 kg at 100-days post-partum. This finding endorses the belief that cows need not be fed quite so well in the

Table 4.9

Analysis of variance of the main effects for post-partum cow liveweight

Source of variation	df	Mean squares (days post-partum) 20	40	60	80	100
Blocks	2	4120.49***	851.59ns	1647.56*	287.61	1584.03**
Treatments	9	894.54**	2102.67***	1230.78**	1308.57***	1132.59***
Age of dam	3	1170.55*	1118.92*	835.49*	832.48ns	984.94*
Sex of calf	1	390.08	56.70	971.71	1177.55ns	2000.24**
Regression on calving date	1	18.87	103.89	55.47	32.89	0.31
Regression on autumn cow liveweight	1	33409.77***	24935.25***	25787.73***	13228.51***	27881.97***
Error	43	286.54	271.04	350.54	307.64	265.38

ns 0.05 < P < 0.10 * P < 0.05 ** P < 0.01 *** P < 0.001

Table 4.10

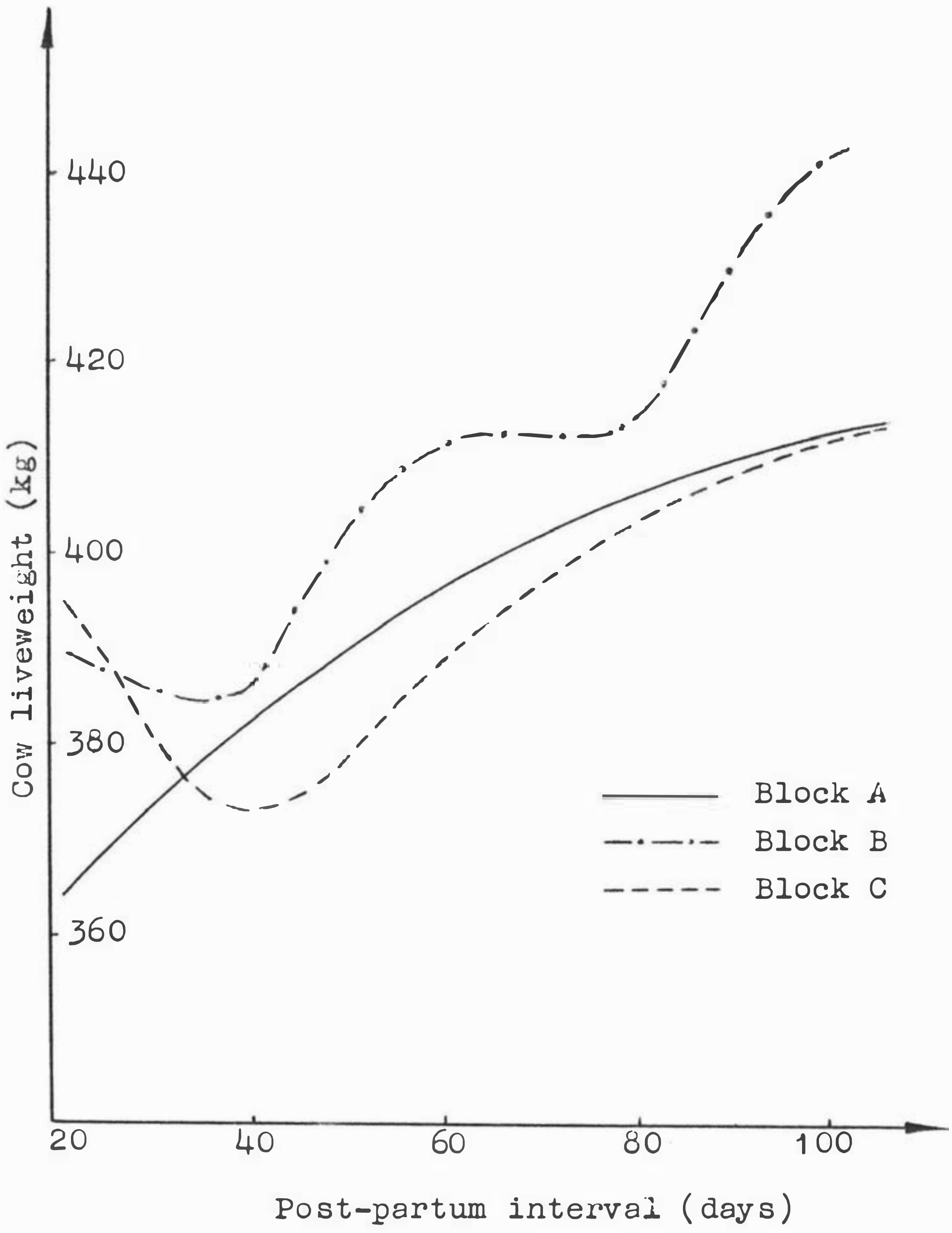
Least squares means and standard errors for the effect of blocks on cow liveweight (kg)

Days post-partum	General Mean	Block A	Block B	Block C
20	382.5 ± 3.5	359.6 ± 6.8[a]	396.3 ± 5.3	391.3 ± 7.1
40	378.4 ± 3.4	381.2 ± 6.6	369.6 ± 5.2	384.5 ± 6.9
60	396.5 ± 3.9	390.7 ± 7.5[ab]	384.9 ± 5.9[a]	413.8 ± 7.8[b]
80	405.7 ± 3.6	403.3 ± 7.1	400.9 ± 5.5	412.9 ± 7.3
100	421.2 ± 3.4	411.0 ± 6.6	411.4 ± 5.1	441.1 ± 6.8[a]

Note: Superscripted values are significantly different from unsuperscripted or differently superscripted values at the 5% level of significance.

Fig. 4.1

Cow liveweight *versus* interval from parturition (for each Block)



first three or so weeks after parturition provided they are well fed after this to recover their loss of weight.

(ii) Treatments - Least squares means for the effect of treatments on cow liveweights are shown in Table 4.11. From Table 4.9 it can be seen that treatments were highly significant sources of variation at 20-days ($P < 0.01$), 40-days ($P < 0.001$), 60-days ($P < 0.01$), 80-days ($P < 0.001$) and 100-days post-partum ($P < 0.001$).

Those cows that remained on the hill throughout the experiment or were removed from the pad at the time of the birth of their calves were consistently heavier than those remaining on the pad until 20- or 40-days post-partum. This advantage remained right through to 100-days post-partum. In Block B the cows in the treatments, namely, off the pad at 20- and 40-days post-partum, lost 3.0 kg and 2.5 kg respectively, over the period of the experiment. These cows had restricted rations for the first two to three weeks after calving and this together with the longer period spent on the pad before calving (compared with Block A) allowed these cows to just maintain their liveweight over the first 100 days after calving.

Block C cows actually gained more liveweight than Block A cows in all treatment groups. This was probably due to the better quality and greater quantity of pasture available to this block of cows. It should also be mentioned that Block C cows calved on average 23 days later than Block A cows.

(iii) Age of dam - Least squares means for age of dam influence on cow liveweights are shown in Table 4.12. The mean differences in Table 4.12 were significant ($P < 0.05$) at 20-, 40-, 60- and 100-days post-partum and approached significance at 80-days ($0.05 < P < 0.10$). Four-year-old cows were the lightest animals in this study. They were lightest at 20-days post-partum and remained so to 100-days post-partum. This reflects the heavy drain of lactation

Table 4.11

Least squares means and standard errors for the effect of treatments on cow liveweight (kg)

Treatment	Days post-partum	Block A	Block B	Block C
Hill	20	356.8 ± 7.4	397.7 ± 6.5	418.5 ± 8.6
	40	382.1 ± 7.2	394.4 ± 6.3	399.4 ± 8.4
	60	389.8 ± 8.2	402.1 ± 7.2	434.8 ± 9.6
	80	394.9 ± 7.6	418.0 ± 6.7	432.6 ± 8.9
	100	402.3 ± 7.1	429.7 ± 6.2	453.6 ± 8.3
PB	20	349.1 ± 6.9	393.3 ± 9.2	400.6 ± 12.1
	40	383.3 ± 6.7	390.4 ± 9.0	399.6 ± 11.7
	60	395.5 ± 7.6	400.3 +10.2	418.1 ± 13.3
	80	412.8 ± 7.1	418.5 ± 9.6	415.4 ± 12.5
	100	420.2 ± 6.6	427.3 ± 8.9	442.8 ± 11.6
P20	20	370.7 ±10.8	392.5 ± 7.6	381.9 ± 6.3
	40	401.9 ±10.5	349.7 ± 7.4	381.5 ± 6.1
	60	397.4 ±12.0	366.3 ± 8.4	412.9 ± 6.9
	80	413.8 +11.2	380.3 ± 7.9	412.7 ± 6.5
	100	421.1 ±10.4	389.6 ± 7.3	444.7 ± 6.1
P40	20	358.9 ± 9.8	401.6 ± 7.6	364.2 ± 6.5
	40	357.5 ± 9.5	343.9 ± 7.4	357.6 ± 6.3
	60	380.0 ±10.8	370.8 ± 8.5	389.5 ± 7.1
	80	391.7 ±10.2	386.7 ± 7.9	390.9 ± 6.7
	100	400.4 ± 9.4	399.0 ± 7.4	422.9 ± 6.2

Table 4.12

Least squares means and standard errors for the effect of age of dam on cow liveweight (kg)

	Days post-partum				
	20	40	60	80	100
General mean	382.5 ± 3.5	378.4 ± 3.4	396.5 ± 3.9	405.7 ± 3.6	421.2 ± 3.4
Age of dam (years)					
4	366.2 ± 7.3^{a}	363.4 ± 7.1^{a}	383.3 ± 8.1^{a}	398.4 ± 7.6	407.7 ± 7.0^{a}
5 + 6	378.5 ± 5.4^{ab}	378.9 ± 5.3^{ab}	395.4 ± 6.0^{ab}	403.4 ± 5.6	418.2 ± 5.2^{ab}
7	391.7 ± 3.2^{b}	391.1 ± 3.1^{b}	406.8 ± 3.6^{b}	418.1 ± 3.3	432.0 ± 3.1^{b}
8 +	393.4 ± 8.6^{b}	380.2 ± 8.4^{ab}	400.4 ± 9.5^{ab}	402.9 ± 8.9	426.9 ± 8.3^{ab}

Note: Superscripted values are significantly different from unsuperscripted or differently superscripted values at the 5% level of significance.

on younger immature cows.

The 8-year-old cows were the heaviest at the start of the period, but then lost weight up to 40-days post-partum. They subsequently regained this weight plus more by 100-days post-partum. This age group produced the most milk at 40-days post-partum which would account for the drop in their liveweight. The cows in the 7-year-old age group were the heaviest in the experiment.

(iv) Sex of calf - Cows suckling male calves were lighter than those suckling female calves (Table 4.13). These differences approached significance at 80-days post-partum ($0.05 < P < 0.10$) and were significant at 100-days post-partum ($P < 0.01$). The difference at 100-days post-partum was 14 kg. If it is accepted that the male calf suckles more frequently than the female calf and so increases its dam's milk production, then the drain of this extra milk production could explain the liveweight difference obtained.

Male calves consumed significantly more milk at 20-days post-partum, but at 40- and 60-days post-partum female calves consumed more although sex differences for the last two ages were not statistically significant. It is possible that male calves have a more prolonged influence on the liveweight of the cow. Unfortunately cow liveweight at weaning was not obtained in this study, but it would be interesting to note if the difference continued up to that stage.

(v) Calving date - The regression coefficients of date of calving on post-partum cow liveweights are shown in Table 4.14. The values presented in the table are small and positive up to 80-days post-partum, ranging from 0.10 to 0.25 days/kg. At 100-days post-partum the value is negative, namely, -0.01 days/kg. Date of birth of the calf influences cow liveweights at the early post-partum weighings, but this effect is negligible at 100-days post-partum.

(vi) Autumn liveweight of the cow - Autumn liveweight of

Table 4.13

Least squares means and standard errors for the effect of sex of calf on cow liveweight

Days post-partum	Cow liveweight (kg) suckling Male calf	Female calf
20	379.5 ± 4.4	385.4 ± 4.3
40	377.3 ± 4.3	379.5 ± 4.1
60	391.8 ± 4.9	401.2 ± 4.7
80	400.5 ± 4.6^{ns}	410.9 ± 4.4
100	414.4 ± 4.2**	428.0 ± 4.1

ns $0.05 < P < 0.10$

** $P < 0.01$

Table 4.14

The least squares regression coefficients for the effect of date of calving and of the autumn liveweight of the cow on her liveweight post-partum

Days post-partum	Regression coefficient: Date of calving (days/kg)	Regression coefficient: Autumn liveweight (kg/kg)
20	0.109	0.721***
40	0.255	0.623***
60	0.186	0.634***
80	0.144	0.653***
100	-0.014	0.659***

*** $P < 0.001$

the cow was expressed in Model 3.2 as a second covariate. The regression coefficients are given in Table 4.14 and these range from 0.62 to 0.72 kg. As was expected the effect of autumn liveweight was highly significant ($P < 0.001$) at each of the post-partum weighings.

4. Calving interval

The analysis of variance of the main effects for calving interval (Model 3.1) is shown in Table 4.15. The only significant source of variation was the regression of calving date on subsequent calving interval. All other factors had non-significant F ratios. The least squares mean was 367.6 days.

(i) Blocks - Table 4.16 presents the least squares means and their standard errors for the effect of blocks on calving interval. The shortest mean interval (361.1 days) was found in Block A while the longest mean interval (376.8 days) was that of the cows in Block C. The same trend was observed in the post-partum interval to first oestrus, where Block A cows had the shortest (72.6 days) and Block C cows the longest (84.3 days) interval. These differences between blocks, however, were not statistically different.

(ii) Treatments - The least squares means for the effect of treatments on calving interval are presented in Table 4.16. Like the effect of treatment on post-partum interval the effect on calving interval was also non-significant.

The cows in treatments P20 and P40 of Block C had relatively longer calving intervals (371.4 and 374.3 days, respectively) compared to the mean (367.6 days). Block C cows were on the pad for an extended period prior to calving, consequently they had longer post-partum intervals to first oestrus. This may account for their prolonged calving intervals.

Table 4.15

Analysis of variance of the main effects for calving interval

Source of variation	df	Mean square
Blocks	2	150.45
Treatments	9	112.99
Age of dam	3	59.37
Sex of calf	1	2.06
Regression on calving date	1	507.55*
Error	34	86.13

* $P < 0.05$

Table 4.16

Least squares means and standard errors for calving interval

Source	No. of records	Mean (days)
General mean	51	367.6 ± 2.2
Blocks		
A	17	361.1 ± 4.2
B	19	364.9 ± 3.3
C	15	376.8 ± 5.6
Block A		
H	7	364.0 ± 4.4
PB	5	370.3 ± 4.2
P20	2	365.5 ± 6.0
P40	3	370.7 ± 5.7
Block B		
H	6	374.3 ± 3.9
PB	2	355.9 ± 6.2
P20	5	373.8 ± 4.3
P40	6	366.4 ± 4.4
Block C		
H	4	358.5 ± 5.5
PB	2	366.1 ± 6.4
P20	5	371.4 ± 4.1
P40	4	374.3 ± 5.2
Age of dam		
4 years	4	364.3 ± 5.3
5 + 6 years	9	367.6 ± 3.7
7 years	33	366.0 ± 1.8
8 + years	5	372.5 ± 4.8
Sex of calf		
Male	27	367.9 ± 2.7
Female	24	367.4 ± 2.6
Regression on calving date	51	-0.85 ± 0.35

(iii) Age of dam - The least squares means for the influence of age of dam on calving interval are given in Table 4.16. An unexpected observation was that the 4-year-old cows had the shortest interval (364.3 days) and the 8-year-old and older cows had the longest interval (372.5 days).

The trend for calving intervals to lengthen as cows become older has been noted earlier by Belling (1963), who found that the most efficient period of reproduction to be between the ages of 3- to 7-years. He also showed that cows older than 8-years-of-age had longer calving intervals.

The differences between age classes, however, were non-significant, with results being restricted by the low sub-class numbers.

(iv) Sex of calf - There was no difference in calving intervals between cows suckling either male or female calves.

(v) Calving date - Calving date significantly influenced the subsequent calving interval ($P < 0.05$). The regression coefficient obtained was -0.85 (Table 4.16). This suggests that for every day later in the calving season a cow calves, the subsequent calving interval will be decreased by 0.85 days. Over a 60-day calving season this would amount to a 51-day decrease in calving interval between the first and last day of the calving season.

(vi) Frequency of calving intervals - Table 4.17 indicates the different frequencies of calving intervals. Only 47.1% of the cows exhibited a 365-day calving interval. However, after 13-months from the previous calving almost all cows (96.1%) had calved.

5. Correlations

Product-moment correlations between interval to first post-partum oestrus and various cow and calf variables are given in Table 4.18.

Table 4.17

Cumulative frequency of calving interval

Calving interval (days)	Cumulative frequency (%)
335	0.0
350	3.9
365	47.1
380	92.2
395	96.1
400	100.0

Table 4.18

Correlations between time to first post-partum oestrus (X variable) and various cow and calf traits (Y variables)

Mean time to first post-partum oestrus = 81.2 days
Standard deviation = ± 16.1 days

Variable (Y)	No. of records	Mean (Y)	Correlation coefficient
Calving interval (days)	51	367.2	0.29*
Calf birth-weight (kg)	59	28.9	0.19
Milk production of cow (kg)			
20 days	61	4.7	0.25*
40 days	61	5.1	0.04
60 days	61	4.9	0.12
Cow liveweight (kg)			
April	61	428.8	0.07
June	61	414.7	0.09
April to June - difference	61	14.1	-0.03
July	61	422.5	0.07
15 July	61	420.3	0.02
June to 15 July - difference	61	5.6	-0.22
20 days post-partum	61	384.6	0.01
40 days post-partum	61	382.0	-0.02
60 days post-partum	61	400.1	-0.09
80 days post-partum	61	409.8	-0.02
100 days post-partum	61	424.9	-0.03
20 to 100 days post-partum - difference	61	40.4	-0.04

* $P < 0.05$

Calving interval showed a positive and significant correlation with the interval to first post-partum oestrus ($r = 0.29$, for 49 df, $P < 0.05$). This indicates that the post-partum interval accounts for 8% of the variation in calving interval. Flores (1971) found that the post-partum oestrus interval contributed to 52.0% of the variation in calving interval. This is considerably greater than that observed in this present study.

Calf birth-weight was not correlated with post-partum interval nor was milk production of the dam at 40- and 60-days post-partum. Milk production at 20-days post-partum, however, was positively and significantly correlated with post-partum interval ($r = 0.25$, for 59 df, $P < 0.05$). Actual 60-day milk production in the study of Whitmore et al. (1974) showed a significant but low correlation with post-partum interval to first oestrus, ($r = 0.16$, for 276 df, $P < 0.05$); but the cows in their study were of dairy breeding. Herman and Edmondson (1950), also working with dairy cows, did not find any relationship between milk production and post-partum interval, while Kaiser (1975) did not find a correlation with butterfat production over the first 6 weeks of lactation.

None of the cow liveweights recorded pre- or post-calving (Table 4.18) was significantly correlated with post-partum interval to first oestrus. Kaiser (1975) has observed the correlation of cow liveweight change from calving to 40-days post-partum to be low and non-significant. Small sub-class numbers are a contributing factor to these low and non-significant correlations in both Kaiser's and this present study.

Calving interval was positively and significantly (Table 4.19) correlated with 20-day milk production ($r = 0.32$, for 49 df, $P < 0.05$). Milk production at 40- and 60-days, however, was not correlated with calving interval.

None of the cow liveweights recorded (Table 4.19) was significantly correlated with calving interval.

Table 4.19

Correlations between calving interval (X variable) and various cow and calf traits (Y variables)

Mean calving interval = 367.2 days
Standard deviation = ±9.9 days

Variable (Y)	No. of records	Mean (Y)	Correlation coefficient
Interval to first post-partum oestrus (days)	51	80.3	0.28*
Milk production of cow (kg)			
20 days	51	4.7	0.32*
40 days	51	5.1	0.04
60 days	51	4.9	0.02
Cow liveweights post-partum (kg)			
20 days	51	391.0	0.08
40 days	51	386.5	0.13
60 days	51	404.1	0.09
80 days	51	414.0	0.08
100 days	51	428.4	0.14
20 to 100 days - difference	51	37.4	0.07

* $P < 0.05$

B. Ministry of Agriculture and Fisheries' Data

1. Post-partum oestrous interval

The analysis of variance of the main effects on interval to first post-partum oestrus included in Model 3.3, is presented in Table 4.20. The only significant sources of variation were year of record and age of dam. All other factors, including the regression of cow liveweight change post-partum on time to first oestrus, had non-significant F ratios. However, the regression coefficient of date of calving on time to first oestrus was a significant source of variation.

The first-order interactions between the non-nested effects of year x sex, year x age and age x sex failed to reach significance so were excluded from Model 3.3.

(i) Year of record - Year of record proved to be a significant source of variation ($P < 0.001$) on interval to first post-partum oestrus. Least squares means and standard errors for the 4 years are presented in Table 4.21. The estimates range from 67.9 days in 1975 to 84.9 days in 1973 with the general mean being 74.7 days. The major component of this yearly variation is probably due to climatic conditions.

The longest interval was recorded in 1973 which was one of the three driest years experienced in New Zealand since recording began in 1900 (New Zealand Meteorological Service, 1973). At Whatawhata the yearly rainfall totalled 1339 mm in 1973 compared with 1772 mm in 1971 and 1889 mm in 1972. A dry autumn and early winter leads to a shortage of feed for the cows in the late winter and early-spring period when feed requirements are at a maximum. This may have contributed to the delay in post-partum ovarian activity. However, the relatively mild autumn-winter period of 1975 (New Zealand Gazette, March, 1975 to October, 1975) probably resulted in better feed supplies being available and therefore reduced the period to first oestrus. The unusually wet spring of 1971 may have contributed to the delayed resumption of post-

Table 4.20

Analysis of variance of the main effects for interval to first post-partum oestrus

Source of variation	df	Mean square
Year	3	2774.48***
Sire	12	338.51
Mating group	10	377.17
Age of dam	4	1161.39**
Sex of calf	1	80.59
Regression on calving date	1	15,058.08***
Regression on cow liveweight change	1	1049.49ns
Error	171	287.86

ns $0.05 < P < 0.10$

** $P < 0.01$

*** $P < 0.001$

Table 4.21

Least squares means and standard errors for the effect of year on interval to first post-partum oestrus

Year	No. of records	Mean (days)
1971	58	$77.3^{a} \pm 2.8$
1972	64	$68.6^{b} \pm 2.8$
1973	51	$84.9^{c} \pm 2.8$
1975	31	$67.9^{b} \pm 3.7$
General mean	204	74.7 ± 1.8

Note: Superscripted values are different from unsuperscripted or differently superscripted values at the 5% level of significance.

partum ovarian activity in that year.

There is a need for closer monitoring of cow liveweight changes with meterological data before any sound conclusions can be made as to the relationship between weather and the length of the post-partum period.

(ii) Age of dam - Least squares means for age of dam influence on time to post-partum oestrus are shown in Table 4.22. The 2-year-old and 3-year-old cows had the longest intervals. These findings are consistent with those reported in the literature.

An interesting observation was that 3-year-old cows returned to oestrus in 83.6 days compared with 79.8 days for 2-year-old cows. This difference, although non-significant, may be attributed to the stress of first calving as a 2-year-old. The findings support the recommendation that 15-month heifers should be mated 20 days before the main herd. This should ensure that they will calve earlier the following season and therefore will have a longer period in which to return to cyclic activity. These heifers should also be fed preferentially right through to their second calving at 3-years-of-age, so that their growth will not be impeded.

Observations made in the present study indicate that this interval shortens as the cow ages and this is in agreement with results in the literature. Insufficient numbers however, prevented a study of the effects of old age on time to first post-partum oestrus.

(iii) Sex of calf - Contrary to the findings at Massey University the 104 cows that nursed male calves returned to oestrus earlier (1.3 days) than the 100 cows nursing female calves (Table 4.23). However, these differences were not statistically significant.

(iv) Calving date - Date of calving significantly ($P < 0.001$) influenced the interval to first post-partum

Table 4.22

Least squares means and standard errors for the effect of age of dam on interval to first post-partum oestrus

Age of dam (years)	No. of records	Mean (days)
2	17	$79.8^{ab} \pm 4.8$
3	14	$83.6^{a} \pm 5.0$
4	24	$73.3^{ab} \pm 3.9$
5	21	$70.7^{b} \pm 4.1$
6 +	128	$66.2^{b} \pm 2.7$
General mean	204	74.7 ± 1.8

Note: Superscripted values are different from unsuperscripted or differently superscripted values at the 5% level of significance.

Table 4.23

Least squares means and standard errors for the effect of sex of calf and the regression coefficients of date of calving and cow liveweight change on interval to first oestrus

	No. of records	Interval to first oestrus (days)
General mean	204	74.7 ± 1.8
Sex of calf		
Male	104	74.0 ± 2.1
Female	100	75.4 ± 2.2
Regression on calving date (days/day)	204	-0.47 ± 0.06***
Regression on cow liveweight change (days/kg)	204	-0.11 ± 0.07ns

ns $0.05 < P < 0.10$

*** $P < 0.001$

oestrus. The estimated regression coefficient of date of calving on time to first oestrus is shown in Table 4.23. The value is -0.47, which means that for each day later that a cow calved, the period from calving to first oestrus was reduced by 0.47 days. Thus over the 90-day calving season at Whatawhata, this produced a difference of 42 days between cows calving on the first and last day of the season.

(v) Cow liveweight change - The difference in cow liveweights recorded prior to mating and within 48 hours of calving failed to reach significance ($0.05 < P < 0.10$). The average change in cow liveweight over this period was 18.6 kg and the estimated regression coefficient was -0.11 kg/day (Table 4.23). Thus for every 0.11 kg liveweight change a decrease in time to first oestrus of 1 day is observed.

(vi) Sire of calf - The sire of the suckled calf had no influence on the post-partum interval.

(vii) Mating group - In this study mating group had no effect on post-partum interval. This can be explained partly by the observation that some cows showed oestrus before they joined a mating group.

The separate grazing of the groups may have resulted in a paddock effect, but this was not demonstrated in these data. Thus it would appear that any nutritional influence on post-partum oestrus was determined prior to the formation of mating groups.

(viii) Frequency of cows showing oestrus - Table 4.24 presents the percentage of the total cows in each year which exhibited oestrus at various post-partum intervals. The shortest post-partum intervals occurred in 1972 and 1975 (Table 4.21) which explains why these years have a high proportion of cows showing oestrus within 90 days.

If a 90-day post-partum interval is taken as the maximum possible to ensure a 365-day calving interval, the percentages of cows that did not meet this standard were: 16.9, 9.4,

Table 4.24

Cumulative frequency of post-partum oestrual activity

Days post-partum	Cumulative frequency (%) Year of record 1971	1972	1973	1975
50	11.9	32.8	3.9	21.2
60	27.1	46.9	11.8	42.4
70	42.4	65.6	27.5	66.7
80	67.8	82.8	54.9	81.8
90	83.1	90.6	74.5	97.0
100	93.2	95.3	88.2	97.0
110	96.6	96.9	98.0	97.0
140	100.0	100.0	100.0	100.0

25.5 and 3.0 for 1971, 1972, 1973 and 1975, respectively. Climatic variables are probably responsible for this yearly variation.

2. Calving interval

The analysis of variance of the main effects for calving interval is shown in Table 4.25. The only factors that significantly influenced this interval were mating groups ($P < 0.05$) and the regression coefficient for date of birth on calving interval ($P < 0.001$). The least squares mean was 365.1 days.

(i) Mating group - Least squares means for the effect of mating group on calving interval are presented in Table 4.26. The values are significantly different ($P < 0.05$) and range from 353.3 to 388.3 days. The group with the longest calving interval also had the longest post-partum interval. This was mating group No. 6, which had a mean calving interval of 388.1 days and post-partum oestrus interval of 85.8 days. In comparison, mating group No. 8 had the shortest mean calving interval of 353.3 days and a post-partum oestrus interval of 57.8 days.

The mating group effect has two components, a bull effect and a paddock effect. However, the cows were only in mating groups for 3 months, so it was unlikely that this contributed to the variation to any extent.

The bull effect, through its influence on gestation length is more important. Hafez (1974) states that the genotype of the foetus is recognised as playing a part in the duration of pregnancy in cows. In their reviews, Anderson and Plum (1965) and Preston and Willis (1974) noted that sire effects within breeds may be as great as differences between breeds in influencing the gestation length.

(ii) Year of record - Year of record accounted for little or no variation in calving interval. The calving interval for 1971/72 was 366.4 days while for 1972/73 it

Table 4.25

Analysis of variance of the main effects for calving interval

Source of variation	df	Mean square
Year	1	93.79
Sire	7	215.69
Mating group	6	780.53*
Age of dam	4	264.76
Sex of calf	1	0.28
Regression on calving date	1	12107.51***
Error	63	18007.74

* $P < 0.05$

*** $P < 0.001$

Table 4.26

Least squares means and standard errors for the effect of mating group on calving interval

Mating group No.	No. of records	Calving interval (days)
1	13	360.2 ± 6.5
2	13	374.6 ± 6.4
3	10	364.1 ± 5.7
4	12	361.5 ± 5.6
5	13	360.8 ± 5.5
6	5	388.3 ± 7.9
7	7	357.8 ± 6.7
8	11	353.3 ± 5.7
General mean	84	365.1 ± 3.4

was 363.8 days. This difference may be related to post-partum oestrus intervals for 1971 and 1972 of 77.3 and 68.6 days, respectively.

Climatic conditions in different years probably influence calving intervals through their effect on pasture production. Other workers have found significant yearly variations in this trait (Wilson and Willis, 1974; Mahadevan et al., 1972).

(iii) Age of dam - Least squares means for the effect of age of dam on calving interval are given in Table 4.27. The differences between age classes were not significant. There was, however, a general trend towards calving intervals being shorter as cows become older. The longest interval (371.8 days) was in the 2-year-old age group, while the shortest interval (358.2 days) was in the 6-year-old and older age group.

Plasse et al. (1968) have noted that calving intervals decreased in length with increasing age while Lindley et al. (1958) have observed that calving intervals continue to decrease in cows up to 10-years-of-age after which they increase.

(iv) Sex of calf - There was no difference in calving interval between cows suckling male or female calves. The sex of the foetus however, was not included in Model 3.4.

(v) Sire of calf - The sire of the suckled calf had no effect on calving interval. The sire of calf carried in utero would be a more important factor than sire of calf at foot.

(vi) Calving date - Calving date significantly influenced calving interval ($P < 0.001$). The regression coefficient was -0.69 (Table 4.27). This means that for every day later in the calving season a calf is born the calving interval is decreased by 0.69 days. Over a 90-day calving season, such as existed at Whatawhata, this amounts to a 60-day decrease

Table 4.27

Least squares means and standard errors for the effect of year of record, age of dam, sex of calf and regression coefficient of calving date on calving interval

	No. of records	Calving interval (days)
Year of record		
1971	48	366.4 ± 3.5
1972	36	363.8 ± 4.7
Age of dam (years)		
2	2	371.8 ±14.5
3	7	365.4 ± 7.3
4	13	369.4 ± 5.5
5	16	360.5 ± 4.7
6 +	46	358.2 ± 3.2
Sex of calf		
Male	39	365.0 ± 3.9
Female	45	365.1 ± 4.2
Regression on calving date (days/day)	84	$-0.69 \pm 0.11^{***}$

*** $P < 0.001$

in calving interval between a cow calving on the first and last day of the calving season.

(vii) Frequency of calving intervals - Table 4.28 shows the different calving intervals and the frequency observed in each of these intervals. Only 63.1% of the cows had a 12-month calving interval. However, the majority (91.7%) calved within a 13-month interval, while all had calved within 14-months.

3. Correlations

Product-moment correlations between interval to first post-partum oestrus, and various cow and calf variables are presented in Table 4.29.

Calving interval showed a significant and positive correlation with post-partum interval to first oestrus ($r = 0.54$, for 82 df, $P < 0.01$). This means that the post-partum interval accounts for 29% of the variation in calving interval.

The calf's liveweight gain is considered a reasonable indirect indicator of a dam's milk production (Barton, 1970). Many authors consider that high milk production may be detrimental to reproductive efficiency. If this is true, then a positive correlation is expected between calf gain and the post-partum interval to first oestrus. The value obtained was positive and significant ($r = 0.28$, for 205 df, $P < 0.01$). There was no significant correlation between calving interval and calf liveweight gain.

Cow liveweight change between April and July was negative and significantly correlated with post-partum interval to first oestrus ($r = -0.33$, for 181 df, $P < 0.01$). Cow liveweights taken post-calving and pre-mating were also significant ($r = 0.19$, for 203 df, $P < 0.01$ and $r = 0.19$, for 204 df, $P < 0.01$). The only other cow liveweight that showed a significant correlation with post-partum interval to first oestrus

Table 4.28

Cumulative frequency of calving interval

Calving interval (days)	Cumulative frequency (%)
335	15.5
350	34.5
365	63.1
380	84.5
395	91.7
410	98.8
424	100.0

Table 4.29

Correlations between time to first post-partum oestrus (X variable) and various cow and calf traits (Y variables)

Mean time to first post-partum oestrus = 70.3 days
Standard deviation = ± 20.9 days

Variable (Y)	No. of records	Mean (Y)	Correlation coefficient
Calf birth-weight (kg)	204	28.2	0.03
Calf liveweight gain to weaning (kg)	207	0.86	0.28**
Day conceived[1]	201	341	0.19**
Calving interval (days)	84	359.6	0.54**
Cow liveweights (kg)			
April	184	407.1	-0.01
June	205	402.2	-0.08
July	206	402.1	-0.11
April to July - difference	183	-7.6	-0.33**
Pre-calving	206	414.1	-0.15*
July to pre-calving - difference	205	11.9	-0.08
Post-calving	205	380.4	-0.19**
Pre-mating	206	398.8	-0.19**
Post-calving to pre-mating - difference	204	18.5	-0.03

Note: [1] Day 1 = 1 January
* $P < 0.05$
** $P < 0.01$

was the pre-calving liveweight ($r = 0.15$, for 204 df, $P < 0.05$).

The correlations involving cow liveweights, however, contain some bias as they did not take age of cow into account. None of the traits reported in Table 4.29 was significantly correlated with calving interval.

CHAPTER FIVE

CONCLUDING DISCUSSION

Perhaps the most significant finding in this present study was the similarity in length of the interval from parturition to first post-partum oestrus between the two locations. The mean interval for the Angus cows on the Massey University Tuapaka farm was 79.2 days compared with 74.7 days for the Ministry of Agriculture and Fisheries' herd at the Whatawhata Hill Country Research Station.

There are no other New Zealand data available to use as a direct comparison; however, the intervals were longer than those reported in the overseas literature for single-suckled Angus cows. Warnick (1955) noted the interval was of 59.0 day's duration while Perkins and Kidder (1963) reported an interval of 52.2 days. Ustinov (1973) also working with Angus cows observed an interval of 67.1 days while Lasley and Bogart (1943) indicated an interval of 80.2 days in Herefords.

The calving intervals for the two locations were 367.6 and 365.1 days for the Massey University and the Ministry of Agriculture and Fisheries herds, respectively. The correlations between post-partum interval to first oestrus and calving interval for the Massey University and the Ministry of Agriculture and Fisheries' data, were 0.29 and 0.54, respectively. These figures indicate that post-partum interval to first oestrus contributes to 8% and 29% of the variation in calving interval respectively for the two locations. However, there are many other factors involved, such as nutrition during the gestation period and sire of the foetus, both of which could not be considered in this study.

It was stated in the introduction to this present work that a 90-day interval to first post-partum oestrus is the maximum allowable if a calving interval of less than 365 days is to be achieved. The results indicate that up to 25% of the cows did not show oestrus within 90-days post-partum and therefore would not calve at yearly intervals.

In the Massey University herd only 80% of the cows had a post-partum oestrous interval of less than 90 days. The proportion of these same cows that calved within 365 days the following year was 47.1%. However, 92.2% had calving intervals of 380 days. This indicates that approximately 50% of the cows conceived at first detected post-partum oestrus, while the rest probably conceived at the next oestrus.

There were 10 cows (16%) in the Massey University herd that did not conceive. Seven of these were in the latter-calving group (Block C) and consequently did not come into oestrus until the last week of the mating season, when possibly the bulls had lost interest. The other three cows experienced unusually long post-partum intervals of 84, 96 and 124 days, respectively, which would allow for only one cycle within the mating season.

First post-partum oestrus in this study was taken as first detected oestrus although it is highly likely however, that cows will experience a silent or quiet ovulation before first detected oestrus. Data are also limited by the use of chin-ball mating harnesses as this method of heat detection on hill country can lead to missed records. It was observed, for instance that a bull mounting a cow up hill will often not leave a mark on the cow's rump. In addition, some of the larger bulls learnt to hold their heads to the side while mounting and dismounting and consequently did not mark some of the cows. Irritation from the leather of the harness on the bull's head may have caused this aberrant behaviour while mounting a cow.

There are a number of factors controlling the length of the post-partum interval. The most important of these being nutrition (both pre- and post-calving), age of dam, date of calving and year of record.

Date of calving influenced the post-partum interval and calving interval at both locations. This was also the case in the study of Warnick (1955), but contrasts with the work of Laster et al. (1973) in which it was noted that the post-partum interval was shorter for cows calving earlier in the season. Their herd calved in the autumn, so seasonal effects may have been involved in producing this difference between the result of the various workers.

The reason for the early return to heat of late-calving cows is not clear. Warnick (1955) suggested that differences in day length could act on the pituitary gland to produce an earlier and higher gonadotrophin secretion. This could cause oestrus to occur earlier in later-calving cows. The possibility also exists that gonadotrophin was sufficient early in the season to cause ovulation without the overt symptoms of oestrus. The early calvers may then experience more silent heats. The time of first ovulation was not determined in this study.

Other environmental factors such as quality and quantity of feed available, temperature changes and an interaction of these and other factors could well be responsible for these seasonal differences. The seasonal nature of pastoral farming in New Zealand means that natural selection is against late-calving cows since they may not conceive before the end of the mating season.

The delayed interval to first post-partum oestrus in beef cows compared to dairy cows (see Table 2.1) is believed to be the result of the suckling stimulus of the calf. There have been few studies on the actual level of milk production and its influence on post-partum interval in beef cows.

An attempt was made in the Massey University data to relate milk production, as assessed by the weigh-nurse-weigh method, to the post-partum interval. Twenty-day milk production was correlated significantly with post-partum interval to first oestrus, but 40- and 60-day milk production was not related to this interval.

This indicates that the Massey University herd had sufficient nutrition for both lactation and reproduction. If nutritional levels are inadequate then the reproductive processes are more likely to be impaired than would lactation. This is especially so in the case of young heifers or high milk-producing cows. Deutscher and Whiteman (1971) have noted extremely poor rebreeding performance of Angus x Friesian cows (13%) that nursed calves compared to straight-bred Angus cows (63%) and they suggested that the level of nutrition was too low to support both high milk production and rebreeding in their crossbred cows.

Milk production taken at 20-days post-partum in the Massey University data was significantly correlated with calving interval. This is probably caused by the 20-day milk production influence on the post-partum interval.

Climatic variables provide a major contribution to the variation in post-partum interval to first oestrus and calving intervals. These are best demonstrated through the yearly variation obtained in the Ministry of Agriculture and Fisheries' data. Climatic conditions can also influence the post-partum interval in a pastoral system of farming through their effect on nutrition. Throughout the literature there is reference to large variations in reproductive performance related to the level of nutrition.

The work of Wiltbank et al. (1962, 1964) suggests that pre-calving energy levels are more important than post-calving energy levels. This explains why the post-calving treatments in the Massey University data had no influence on the post-partum interval. All cows, it seems, were fed adequately before entering the pad and any depression of nutrition levels after calving had no effect on their return to cyclic activity.

Recent research by Somerville et al. (1976) supports this finding. In their study, Hereford x Friesian cows were fed either high or low nutritive levels during the first 150 days of lactation. They produced the same amount of milk and their calves had similar liveweight gains, although the low level cows lost considerably more weight. These authors suggest that the low plane cows mobilised body reserves to maintain their milk production, however, this had no effect on their subsequent rebreeding performance. The cows weighed 500 kg at calving, which suggests they were still in a suitable condition for rebreeding even after some weight loss. Baker and Barker (1976) also noted that a lowered level of nutrition over the first 54 days of lactation had no effect on milk production or calf liveweight gain.

The influence of nutrition on the reproductive performance of the beef cow cannot be overstressed. To obtain optimum reproductive performance cows should be in good condition at calving. The reproductive performance after calving will largely be determined during the last 3 to 6 weeks of gestation. To allow feed to be saved for this period, cows may lose up to 15% of their autumn liveweight over the early-winter period. For the first 40 days after calving, cows can be fed only maintenance levels.

Hence the pre-calving nutritional level is a critical factor. However, if this level has been inadequate, a higher plane of nutrition after calving will be required if the cows are to return early to cyclic activity. In general, lactating cattle should be offered an adequate supply of nutrients from parturition to conception, regardless of their pre-calving nutritional background.

Lamond (1970) has suggested that it is necessary to know the minimum liveweight and body condition (hence nutrient status of the animal) in lactating cows if normal fertility is to be attained. The method by which this particular "critical" liveweight is achieved depends on the farm manager. However, it is suggested that due to high feed requirements on most hill country sheep/beef-cattle farms during the spring, it may be advisable to ensure that pre-calving energy levels are such that cows can be fed to maintain liveweight over the first 40 days of lactation. Evidence from the present study supports this theory.

Cows bred for high milk production may complicate the above theory. Willham (1970) suggested that with such cows there is a possibility that feed requirements may be under-estimated and that this would result in lowered reproductive performance. He further stated that for a given available intake, increase in milk production cannot exceed that which leaves enough nutrients for the cow to rebreed successfully. Natural selection operating through reproductive potential, has been against increased milk production in the typical beef production system.

The most important problems facing beef cattle breeders in New Zealand are lowered calf crops and long calving seasons, both of which perpetuate reduced production. The opportunity for individual cows to have calving intervals of longer than 12-months is increased in herds which have long rather than short mating seasons. Furthermore, management of the cows becomes easier when calving is concentrated.

If the time to first post-partum oestrus is 80 days, then late-calving cows do not have sufficient time to return to oestrus early in the mating season. This is supported by the work of Reynolds (1967) who showed that cows which became pregnant early in the mating season one year had a better opportunity to become pregnant the next year. He found that of 145 young cows which conceived during the first 42 days of the mating season, 79% became pregnant the following season. In contrast only 40% of the young cows which became pregnant between the 43rd and the 75th day of the first mating season were pregnant the second year.

Short mating and calving seasons will lengthen the period between the end of calving and the start of the next mating season.

The most effective improvements in reproductive performance are made through increasing the number of cows that show oestrus during the first 21 days of the mating season, and then subsequently increasing the conception rate at first service. The proportion of cows that show oestrus early in the mating season is largely determined by:

(i) The interval from calving to first oestrus
(ii) The interval from calving to the beginning of mating
(iii) Age of the cow
(iv) The level of nutrition before and after calving

The average time from parturition to first oestrus in suckled Angus beef cows is 80 days, therefore mating should commence approximately 70 days after calving. Mating should continue for two cycles, i.e., 42 days, although in some cases it may be desirable to have a 60-day mating season. Maiden heifers need to be mated up to 21-days before the main herd since they experience a longer post-partum anoestrus following the birth of their first calf than do mature cows.

The information collected in this study, on the post-partum interval to first oestrus, provide the basis for the development of new approaches towards the improvement of reproductive performance. In summary it can be stated that for greater performance of the cow mating should commence 70 days after calving, and continue for 42 days. Maiden heifers should be mated 21 days before the main herd. Particular attention needs to be given to pre-calving nutrition, while for the first 40 days post-partum, cows should be fed to maintain liveweight. Adoption of these practices should lead to a substantial improvement in the reproductive status of the breeding herd.

BIBLIOGRAPHY

(A.B.A. refers to Animal Breeding Abstracts)

Acharya, R.M.; Dhillon, J.S.; Aggarwal, S.C., (1971). A note on the factors affecting post-partum oestrus interval in Hariana cattle. Indian J. Anim. Sci., 41: 524-525. A.B.A., 40: No. 3035.

Anderson, H.; Plum, M., (1965). Gestation length and birth weight in cattle and buffaloes: A review. J. Dairy Sci., 48: 1224-1235.

Anon., (1974). Germ Plasm Evaluation Program. Report No. 1. U.S. Meat Animal Research Center, Clay Center, Nebraska, ARS-NC-13.

Anon., (1975). Germ Plasm Evaluation Program. Report No. 2. U.S. Meat Animal Research Center, Clay Center, Nebraska, ARS-NC-22.

Arije, G.R.; Wiltbank, J.N.; Hopwood, M.L., (1974). Hormone levels in pre- and post-parturient beef cows. J. Anim. Sci., 39: 338-347.

Baker, A.A., (1965). Comparison of heat detectors and classical methods for detecting heat in beef cattle. Aust. Vet. J., 41: 360-361.

Baker, A.A., (1968). Oestrus and ovarian activity in lactating Sahiwal-Shorthorn beef cows in south-eastern Queensland. Proc. Aust. Soc. Anim. Prod., 7: 172-176.

Baker, R.D.; Barker, J.M., (1976). Effect of plane of nutrition in early lactation on suckler cow and calf performance. Anim. Prod., 22(1): 141 Abstr.

Barton, R.A., (1958). Quality Beef Production, Publ. by Massey Agric. College, Palmerston North, 108 pp.

Barton, R.A., (1970). The yield and composition of milk of suckled beef cows and their relation to calf liveweight gain. In: New Zealand Beef Production, Processing and Marketing. Ed. A.G. Campbell. N.Z. Inst. Agric. Sci., Wellington, p 130.

Belling, T.H., (1963). Reproductive efficiency in the Hereford cow. J. Amer. Vet. Med. Assoc., 142: 494-501

Bellows, R.A.; Short, R.E.; Urick, J.J.; Pahnish, O.F., (1974). Effects of early weaning on postpartum reproduction of the dam and growth of calves born as multiples or singles. J. Anim. Sci., 39: 589-600.

Ben-David, B., (1964). Observations on the occurrence of first oestrus, second oestrus and anoestrus following parturition in dairy cattle in the Yezre'el Valley. Refuah. vet., 21: 189-193 A.B.A., 33: No. 3330.

Biswal, G.; Rao, A.M., (1960). Effect of weaning on Red-Sindhi cows. Part II. Occurrence of oestrus after calving and inter-calving interval. Indian Vet. J., 37: 383-387. A.B.A., 29: No. 783.

Bosman, D.J.; Harwin, G.O., (1969). The occurrence of post-partum oestrus in beef cows under ranching conditions. Proc. S. Afr. Soc. Anim. Prod., 8: 165-166.

Britt, J.H., (1975). Early post-partum breeding in dairy cows: A review. J. Dairy Sci., 58(2): 266-271.

Britt, J.H.; Morrow, D.A.; Kittok, R.J.; Seguin, B.E., (1974). Uterine involution, ovarian activity and fertility after melengestrol acetate and estradiol in early post-partum cows. J. Dairy Sci., 57: 89-92.

Brown, L.O.; Durham, R.M.; Cobb, E.; Knox, J.H., (1954). An analysis of the components of variance in calving intervals in a range herd of beef cattle. J. Anim. Sci., 13: 511-516.

Buch, N.C.; Tyler, W.J.; Casida, L.E., (1955). Postpartum estrus and involution in an experimental herd of Holstein-Friesian cows. J. Dairy Sci., 38: 73-79.

Carmen, G.M., (1955). Interrelations of milk production and breeding efficiency in dairy cows. J. Anim. Sci., 14: 753-759.

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

Casida, L.E.; Wisnicky, W., (1950). Effects of diethylstilbestrol dipropionate upon postpartum changes in the cow. J. Anim. Sci., 9: 238-242.

Casida, L.E.; Graves, W.E.; Hauser, E.R.; Lauderdale, J.W.; Riesen, J.W.; Saiduddin, S.; Tyler, W.J., (1968). Studies on the postpartum cow. Res. Bull. 270. College of Agricultural and Life Sciences, Univ. of Wisconsin. p 1.

Chapman, A.B.; Casida, L.E., (1937). Analysis of variation in the sexual cycle and some of its component phases, with special reference to cattle. J. Agric. Res., 54: 417-435.

Choudhury, G.; Agasti, M.K.; Banerjee, G.C.; Ghosh, M.N., (1974). Studies on certain aspects of uterine involution in Holstein x Hariana females at first calving. Indian Vet. J., 51: 395-400. A.B.A., 43: No. 4499.

Clapp, H., (1937). A factor in breeding efficiency of dairy cattle. Proc. Amer. Soc. Anim. Prod. pp 259-265.

Connor, J.S.; Tribble, R.L.; Woodward, T.L.; Fleeger, T.L.; Beverly, J.R.; Sorensen, A.M., (1974). Post partum ovarian activity in first-calf Hereford heifers. Beef Cattle Research in Texas. (1973) pp 24-28. A.B.A., 44: No. 2110.

Corah, L.R.; Dunn, T.G.; Kaltenbach, C.C., (1975). Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. J. Anim. Sci., 41(3): 819-824.

Cundiff, L.V.; Gregory, K.E.; Koch, R.M., (1974). Effects of heterosis on reproduction in Hereford, Angus and Shorthorn cattle. J. Anim. Sci., 38: 711-727.

De Alba, J., (1960). Milking with the calf, and reproductive efficiency in the cow. Turrialba 10: 64-67. A.B.A. 30: No. 113.

Deutscher, G.H.; Whiteman, J.V., (1971). Productivity as two-year-olds of Angus-Holstein crossbreds compared to Angus heifers under range conditions. J. Anim. Sci., 33: 337-342.

Dessouky, F.I.; Rakha, A.H., (1961). Studies on the gestation period and post-partum heat of Friesian cattle in Egypt. J. Agric. Sci., 57: 325-327.

Dumitrescu, I., (1969). Correlations between the corpus luteum and post-partum milk secretion in the cow. Atti. III Simp. int. Zootec., Milan, 1968: 798-804. A.B.A., 37: No. 3513.

Dunn, T.G.; Ingalls, J.E.; Zimmerman, D.R.; Wiltbank, J.N., (1969). Reproductive performance of 2-year-old Hereford and Angus heifers as influenced by pre- and post-calving energy intake. J. Anim. Sci., 29: 719-726.

Edwards, J., (1950). Fertility in cattle : Effect of post-partum interval. Vet. Rec., 61: 310.

El-Sheikh, A.S.; El-Fouly, M.A., (1964). Post-conception oestrus in Friesian cattle raised in the Tahreen Province of the U.A.R. 5 int. Congr. Anim. Reprod. A.I., Vol. III : 220-224. A.B.A., 33: No. 228.

England, B.G.; Hauser, E.R.; Casida, L.E., (1973). Some effects of unilateral ovariectomy in the postpartum beef cow. J. Anim. Sci., 36: 45-50.

Everitt, G.C.; Phillips, D.S.M.; Whiteman, D.P., (1968). Suckling: Effects on the calf and the cow. Proc. Ruakura Fmrs'. Conf. Week, pp 158-175.

Falk, D.G.; Christian, R.E.; Bull, R.C.; Sasser, R.G., (1975). Prepartum energy effects on cattle reproduction. J. Anim. Sci., 41: 267 Abstr.

Fallon, G.R., (1958). Some aspects of oestrus in cattle, with reference to fertility on artificial insemination. 1. The pattern of oestrous cycles. Qd. J. Agric. Sci., 15: 25-33.

Fielden, E.D.; MacMillan, K.L.; Watson, J.D., (1973). The anoestrus syndrome in New Zealand dairy cattle. 1. A preliminary investigation. N.Z. Vet. J., 21: 77-81.

Flores, A.G., (1971). A study of calving intervals. Diss. Abstr., 32B: 4320.

Foote, R.H., (1975). Estrus detection and estrus detection aids. J. Dairy Sci., 58(2): 248-256.

Foote, W.D., (1971). Endocrine changes in the bovine during the post-partum period: IX Biennial Symp. Anim. Rep., J. Anim. Sci., 32: Suppl. I. pp 73-77.

Foote, W.D.; Hunter, J.E., (1964). Post-partum intervals of beef cows treated with progesterone and oestrogen. J. Anim. Sci., 23: 517-520.

Foote, W.D.; Saiduddin, S., (1964). Hormone treatment of post-partum beef cows. J. Anim. Sci., 23: 592 Abstr.

Foote, W.D.; Hauser, E.R.; Casida, L.E., (1960a). Some causes of variation in post-partum reproductive activity in Hereford cows. J. Anim. Sci., 19 : 238-241.

Foote, W.D.; Hauser, E.R.; Casida, L.E., (1960b). Influence of progesterone treatment on post-partum reproductive activity in beef cattle. J. Anim. Sci., 19: 674-677.

Fosgate, D.T.; Cameron, N.W.; McLeod, R.J., (1962). Influence of 17-alpha-hydroxyprogestrone-n-caproate upon post-partum reproductive activity in the bovine. J. Anim. Sci., 21: 791-793.

Furr, R.D.; Nelson, A.B., (1964). Effect of level of supplemental winter feed on calf weight and on milk production of fall calving range beef cows. J. Anim. Sci., 23: 775-781.

Gier, H.T.; Marion, G.B., (1968). Uterus of the cow after parturition: involution changes. Am. J. Vet. Res., 29: 83-96.

Graves, W.E.; Lauderdale, J.W.; Hauser, E.R.; Casida, L.E., (1968). Relation of postpartum interval to pituitary gonadotrophins, ovarian follicular development and fertility in beef cows. Res. Bull. 270. College of Agric. and Life Sciences. Univ. of Wisconsin. p 23.

Hafez, E.S.E., (1974). Reproduction in Farm Animals. 3rd ed. Publ. Lea and Febiger, Philadelphia. 480 pp.

Harvey, W.R., (1975). Least-squares analysis of data with unequal subclass numbers. U.S. Dept. Agric., Agric. Res. Service., ARS H-4.

Herman, H.A.; Edmondson, J.H., (1950). Factors affecting the interval between parturition and first oestrus in dairy cattle. Mo. Agr. Exp. Sta. Res. Bull., No. 462.

Hight, G.K., (1966). The effects of undernutrition in late pregnancy on beef cattle production. N.Z.J. Agric. Res., 9: 479-490.

Hight, G.K., (1968a). Plane of nutrition effects in late pregnancy and during lactation on beef cows and their calves to weaning. N.Z.J. Agric. Res., 11: 71-84.

Hight, G.K., (1968b). A comparison of the effects of three nutritional levels in late pregnancy on beef cows and their calves. N.Z.J. Agric. Res., 11: 477-86

Howes, J.R.; Hentges, J.F.; Warnick, A.C.; Cunha, T.J., (1960). Yield and composition of milk from Brahman and Hereford heifers and cows fed two levels of protein and the correlated calf growth. J. Anim. Sci., 19: 654 Abstr.

Jeffery, H.B.; Berg, R.T.; Hardin R.T., (1971). Factors influencing milk yield of beef cattle. Can. J. Anim. Sci., 51: 551-560.

Kaiser, A.G., (1975). Rearing dairy beef calves by multiple suckling. I. Effects on liveweight change, onset of oestrus and post-weaning milk production. Aust. J. Exp. Agric. Anim. Husb., 15: 17-24.

King, G.J.; Hurnik, J.F.; Robertson, H.A., (1976). Ovarian function and estrus in dairy cows during early lactation. J. Anim. Sci., 42: 688-692.

Kohli, H.L.; Suri, K.R., (1960). Postpartum breeding interval and reproductive efficiency in the Hariana cow. Indian J. Dairy Sci., 13: 61-67. A.B.A., 30: No. 212.

Labhsetwar, A.P.; Tyler, W.J.; Casida, L.E., (1963). Genetic and environmental factors affecting quiet ovulations in Holstein cattle. J. Dairy Sci., 46: 843-845.

Labhsetwar, A.P.; Collins, W.E.; Tyler, W.J.; Casida, L.E., (1964). Some pituitary-ovarian relationships in the periparturient cow. J. Rep. Fert., 8: 85-90.

Lamond, D.R., (1969). Sources of variation in reproductive performance of selected herds of beef cattle in north-eastern Australia. Aust. Vet. J., 45: 50-57.

Lamond, D.R., (1970). Influence of undernutrition on reproduction in the cow. Anim. Breed Abstr., 38: 359-372.

Lang, D.R.; Hight, G.K.; Uljee, A.E.; Young, J., (1968). A working device for detecting oestrous activity of cattle. N.Z.J. Agric. Res., 11: 955-958.

Lasley, J.F.; Bogart, R., (1943). Some factors influencing reproduction efficiency of range cattle under artificial and natural breeding conditions. Mo. Agr. Exp. Sta. Res. Bull., No. 376.

Lasley, J.F.; Day, B.N.; Comfort, J.E.; Subramanian, R., (1961). Some causes of variations in the calving interval. J. Anim. Sci., 20: 908 Abstr.

Laster, D.B.; Glimp, H.A.; Gregory, K.E., (1973). Effects of early weaning on postpartum reproduction of cows. J. Anim. Sci., 36: 734-740.

Lauderdale, J.W.; Graves, W.E.; Hauser, E.R.; Casida, L.E., (1968). Relation of postpartum interval to corpus luteum development, pituitary prolactin activity, and uterine involution in beef cows. Res. Bull. 270, College of Agricultural and Life Sciences, Univ. of Wisconsin, p 42.

Lindley, C.E.; Easley, G.T.; Whatley, J.A.; Chabers, D., (1958). A study of the reproductive performance of a purebred Hereford herd. J. Anim. Sci., 17: 336-342.

Little, D.A., (1975). Effects of dry season supplements of protein and phosphorus to pregnant cows on the incidence of first post-partum oestrus. Aust. J. Exp. Agric. Anim. Husb., 15: 25-31.

Mahadevan, P.; Harricharan, H.; Springer, B.G.F., (1972). The performance of Santa Gertrudis, Sahiwal, Brahman and crossbred animals in the intermediate Savannahs of Guyana. J. Agr. Sci., 79: 67-74.

Marion, G.B.; Gier, H.T., (1968). Factors affecting bovine ovarian activity after parturition. J. Anim. Sci., 27: 1621-1626.

Marion, G.B.; Norwood, J.S.; Gier, H.T., (1968). Uterus of the cow after parturition : Factors affecting regression. Am. J. Vet. Res., 29: 71-75.

Melton, A.A.; Riggs, J.K.; Nelson, L.A.; Cartwright, T.C., (1967). Milk production, composition and calf gains of Angus, Charolais and Hereford cows. J. Anim. Sci., 26: 804-809.

Menge, A.C.; Mares, S.E.; Tyler, W.J.; Casida, L.E., (1962). Variation and association among postpartum reproduction and production characteristics in Holstein-Friesian cattle. J. Dairy Sci., 45: 233-241.

Moller, K., (1970a). A review of uterine involution and ovarian activity during the postparturient period in the cow. N.Z. Vet. J., 18: 83-90.

Moller, K., (1970b). Uterine involution and ovarian activity after calving. N.Z. Vet. J., 18: 140-145.

Morgan, J.H.L.; Cummins, L.J.; Saul, G.R., (1974). The reproductive and maternal performance of young Hereford and Friesian cows. Proc. Aust. Soc. Anim. Prod., 10: 21-24.

Morrow, D.A., (1969). Postpartum ovarian activity and involution of the uterus and cervix in dairy cattle. Vet. Scope., 14(1): 2-13.

Morrow, D.A., (1971). Effects of periparturient disease on postpartum reproduction in dairy cattle. IX Biennial Symp. Anim. Reprod., J. Anim. Sci., 32: Suppl. I pp 17-21.

Morrow, D.A.; Roberts, S.J.; McEntee, K., (1969a). A review of postpartum ovarian activity and involution of the uterus and cervix in cattle. Cornell Vet., 59: 134-154.

Morrow, D.A.; Roberts, S.J.; McEntee, K., (1969b). Postpartum ovarian activity and involution of the uterus and cervix in dairy cattle. I. Ovarian activity. Cornell Vet., 59: 173-190.

Morrow, D.A.; Roberts, S.J.; McEntee, K., (1969c). Postpartum ovarian activity and involution of the uterus and cervix in dairy cattle. II. Involution of the uterus and cervix. Cornell Vet., 59: 190-198.

Morrow, D.A.; Roberts, S.J.; McEntee, K., (1969d). Postpartum ovarian activity and involution of the uterus and cervix in dairy cattle. III. Days nongravid and services per conception. Cornell Vet., 59: 199-210.

Morrow, D.A.; Roberts, S.J.; McEntee, K.; Gray, H.G., (1966). Postpartum ovarian activity and uterine involution in dairy cattle. J. Amer. Vet. Med. Assoc., 149: 1596-1609.

Mylrea, P.J., (1962). Clinical observations on reproduction in dairy cows. Aust. Vet. J., 38: 253-258.

Neville, W.J., (1962). Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J. Anim. Sci., 21: 315-319.

Norwood, J.S., (1963). Factors affecting postpartum regression of the bovine uterus. Diss. Abstr., 24B: 361-362.

N.R.C., (1958). Nutrient requirements of farm animals, No. 579. Nutrient requirements of beef cattle, National Research Council, Washington, D.C.

Olds, D.; Sheath, D.M., (1953). Repeatability, heritability and the effect of level of milk production on the occurrence of first oestrus after calving in dairy cattle. J. Anim. Sci., 12: 10-14.

Oxenreider, S.L., (1968). Effects of suckling and ovarian function on postpartum reproductive activity in beef cows. Am. J. Vet. Res., 29: 2099-2102.

Oxenreider, S.L.; Wagner, A.C., (1971). Effect of lactation and energy intake on postpartum ovarian activity in the cow. J. Anim. Sci., 33: 1026-1031.

Perkins, J.L.; Kidder, H.E., (1963). Relation of uterine involution and postpartum interval to reproductive efficiency in beef cattle. J. Anim. Sci., 22: 310-315.

Pinney, D.O.; Stephens, D.F.; Pope, L.S., (1972). Lifetime effects of winter supplementation feed level and age at first parturition on range beef cows. J. Anim. Sci., 34: 1067-1074.

Plasse, D.; Koger, M.; Warnick, A.C., (1968). Reproductive behaviour of Bos indicus females in a subtropical environment. 3. Calving intervals, intervals from first exposive to conception and interval from parturition to conception. J. Anim. Sci., 27: 105-112.

Pleasants, A.B., (1974). The wintering and calving of Angus beef cows on a sawdust pad. Master of Agricultural Science Thesis, Massey University, 169 pp.

Pleasants, A.B.; Barton, R.A., (1974). Wintering and calving of beef cows on a sawdust pad. Sheepfarming Annual: 85-95.

Preston, T.R.; Willis, M.B., (1974). Intensive Beef Production. 2nd ed. Publ. Pergamon Press, Oxford. 544 pp.

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

Rasbeck, N.D., (1950). The normal involution of the uterus of the cow. Nord. Vetmed., 2: 655-670.

Renbarger, R.E.; Smithson, L.J.; Stephens, D.F.; Pope, L.S., (1964). Effect of nutrition before and after calving on performance of beef heifers. J. Anim. Sci., 23: 293 Abstr.

Reynolds, W.L., (1967). Breeds and reproduction. In: Factors Affecting Calf Crop. Ed. T.J. Cunha, A.C. Warnick, M. Koger. Publ. Univ. of Florida Press, Gainesville, p 244.

Reynolds, W.L., (1973). Reproduction of Brahman, Angus, Africander, and their crosses at Jeanerette, Louisiana. In: Crossbreeding Beef Cattle Series 2. Ed. M. Koger, T.J. Cunha, A.C. Warnick. Publ. Univ. of Florida Press, Gainesville, p 135.

Riesen, J.W., (1968). The effects of suckling on reproductive function in postpartum dairy cows - Pituitary prolactin, copora lutea, and uterine histology. Diss. Abstr., 29B: 348.

Riesen, J.W.; Saiduddin, S.; Tyler, W.J.; Casida, L.E., (1968). Relation of postpartum interval to corpus luteum development, pituitary prolactin activity, and uterine involution in dairy cows. Res. Bull. 270, College of Agricultural and Life Sciences, Univ. of Wisconsin, p 27.

Saiduddin, S.; Riesen, J.W.; Graves, W.E.; Tyler, W.J.; Casida, L.E., (1967a). Effect of suckling on the interval from parturition to first estrus in dairy cows. J. Anim. Sci., 26: 950 Abstr.

Saiduddin, S.; Riesen, J.W.; Tyler, W.J.; Casida, L.E., (1967b). First estrus and ovulation in the postpartum dairy cow. J. Anim. Sci., 26: 1494 Abstr.

Saiduddin, S.; Riesen, J.W.; Tyler, W.J.; Casida, L.E., (1968). Relation of postpartum interval to pituitary gonadotrophin ovarian follicular development and fertility in dairy cows. Res. Bull. 270, College of Agricultural and Life Sciences, Univ. of Wisconsin, p 15.

Schalles, R.R., (1967). Reproductive and genetic patterns in a herd of Angus cows. Diss. Abstr., 27B: 3361.

Schottler, J.H.; Williams, W.T., (1975). The effect of early weaning on Brahman cross calves on calf growth and reproductive performance of the dam. Aust. J. Exp. Agric. Anim. Husb., 15: 456-459.

Searle, S.R., (1966). Matrix Algebra for the Biological Sciences. Publ. John Wiley and Sons, Inc, New York, 269 pp.

Searle, S.R., (1971). Linear Models. Publ. John Wiley and Sons, Inc., New York, 532 pp.

Self, H.L.; Burrell, C.B., (1975). Season, calf weaning age and cow reproduction. J. Anim. Sci., 41: 275 Abstr.

Short, R.E.; Bellows, R.A.; Moody, E.L.; Howland, B.E., (1972). Effects of suckling and mastectomy on bovine post-partum reproduction. J. Anim. Sci., 34: 70-74.

Snedecor, G.W.; Cochran, W.G., (1967). Statistical Methods. 6th ed. Publ. Iowa State Univ. Press, Ames, Iowa, 593 pp.

Somerville, S.H.; Lowman, B.G.; Edwards, R.A., (1976). Effects of plane of nutrition during lactation on the milk yield and weight change of suckled beef cows. Anim. Prod., 22: 141 Abstr.

Symington, R.B.; Gregor, A.; Hale, D.H., (1967). Sexual activity in lactating ranch cows. Rhod. Zamb. Mal. J. Agric. Res., 5: 233-239.

Tennant, B.; Kendrick, J.W.; Peddicord, R.G., (1967). Uterine involution and ovarian function in the post-partum cow. A retrospective analysis of 2,338 genital organ examinations. Cornell Vet., 57: 543-557.

Thatcher, W.W.; Wilcox, C.J., (1973). Post-partum estrus as an indicator of reproductive status in the dairy cow. J. Dairy Sci., 56: 608-610.

Tomar, S.S.; Arneja, D.V., (1972). Influence of sex of the calf on the reproductive efficiency of Hariana dams. Indian Vet. J., 49: 1115-1119. A.B.A., 41: No. 2599.

Trimberger, G.W., (1956). Ovarian functions, intervals between estrus and conception rates in dairy cattle. J. Dairy Sci., 39: 448-455.

Trimberger, G.W.; Fincher, M.G., (1956). Regularity of oestrus, ovarian function, and conception rates in dairy cattle. Cornell Univ. Agr. Exp. Sta. Bull., No. 911.

Turman, E.J.; Laster, D.B.; Renbarger, R.E.; Stephens, D.F., (1971). Multiple births in beef cows treated with equine gonadotrophin (PMS) and chorionic gonadotrophin (HCG). J. Anim. Sci., 32: 962-967.

Turman, E.J.; Smithson, L.; Pope, L.S.; Renbarger, R.E.; Stephens, D.F., (1964). Effect of feed level before and after calving on the performance of two-year-old heifers. Okla. Agr. Exp. Sta. Misc. Pub., 74: 10-17. A.B.A., 33: No. 1165.

Ugarte, J.; Preston, T.R., (1975). Restricted suckling. VI. Effects on milk production, reproductive performance and incidence of clinical mastitis throughout the lactation. Cuban J. Agric. Sci., 9: 15-26.

Ustinov, A., (1973). Reproduction in beef cows and measures for its improvement. Molochnoe i Myasnoe Skotovodstvo., No. 11: 18-30, A.B.A., 42: No. 1017.

Van Demark, N.L.; Salisbury, G.W., (1950). The relation of the postpartum breeding interval to reproductive efficiency in the dairy cow. J. Anim. Sci., 9: 307-313.

Wagner, W.C.; Hansel, W., (1969). Reproductive physiology of the post-partum cow. I. Clinical and histological findings. J. Reprod. Fert., 18: 493-500.

Wagner, W.C.; Oxenreider, S.L., (1971). Endocrine physiology following parturition. IX Biennial Symp. Anim. Reprod., J. Anim. Sci., 32: Suppl. I. pp 1-16.

Warnick, A.C., (1955). Factors associated with the interval from parturition to first estrus in beef cattle. J. Anim. Sci., 14: 1003-1008.

Wettemann, R.P.; Turman, E.J.; Wyatt, R.D.; Totusek, R., (1976). Suckling intensity and reproduction in range cows. J. Anim. Sci., 42: 267 Abstr.

Wettemann, R.P.; Turman, E.J.; Wyatt, R.D.; Knori, L.; Totusek, R., (1976). Reproductive performance of range cows with various suckling intensities. Animal Science and Industry, Oklahoma State University, MP-96, pp 121-125.

Whitman, R.W.; Remmenga, E.E.; Wiltbank, J.N., (1975). Weight change, condition and beef cow reproduction. J. Anim. Sci., 41: 387 Abstr.

Whitmore, H.L.; Tyler, W.J.; Casida, L.E., (1974). Effects of early post-partum breeding in dairy cattle. J. Anim. Sci., 38: 339-346.

Willham, R.L., (1972). Beef milk production for maximum efficiency. J. Anim. Sci., 34: 864-869.

Wilson, A.; Willis, M.B., (1974). Comparative reproductive performance of Brahman and Santa Gertrudis cattle in a hot humid environment. 2. Factors affecting calving interval. Anim. Prod., 18: 43-48.

Wiltbank, J.N., (1970). Research needs in beef cattle reproduction. J. Anim. Sci., 31: 755-762.

Wiltbank, J.N.; Cook, A.C., (1958). The comparative reproductive performance of nursed cows and milked cows. J. Anim. Sci., 17: 640-648.

Wiltbank, J.N.; Warnick, E.J.; Vernon, E.H.; Priode, B.M., (1961). Factors affecting net calf crop in beef cattle. J. Anim. Sci., 20: 409-415.

Wiltbank, J.N.; Rowden, W.W.; Ingalls, J.E.; Gregory, K.E.; Koch, R.M., (1962). Effect of energy level on reproductive phenomena of mature Hereford cows. J. Anim. Sci., 21: 219-225.

Wiltbank, J.N.; Rowden, W.W.; Ingalls, J.E.; Zimmerman, D.R., (1964). Influence of post-partum energy level on reproductive performance of Hereford cows restricted in energy intake prior to calving. J. Anim. Sci., 23: 1049-1053.

Zimmerman, D.R.; Clanton, D.C.; Matsushima, J.K., (1961). Post-partum reproductive performance in beef cows as affected by protein and energy intake during gestation. J. Anim. Sci., 20: 957 Abstr.