

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 LACTATIONAL AND REPRODUCTIVE  
PERFORMANCES OF AUTUMN OR SPRING CALVING  
COWS IN COMMERCIAL WINTER MILK SUPPLY HERDS**

**A thesis presented in partial fulfilment of the requirements for the degree of  
Master of Agricultural Science in Animal Science**

**Department of Animal Science  
Massey University  
NEW ZEALAND**

**Francis Benjamin Chang'endo  
1996**

## ABSTRACT

**Chang'endo.F.B** (1996). *A study of lactational and reproductive performances of autumn or spring calving cows in winter milk supply herds.* Master in Agriculture Science Thesis Massey University. Palmerston North New Zealand.

Data on lactational and reproductive performances for 1993 and 1994 of dairy cows which calved in autumn or in spring on eight commercial winter milk supply farms around Palmerston North were collected. The eight commercial winter milk supply herds had a calving spread condensed into autumn and spring seasons. There were 7689 calvings recorded involving 3787 cows.

The lactational parameters measured were yields of milk fat and milk protein per lactation, and days in milk (DIM) per cow. The mean milk fat production for the autumn calved cows was 206 kg/cow and 166 kg milk protein/cow (372 kg milk solids) per lactation while the spring calved cows produced 199 kg milk fat/cow and 160 kg milk protein/cow (359 kg milk solids) per lactation. The mean lactation length (DIM) for the autumn calved cows was 282 days, while the spring calved cows had a mean lactation length of 258 days ( $P<0.05$ ). The mean daily milk fat yield averaged across the days in milk was 0.73 kg per cow for the autumn calved cows while the spring calved cows had a mean daily milk fat yield of 0.77 kg/cow ( $P<0.05$ ). The mean values of milk production in the second and third months of lactation were 18 litres per day and 17 litres per day for the autumn calved cows while spring calved cows produced 22 litres per day during the second month of lactation and 19 litres per day during the third month of lactation respectively.

The reproductive parameters measured were calving interval (CI), 4 weeks submission rates (SR), 42 day non-return rates (NNR), services per conception, 4 week calving rates and empty rates.

The autumn calved cows had a longer CI than the spring calved cows; 390 days vs 372 days ( $P<0.05$ ).

The autumn calved cows had a lower average 4 weeks SR than the spring calved cows; 71% vs 81% ( $P<0.05$ ).

The autumn calved cows had a lower average 42 day NNR (conception rate) than the spring calved cows; 55% vs 64% ( $P<0.05$ ).

The autumn calved cows had a higher average of services per conception than the spring calved cows; 1.9 vs 1.6 ( $P<0.05$ ).

The autumn calved cows had a lower 4 week calving rate than the spring calved cows; 41% vs 54% ( $P<0.05$ ).

The autumn calved cows had a higher average empty rate than the spring calved cows; 12% vs 10% ( $P<0.05$ ).

These results show that cows which calved in autumn actually produced larger yields of milk fat and milk protein per lactation than those which calved in spring. However, these higher yields were achieved in longer lactations, and the autumn cows produced lower average daily yields than the spring calved cows.

The lower daily yields during the second and third months of lactation by the autumn cows, indicated that these cows were on a lower level of feeding at this stage than the spring calved cows.

The autumn calved cows had lower values for all aspects of reproductive performance than the spring calved cows. This difference is probably due to, at least partly, to the lower level of feeding in early lactation.

These herds are relatively high producing, and therefore it can be deduced that they are generally well managed. Nevertheless the autumn calved cows were fed less well in early lactation than the spring calved cows, causing slightly poorer performances.

## ACKNOWLEDGEMENTS

I wish to express my deepest respect and sincere thanks to my supervisors, Dr C.W.Holmes and Dr M.F.McDonald for their invaluable guidance, valuable advice, encouragement and stimulating criticism throughout this study and for their dedicated assistance during the whole process of preparing this thesis.

I also extend sincere thanks to the eight commercial winter milk supply farmers, who took time to show me their farm records and to answer the many questions about their production systems which I asked them. This thesis is based entirely upon data provided by these farmers and without their cooperation, the study would not have been possible.

Data analysis has been done with the patient help of Dr Charles Lawoko and Mrs Wallbutton.

I wish to express special appreciation to my dear wife Eunice who has been a loving and supportive partner throughout the period I have been away from Tanzania, made this opportunity for higher studies possible.

Finally, I would like to express my sincere appreciation to the New Zealand Government for financial support and the Principal Secretary Ministry of Agriculture and Livestock Development for allowing me to undertake post graduate studies at Massey University.

## TABLE OF CONTENTS

	<b>Page</b>
<b>ABSTRACT</b>	i
<b>ACKNOWLEDGEMENTS</b>	iv
<b>LIST OF TABLES</b>	ix
<b>LIST OF FIGURES</b>	xi
<b>LIST OF ABBREVIATIONS</b>	xiii
 <b>CHAPTER ONE</b>	
<b>Introduction and Objectives of this study</b>	1
 <b>CHAPTER TWO</b>	
<b>Factors Influencing Reproductive and Lactational Performances in Winter Milk Supply Herds</b>	3
2:1 Calving interval (CI)	4
2:1:1 Days from calving to first service	5
2:1:2 Days open (DO)	6
2:2 Calving date and calving pattern	7
2:2 (i) Calving date and calving pattern in winter milk supply herds	9
2:2 (ii) Calving date and calving pattern in seasonal milk supply herds	10

2:3 Submission rate (SR)	12
2:3:1 Accurate and thorough oestrus detection	12
2:3:2 Previous calving pattern	13
2:3:3 Nutritional deficiencies	13
2:3:4 Periparturient diseases	13
2:3:5 Return interval	13
2:4 Conception rate (CR)	14
2:4:1 Female factors	14
2:4:2 Environmental factors influencing conception rate	21
2:4:3 Male factors	22
2:4:4 Management factors influencing conception rate	23
2:5 Factors affecting milk production in winter milk supply herds	42
2:5:1 Pasture utilization	43
2:5:2 Effect of stocking rate on pasture production	44
2:5:3 Pasture intake per cow and per hectare and FCE	45
2:5:4 Milk fat production per cow and per hectare	45
2:5:5 Animal genotype	47
2:5:6 Grazing management	47
2:5:7 Grazing methods	48
2:5:8 Dairy cattle management relevant to winter milk production	49
2:6 Summary	50
<b>CHAPTER THREE</b>	
<b>Objectives and Methods</b>	
3:1 Objectives of the study	52
3:2 Location of farms, soils and management	52
3:3 Methods and data collection	54
3:4 Statistical procedures	57

## CHAPTER FOUR

### Results

4:1 Milk production	58
4:2 Reproductive performances	63
4:3 Lactational and reproductive performances for the different age groups of autumn and spring calved cows	69

## CHAPTER FIVE

### Discussion

5:1 Milk production	72
5:2 Fertility	73
5:3 Feed requirements related to feed supply	79
5:4 The influence of season on lactational and reproductive performances	79
5:5 Conclusions	81

## APPENDICIES

I Pasture production, rainfall and supplements fed in a winter milk supply farm	82
II Effective milking area, number of cows milked (autumn and spring cows), lactation yields (milk fat and milk protein), days in milk (DIM) of the autumn and spring calved cows and daily winter milk contract for 1993 in eight commercial winter milk supply herds	83
III Effective milking area, number of cows milked (autumn and spring cows), lactation yields (milk fat and milk protein), days in milk (DIM) of the autumn and spring calved cows and daily winter milk contract for 1994 in eight commercial winter milk supply herds	84

IV	Reproductive performances, number of cows in the herd per season, calving interval (days/cow), conception rate or 42 day non-return rate (% of the herd), 4 weeks submission rate (% of the herd), services per conception per cow, 4 week calving rate (% of the herd) and empty rate (% of the herd) of autumn and spring calved cows in 1993	85
V	Reproductive performances, number of cows in the herd per season, calving interval (days/cow), conception rate or 42 day non-return rate (% of the herd), 4 weeks submission rate (% of the herd), services per conception per cow, 4 week calving rate (% of the herd) and empty rate (% of the herd) of autumn and spring calved cows for 1994	86
VI	Mean values for weekly calving patterns for autumn and spring calved cows in eight commercial winter milk supply herds for 1993	87
VII	Mean values for weekly calving patterns for autumn and spring calved cows in eight commercial winter milk supply herds for 1994	88
VIII	Average value of total feed required/day, energy requirements for maintenance and for milk production for autumn and spring calved cows in a commercial winter milk supply farm	89
	<b>REFERENCES</b>	90

## LIST OF TABLES

	<b>Page</b>
<b>Table 1.0</b> The effect of stocking rate and breed on animals that ovulated and detected in oestrus by weekly milk progesterone assay	33
<b>Table 2.0</b> Summary of protein/reproduction trials	36
<b>Table 3.0</b> Summary of data for eight commercial winter milk supply farms, average for 1993 and 1994. Mean values of milking area (ha), number of cows (total milked, calved in autumn and spring), milk yields (milk fat and milk protein tonnes/farm), days in milk per cow (DIM) for autumn and spring calved cows and daily winter milk quota (litres/day/cow) and per hectare production	55
<b>Table 4.1</b> Mean lactation values for autumn and spring calved cows for 1993 and 1994, number of cows (total milked) milk yields (milk fat and milk protein/cow/lactation), days in milk (DIM) and daily milk fat and milk protein production (per cow)	59
<b>Table 4.1.1</b> Overall mean values of combined data for 1993 and 1994 for autumn and spring calved cows, number of cows (total milked), milk yields (milk fat and milk protein /cow/lactation), days in milk (DIM) and daily milk fat and milk protein production (per cow)	60
<b>Table 4.1.2</b> Average daily milk production for autumn and spring calved cows on each test date for 1993 and 1994 (litres/cow)	61
<b>Table 4.2.1</b> Mean reproductive performance values for autumn and spring calved cows 1993 and 1994, number of cows (herd size), calving interval (days/cow), 4 weeks submission rate (% of the herd), 42 day non-return rate (% of the herd), services per conception/cow, 4 week calving rate (% of the herd) and empty rate (% of the herd)	65

- Table 4.2.2** Overall mean reproductive values for autumn and spring calved cows, number of cows (herd size), calving interval (days/cow), 4 weeks submission rate (% of the herd), 42 day non-return rate (% of the herd), services per conception/cow, 4 weeks calving rate (% of the herd) and empty rate (% of the herd) 66
- Table 4.3** Mean values of milk production and reproductive performances of different age groups of autumn calved cows in eight commercial winter milk supply herds in 1993 and 1994 70
- Table 4.3.1** Mean values of milk production and reproductive performance of different age groups of spring calved cows in eight commercial winter milk supply herds in 1993 and 1994 71
- Table 5.1** Comparison of the present study with other published data for milk production in winter milk supply herds 73
- Table 5.2** Comparison of present study with other published data for fertility performances in winter milk supply herds 74

## LIST OF FIGURES

	<b>Page</b>
<b>Figure 2.1</b> The components of the calving interval	4
<b>Figure 2.2</b> Good calving pattern based on spring calving in Ireland	8
<b>Figure 2.2.1</b> The factors influencing the calving pattern	11
<b>Figure 2.4</b> Conception rates for cows of different ages	19
<b>Figure 2.4.1</b> Conception rate for different classes of breeding index	20
<b>Figure 2.4.2</b> The estimated probability of conception rate at first service determined by logistic regression and observations	24
<b>Figure 2.6</b> A simplified illustration of the main components of pastoral milk production systems	42
<b>Figure 2.6.1</b> Diagram of pasture utilization	43
<b>Figure 2.6.2</b> The influence of stocking rate on rates of herbage growth, senescence and net production	44
<b>Figure 3.0</b> Location of eight winter milk supply farms, five located in Kairanga and the remaining three located near Feilding	53
<b>Figure 4.1</b> Average lactation curves for autumn calved cows and spring calved cows on each herd test date (litres/day) for 1993 and 1994	62
<b>Figure 4.2</b> Calving pattern for the autumn calved cows in eight commercial winter milk supply herds for 1993 and 1994	67

**Figure 4.2.1** Calving pattern for the spring calved cows in eight commercial winter milk supply herds for 1993 and 1994

**LIST OF ABBREVIATIONS**

- AB**=Artificial breeding  
**AC**=Autumn calved cows  
**AI**=Artificial insemination  
**BI**=Breeding index  
**BCS**=Body condition score  
**Ca**=Calcium  
**CI**= Calving interval  
**CL**=Corpus luteum  
**CP**=Crude protein  
**CR**=Conception rate  
**DIM**=Days in milk  
**DIP**=Degradable intake protein  
**EB**=Energy balance  
**FCE**=Feed conversion efficiency  
**FFA**=Free fatty acid  
**FSH**=Follicle stimulating hormone  
**ha**=Hectare  
**K**=Potassium  
**KgDM**=Kilogram dry matter  
**LH**=Luteinising hormone  
**LIC**=Livestock improvement corporation  
**MCD**=Median calving date  
**ME**=Metabolisable energy  
**Mg**=Magnesium  
**MT**=Empty rate  
**N**=Nitrogen  
**NEFA**=Non-esterified fatty acid  
**NNR**=Non-return rate  
**NRC**=National research council

**NZDB**=New Zealand dairy board

**NS**=Non significant

**P**=Phosphorus

**PPA**=Post partum anoestrus

**PUN**=Plasma urea nitrogen

**PSC**=Planned start of calving

**PSM**=Planned start of mating

**Rel**=Reliability

**SAG**=Sexual active group

**SC**=Spring calved cows

**SD**=Standard deviation

**SR**=Submission rate

**SUN**=Serum urea nitrogen

**tDM**=Tonne dry matter

**UDP**=Undegradable protein

## CHAPTER ONE

### Introduction and Objectives of this study

Reproductive efficiency is an important determinant of how effectively, and economically, a herd is capable of producing milk. The need for fresh milk supply is relatively constant throughout the year. During nine months of the year this can be supplied by seasonal-supply dairy herds that comprise 93% of all New Zealand dairy herds. But the milk required during the three winter months (May, June and July) is generally supplied by winter/town-milk herds that comprise 7% of all New Zealand dairy herds (Holmes *et al.*,1990).

Dairying under winter milk supply conditions requires different management from dairying for seasonal factory-supply. For example, on the majority of winter farms a proportion of the herd calves in autumn and a proportion calves in spring (in a few cases the entire herd calves in autumn). These farms have special contracted agreements (winter contracts) or daily quotas which specify the minimum volume of milk which must be supplied to the milk processor each day for the contract period.

The specified daily volume of milk attracts a relatively large price premium above the normal price for seasonal manufacturing milk. It is this factor and its ramifications which differentiate a winter supply herd from its seasonal counterpart.

The higher the proportion of total annual production that is required to meet quota then the more spread and the regular calving pattern must be throughout the year to fulfil a daily quota (Eede,1981), this is true where the daily quota must be supplied everyday of the year. A stabilised calving pattern helps simplify pasture and grazing management which is already complicated by having a herd of cows at varying stages of lactation and an increased number of different classes of stock, often in the one property.

Seasonal supply farmers calve their herds in spring and they do not produce milk during winter and they place their emphasis on a concentrated late winter/early spring calving programme.

The calving date of seasonal calving herds should ideally coincide with or precede slightly, the increased pasture growth in order to make optimum use of spring pasture growth and early lactation. However, cows calving in other seasons of the year, as in the case of winter milk herds, are unable to match feed demand with the availability of sufficient high quality pasture. Therefore, winter milk supply farms must use more supplementary feed than the seasonal farms, fed mainly during winter to provide approximately half of the daily ration.

Dates of calving are also important characteristics of the herd's overall productivity because these dates determine the timing of the herds milk supply. This aspect is very important on farms which have contractual agreements to supply specific quantities of milk to market during particular periods of the year, and also determine the timing of the large increase in the herd's daily feed requirements which occurs at the start of lactation hence influencing the lactation curve and cow condition.

Costs of production for winter supply are at their highest during the winter period when natural pasture growth is low, and calving management is particularly important at this time of the year. The time and rate at which cows calve during periods of high natural pasture growth is still critical to minimise wastage of pasture.

The principal objectives of this particular study are to use data from eight winter milk herds for 1993 and 1994:-

- a) To analyse the lactational performances (days in milk (DIM), milk fat and milk protein production per cow) of cows which calved in autumn or in spring.
- b) To analyse reproductive performances (intercalving interval, services per conception, conception rates (42-day non-return rates), 4 weeks submission rates (SR), empty rates (MT) and 4-week calving rates) of cows which calved in autumn or in spring.

## CHAPTER TWO

### **Factors Influencing Reproductive Performances In Winter Milk Supply Herds**

The primary objective of a winter milk herd is to meet the daily milk quota that the farmer has contracted to supply to the local milk authority. This quota system and its ramifications differentiate a winter milk herd from the seasonal herd (Wiseman,1988). The calving spread must ensure that there are sufficient cows entering the herd in the autumn and or winter to meet quota plus a safety margin.

The number of cows calving into the spring herd must be able to utilise most of the spring grass growth, but still leave sufficient pasture for conservation of silage/hay reserves for likely summer and winter deficits.

The proportion of the herd calving in the autumn or spring or the necessity to calve during the winter months will largely be determined by the size of the milk quota. Once established, the calving pattern is maintained by aiming for an interval between calvings of 365 days and the entry of heifers into the herd is determined by the rate of voluntary and involuntary losses of mature cows from the so called autumn and spring herds in the same property.

In order to maintain a 365 day inter- calving interval, cows must conceive within 83 days after they calved, cows should get in calf during the first 3-4 weeks of the breeding programme, irrespective to their post-partum interval. Events that occur during the post-partum period are of critical importance to the success of the breeding programme (Macmillan,1985a).

## 2:1 Calving Interval (CI)

Is the average period between consecutive calvings of individual cows within a herd. While it is widely used in many countries with year-round calving as an index of a herd's reproductive performance, it is of little value in New Zealand's spring calving herds, where all cows must maintain a 364 day calving interval, but it may be a relevant and valuable indicator of reproductive performance in winter milk, or all-year round milk supply herds.

The calving interval of New Zealand seasonal herds is 364 days (Macmillan and Moller, 1977) and for winter milk herds is 384 days respectively (Fielden *et al.*, 1980). These compare with 395 days in USA, 405 days in the U.K and 420 days in Tanzania, but these values may be poor indicators of the herds fertility and profitability as they do not consider the rate of culling from low fertility.

The components of the calving interval are shown in figure 2.1 with factors known to influence each parameter.

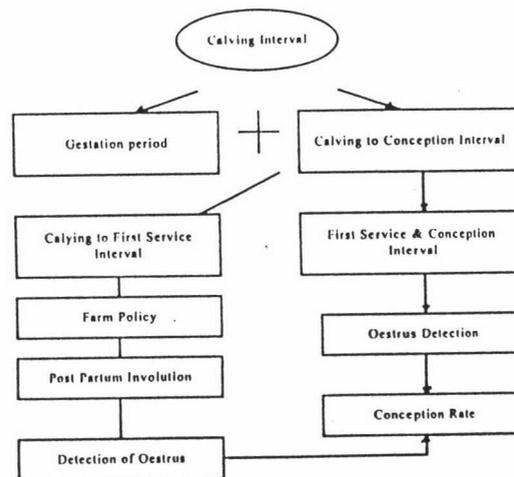


Figure 2.1. The components of the calving interval. From McKay (1988).

The components of the calving interval are gestation period (which is generally constant at about  $282 \pm 4.5$  days (Macmillan and Curnow, 1976a) and for practical purposes it can be changed by management practices such as induction) calving to first service interval and first service to conception interval.

Research studies and field reports indicate that prolonged calving interval (>365 days) results in less net income. While cows with higher producing ability and long calving intervals have a decided advantage in daily milk flow and profitability over low producing cows, cows with extended periods between calves spend a smaller proportion of time in the high-yield profit phase of lactation (Call, 1978).

It is possible that even greater profit would be obtained with calving intervals shorter than one year. For example, calving intervals of 355-365 days gave the highest milk yields while calving intervals less than those mentioned above led to a depression in milk production (Esslemont and Eddy, 1977).

The main cause of variation between herds in days-open (DO), calving to first oestrus and calving to first service has been attributed to differences in practices for detection of oestrus (Bozworth *et al.*, 1972).

Many factors are likely to be important in determining the length of the calving intervals, including conception rate (Marion *et al.*, 1968), high milk production (Smith *et al.*, 1962), seasonal and environmental factors, age of the cow and service sire (Gwazdauskas *et al.*, 1973). However, the interplay of time intervals from calving to eventual conception and various physiological, environmental and managemental factors make it difficult to determine how to manage for optimum length of calving interval (Slama *et al.*, 1976).

### **2:1:1 Days From Calving To First Service**

This is the interval from when an animal calves until she is next bred. This depends on :-

- (a) Post-partum involution
- (b) The cow returning to overt heat after calving (cyclical activity)
- (c) The manager's decision as to when to begin the breeding of each cow  
(farm policy)
- (d) Heat detection

Management should be organised so that these events can be fulfilled as part of a 365-day calving interval programme.

In the past a number of workers advanced the view that mating early in the post-partum period cause breeding problems (Esslemont 1974). Uptodate evidence however, demonstrates no ill effects from early post partum breeding although the conception rate is likely to be lower, and a number of researchers advocate breeding earlier than 60 days post partum in order to try to achieve a 365-day calving interval of the herd (Esslemont,1992).

Days from calving to first service interval may deliberately manipulated. In Israel cows may be excluded from the breeding programme until maximum levels of production have started to fall for at least two consecutive weeks, or daily production is 90% of peak lactation (Macmillan,1985). Therefore, cows with lower lactational persistency are mated sooner than high producing herd mates with higher persistency. With normal levels of fertility this allows feed conversion efficiency and lactational persistency to be effectively exploited, although at the expense of a longer calving interval.

### **2:1:2 Days Open (DO)**

This is the average of number of days from calving to conception for the cows which conceived and the number of days from calving to culling for those that did not conceive (Esslemont,1992), and it is the major cause of variation in calving interval since gestation length is relatively constant at 282 days (range 272-293) for cows in New Zealand dairy herds mated to Jersey, Friesian and Angus sires (Macmillan and Curnow,1976).

The two major variables that make up calving to conception interval (DO) are the calving to first service interval and the first service to conception interval. There are problems in measuring the date of conception accurately although first service to conception interval reflects only one of the two components of days open (DO), it is an important measure of fertility once breeding after parturition has begun. First service to conception interval is thought to have a high association with the calving interval, second only to the *oestrus index* used by Jansen *et al.*, (1987) as a measure of efficiency

of detection of oestrus.

Days open provides a relatively accurate measurement of reproductive performance before an animal calves but has the disadvantage of not taking account of losses which may occur during pregnancy after the estimate is actually made. The advantage of this value is that it may be calculated at the end of the breeding season, thus making the value more current and of more value.

Assuming a 282 day gestation length, the target for average calving to conception interval (DO) is  $83 \pm 40$  (SD) days. In assessing herd fertility the calving to conception interval must not be considered in isolation because artificially low figures may be obtained by heavy culling for infertility. Farmers routinely cull for infertility after three or four services, so producing a low calving to conception interval in the surviving cows, whereas other farmers may persist with these cows and have a high calving to conception interval but a lower culling rate (McKay,1988).

## **2:2 Calving Date and Calving Pattern**

Dates of calving are important characteristics of the herd's overall productivity in three main ways:

a) These dates determine the timing (during the year) of the herd's milk supply. This aspect is very important on farms which have contractual agreements to supply specific quantities of milk to the market during particular periods of the year e.g, winter or market milk producers with winter contracts.

b) Calving dates determine the timing of the large increase in the herds daily feed requirements which occurs at the start of lactation (daily feed requirement increases by 1.5-2.0 times, by comparison with the non-lactating cow). Therefore, these dates are important *feed management factors* which operate within the framework imposed by the farm's stocking rate. However, the herd's calving dates were determined by the conception dates in the previous year. Therefore, this important management decision must be made about one year in advance of actual events (Holmes,1986).

c) Calving date and compact calving has also an influence on the milk production system in terms of animal health, labour demand, cost of feeding cows etc. The milk supply pattern available to the food industry is primarily influenced by the calving pattern on dairy farms. This in turn has an influence on milk price paid to the dairy farmers (Dillon *et al.*,1994).

### Calving Pattern:

The calving pattern is dictated by the distribution of calving dates for individual cows and the conception pattern. High submission rates are necessary to achieve a compact calving pattern. It is important to recognise that calving pattern does not follow a normal distribution (Dillon *et al.*,1994), but has a skewed distribution as illustrated in fig 2.2 While the mean calving date is a widely used statistic, it is important to recognise that the distribution of calvings is also important. The use of mean calving date and the proportion of the herd calving in the autumn and spring does not give enough information about the calving pattern (Dillon *et al.*,1994).

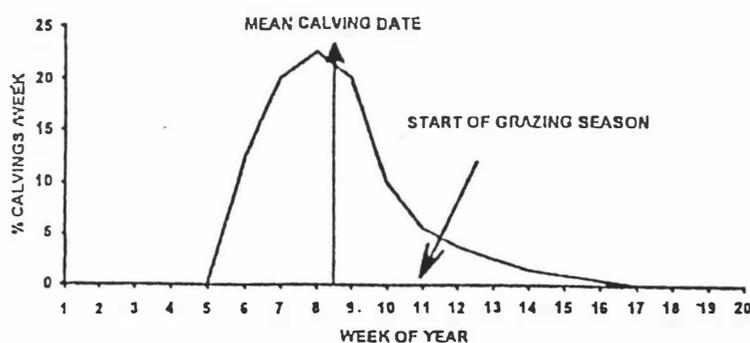


Fig 2.2 Good calving pattern based on spring-calving in Ireland. From (Dillon *et al.*,1994).

The number of calvings per week over a particular period from the start of the calving season is a better system for evaluating a calving pattern for a particular milk production system. In fig 2.2 the calving season starts on week 5 but there is a compact calving pattern with 90% of the herd calving in 6 weeks, before turnout date.

In Ireland, the optimum calving dates to maximise profit from pasture dairying system is based on autumn calving (40%-45% of the herd) and spring calving (50%-55% of the herd) (Dillon *et al.*,1994).

### **(i) Winter Milk Herds**

Winter milk farmers need to calve cows at different times of the year in order to meet a daily quota. The number of cows which must be calved at different times of the year will depend mainly on the size of the farm quota (litres per hectare/day) and also on any special feed supply problems which may exist on the farm (Holmes,1986). The higher the proportion of total annual production that is required to meet quota, then the more spread and regular the calving pattern must be throughout the year (Eede,1981).

Generally, quotas of up to 15 litres per hectare can be met by calving a proportion of the herd in spring and a proportion in autumn. However, very high quotas (>30 litres/hectare) can be met by calving an equal number of cows in each month of the year (Holmes 1986, Eede,1981).

In systems with two calving herds, the aims should be to achieve compact calving patterns within both calving groups (e.g, 90% calved about in 7 weeks) (Macmillan,1985). All the principles of mating management which apply to seasonal supply herds should be applied to both the autumn and spring calving groups, which will be mated in winter and late spring respectively.

In Tasmania, cows in autumn calving herds produced less kilograms milk fat/cow/lactation than cows in spring calving herds (Fulkerson *et al.*,1987), primarily due to a reduced feed supply available to autumn calving cows. The following factors were among those considered important:-

- \* Wastage of total feed available due to high conservation losses
- \* Reduced pasture regrowth due to high pasture damage in winter and hard grazing/high conservation in spring
- \* Low utilization of winter pasture due to lax grazing cows in full lactation during winter.

There is however, no evidence to suggest that if autumn calvers are offered the same quantity and quality of feed throughout lactation as spring calvers, they should produce any less milk fat over a lactation. (Thomas *et al.*,1985) showed that autumn calvers fed large quantities of supplement and concentrates produced more milk fat than predominately pasture fed spring calvers.

On most winter-milk farms, at the stocking rates which are widely used the lactating cow would be severely underfed and the pastures would be severely overgrazed if supplements were not fed during winter (Holmes *et al.*,1991).

### **(ii) Seasonal Supply Herds**

The choice of calving date is a decision which, through its effects on level of feeding in early lactation and on length of lactation, is of considerable importance in relation to farm productivity (Holmes & Macmillan,1982). The quantity of milk produced by a cow during a lactation is determined by two factors:-

- a)The total length of lactation (days in milk)
- b) The average daily milk production during lactation (Holmes,1986).

In a seasonal supply system where drying off-date is the same for all cows, late calving cows (e.g, September) clearly have shorter lactations than July or August calving cows, but may achieve a higher level of milk production per cow per day than early calving cows (Hutton 1968). However, this higher daily production may be insufficient to offset the shorter lactation, so September/October calvers produce less total milk fat than July or August calvers (NZDB,1951).

On the other hand, early calvers (June) although they have long lactations, may have lower average daily production per cow and total kg milk fat per cow/annum than August calvers, probably because of underfeeding in early lactation (Holmes,1986).

In deciding a calving date, the principle is to achieve the best match of feed demand and supply. While feed supply is dependant on pasture growth rates, feed demand will depend on three things (Simmonds,1985):-

- a) Cow feed requirements when cows are dry or lactating. According to Holmes and Wilson (1984), the daily feed requirements of a cow increase by 50% to 100% as soon as it calves.
- b) The pattern of calving which is variable between herds due to differences in rates of submission and conception (Macmillan & Curnow,1976).
- c) Stocking rate.

The most important objective of the breeding programme for a seasonal dairy herd is to have a concentrated calving pattern relative to pasture growth. One system used to analyse the calving pattern in New Zealand dairy herds is as follows :-

- a) The number of days for the first 50% of the herd to calve
- b) The number of days for the next 25% of the herd to calve
- c) The number of days for the last 25% of the herd to calve

The division of the calving pattern allows different aspects of the herd management to be assessed (Macmillan, 1985b). Two measures of spread have evolved to describe the calving pattern and each has its advantages and disadvantages. The first is the percentage of eligible cows calving by a set time in relation to the PSC date (calving rate). The calving rate for a herd is defined as the percentage of cows eligible to calve, which have calved by a defined day, relative to planned start of calving date (PSC) (McKay,1988).

An outline of factors influencing the calving pattern in New Zealand dairy herds is shown in figure 2.2.1

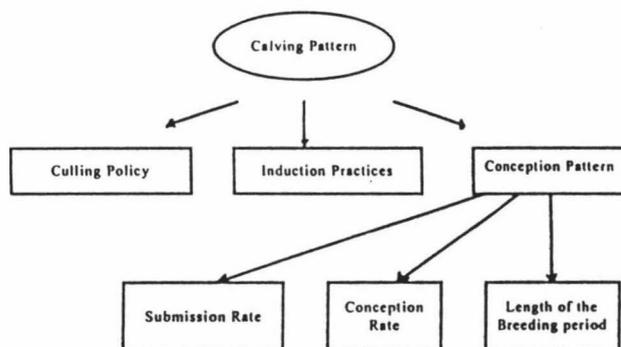


Fig 2.2.1 The factors influencing the calving pattern. From McKay (1988).

The second measure of the calving spread is based on the number of days it takes a predetermined percentage of the eligible herd to calve. This is sometimes called the *calving spread*. It is usually broken into three periods as described by (Macmillan 1985b).

### **2:3 Submission Rate (SR)**

This is the percentage of cows in the herd which are submitted for mating during a set period after the start of mating. It is common to refer to *28 day submission rates* because many cows have cycle lengths of slightly more than 21 days and therefore, can not be expected to be detected in oestrus during the first three weeks. However, many herd owners now prefer to relate submission rate to 3 weeks (Macmillan,1985).

In a well managed herd at least 80% of the herd should be inseminated during the first three weeks of the AB programme and 60% to 65% of these cows should conceive to the first insemination. The conception rate (CR) can be influenced by some factors beyond the herd owner's control (e.g, semen quality, inseminator competence) but submission rate (SR) is solely the herd owner's responsibility.

In addition the SR requires constant daily attention from the herd owner, but the CR cannot reasonably be estimated until the AB programme has been in progress for at least 4 weeks. Therefore, a herd owner should concentrate on achieving a high SR. This is because a high SR is essential if the herd is to have a concentrated calving pattern and it will minimise the effects of an unexpectedly low CR on the calving pattern (Macmillan,1985).

Some factors are of differing importance to SR and CR namely:-

#### **2:3:1 Accurate and Thorough Oestrus Detection**

This is an important factor which influences submission rates. Poor detection of oestrus has been identified as the major factor reducing reproductive efficiency in many dairy herds (Esslemont and Ellis 1974, Morris *et al.*,1976, de Kruif and Brand 1978, Jansen *et al.*,1987, Macmillan *et al.*,1984).

### **2:3:2 Previous Calving Pattern**

Late calving cows are less likely to return to cycle before the planned start of mating and hence must be mated at their first postpartum oestrus (Macmillan,1985a). Cows which have calved more than 40 days at planned start of mating (PSM) are more likely to have cycled before the start of the breeding programme, since the interval from calving to first oestrus in New Zealand dairy herds is 47-50 days (Macmillan and Clayton,1980).

### **2:3:3 Nutritional Deficiencies**

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

### **2:3:4 Periparturient Diseases**

Periparturient diseases such as calving difficulties, retained foetal membranes and metritis will delay the interval from calving to first oestrus (Eddy,1980).

Moller and MacDiarmid (1981a), showed that late calving cows which were induced to calve prematurely had prolonged intervals from calving to first oestrus in 2 out of 18 survey herds, with an average interval of 74.6 days, compared with a mean interval for induced cows in the other herds of 36.9 days. It was speculated that induced cows in these 2 herds were in poor condition at the time of calving and that caused a lengthy post-parturient anoestrus period to occur.

### **2:3:5 Return Interval**

If 67% of the inseminated cows conceive,33% should return to oestrous within 18-24 days. An optimal pattern of return interval would be that all non-conceivers return within 18-24 days after insemination or mating, because 18-24 days is the oestrous interval in normally cycling cows (Holmes and Wilson 1987, Macmillan *et al.*,1984).

A deviation from the normal oestrous interval will usually reflect inaccurate oestrous detection. The categorisation of oestrous return intervals into short, medium and long allows better diagnosis of a possible fertility problem. At least 60% of all returns should be in the 18-24 day range (Grimmet 1986).

#### **2:4 Conception Rate(CR)**

The conception rate is the number of cows pregnant per 100 matings (Holmes and Wilson 1987). Macmillan (1984), defined conception rate as percentage of cows mated once that are not recorded as returning within 49 days of first insemination. This definition is equal to non-return rate which can be measured at periods between 30-60, 60-90 or 90-120 days post insemination.

The most appropriate method to measure the conception rates in these winter milk herds is based on pregnancy diagnosis findings especially on rectal examination, not on non-return rates as is the case in seasonal herds (Wiseman,1988).

Macmillan (1985a) described factors which influenced conception rate. These include female factors (cow fertility), male factors (sire, semen processing, semen quality and inseminating) and management factors (oestrus detection, nutrient supply).

#### **2:4:1 Female Factors**

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

##### **a) Post partum anoestrus (PPA)**

Cows undergo ovulation and oestrus at regular intervals of around 21 days following puberty. These cycles are normally interrupted by pregnancy and for a variable period of time after calving. This period following calving before the ovulatory cycles are re-established is called *Post partum anoestrus (PPA)*. PPA may be defined as the interval between calving and the first post partum ovulation. However, as this ovulation may not

be accompanied by behavioural oestrus, PPA is often defined as the interval from calving to first detected post-partum oestrus (McDougall,1994).

A late calving cow has less time before the start of the mating period for uterine involution and re-establishment of the relationship within the Hypothalamic-pituitary-ovarian axis, and hence a reduced probability that insemination and conception will occur within the planned mating period. However, cows that calve early in the calving period and that have extended periods of PPA, may also not be inseminated or conceive within the mating period, or may conceive late in the mating period resulting in late calving in the subsequent year (McDougall *et al.*,1993).

Moller (1970) demonstrated that the calving to first ovulation interval was 35 days for cows >4 years old, but >50 days for cows that were 2 or 3 years old. The calving to first oestrus interval has been reported as 47 days for one New Zealand dairy herd (Macmillan and Clayton,1980). By 4 weeks into the seasonal mating period, 14% of all cows had not been inseminated and of these animals, 73.7% had calved more than 50 days earlier and rectal palpation of the ovaries of these cows indicated that >85% of 2 and 3 year old cows had no palpable *Corpus luteum* (CL), suggesting that failure of resumption of postpartum ovarian activity, rather than failure of detection or expression of behavioural oestrus, was the underlying problem (Fielden *et al.*,1973).

These data indicate that the PPA interval of pasture-fed New Zealand dairy cows may be considerably longer than that of cows under different management systems. A significant proportion of the national herd may fail to commence ovulatory activity by the designated start of the mating period.

Overseas studies where concentrate feeding and *ad-libitum* pasture provision dominate (USA and Europe) the PPA intervals are considerably shorter. For example, the interval from calving to first post-partum ovulation has been variously reported as 19.1 (Carruthers and Hafs,1980), 23.6 (Britt *et al.*,1974), 24.3 (Lamming and Bulman,1976) and 30.6 days (Fagan and Roche,1986) and with between 7% -14% of cows not having ovulated by 50 days postpartum (Fagan and Roche,1986). The interval from calving to first oestrus is generally reported as 2-3 weeks longer (e.g 35.7 and 39.60 days, Britt *et al.*,1974).

Longer intervals from calving to first oestrus than from calving to first ovulation are at least partially due to a failure of detection of behavioural oestrus at first postpartum ovulation. However, these intervals are also affected by genetic, physiological and managerial factors.

Factors associated with extended periods of PPA have not been examined systematically in New Zealand dairy cows. No data on ovarian follicular turnover or endocrine status are available for New Zealand cows. Although treatment responses of cows with extended periods of PPA have been reported (Macmillan and Day,1987; Macmillan and Peterson,1993) the factors contributing to the failure to detect in oestrus up to 25% of cows and the large variation in treatment responses between farms have not been identified.

#### **Factors affecting the duration of PPA**

Suckling of cows prolongs their period of PPA in comparison to machine milked cows (Smith *et al.*,1981). Season of calving may also affect the PPA interval, both due to indirect effects of seasonal differences in nutrient quality and quantity.

The PPA interval for Jersey cows is shorter than for Friesians (Fonseca *et al.*,1983) or Friesian cross Jersey cows (Macmillan and Clayton,1980). Young cows have longer PPA intervals than older cows (Macmillan and Clayton,1980).

Extended periods of PPA have been associated with dystocia and cystic ovaries in heifers and retained foetal membranes, ovarian cysts and metritis in cows (Erb *et al.*,1985). Additionally, cows diagnosed as anoestrus (not detected in oestrus by 50 or 70 days post partum) had longer intervals to first service and conception (Etherington *et al.*,1985), lower first and total service conception rates (Francos and Mayer,1988) and a higher probability of being culled.

Body condition score (BCS) is an estimate of the percentage of the body that is adipose tissue, based on the external appearance of the animal (MacDonald and Macmillan,1993). Cows in lower BCS at calving have longer period of PPA than in higher BCS (Grainger *et al.*,1982).

By 40 days post-partum, a larger number of cows of the high condition score had ovulated than the low condition score cows (11 of 15 vs 4 of 15). The calving to ovulation interval was shorter in the high condition score cows than the low condition cows ( $27 \pm 15.1$  vs  $42.4 \pm 14.4$  days) respectively (McDougall, 1992).

Following calving, cows undergo a series of physiological changes associated with lactation. The transition from one state to another e.g, gestation to lactation is controlled by the homeorhetic mechanisms (Bauman and Curie, 1980) which orchestrate the required changes in metabolic processes.

The daily nutrient intake of many cows is less than that required to support milk production during the first 2-4 months of lactation. During this period of negative energy (EB) and protein balance (Butler *et al.*, 1981) body tissue is mobilised to meet the energy deficit. In opposition to the homeorhetic processes, the homeostatic processes attempt to maintain the body in its existing state. If excess body tissue is being mobilised in the early postpartum period, the homeostatic mechanisms may be activated so that milk production, the major energy requiring process, is reduced.

The duration and depth of negative energy balance have been correlated with the duration of PPA (Lucy *et al.*, 1992). The duration and depth of negative energy balance is a result of the complex interactions between the level of milk production, nutrient intake and the amount of body tissue available for mobilisation.

The interaction between the homeostatic and homeorhetic mechanisms is not well understood (Sauvant, 1994). For example, cows selected for high production have higher nutrient intake and mobilise more tissue than cows unselected for production, despite being offered an equivalent amount of feed (Bryant and Trigg, 1981).

In the group-grazing, pasture-fed dairy systems of New- Zealand, estimation of individual pasture intake and hence energy balance is technically difficult. Condition score, liveweight and blood concentrations of carbohydrates, lipid and protein metabolites (Payne and Payne, 1987) may be useful indirect measure of energy balance in grazing cows.

Reduction of LH concentration and pulse frequency have been observed in animals that are underfed and in negative energy balance, the underfeeding was associated with reduced blood glucose and insulin concentrations and elevated non-esterified fatty acid (NEFA) concentrations (Canfield and Butler,1990). Low blood glucose has been associated with poor expression of behavioural oestrus and lowered conception rates and LH concentration was reduced by pharmacologically-induced hypoglycaemia (Rutter and Manns,1987).

Undernutrition can exert inhibitory effects on the hypothalamic-pituitary-ovarian axis independent of the ovary, as ovariectomised, underfed sheep (Rhind *et al.*,1989) and cattle (Imakawa *et al.*,1986) have lower LH concentrations than fully-fed controls.

#### **b) Body condition score (BCS)**

Dairy cows calving in higher body condition score have adequate fat reserves to support milk production but often have lower feed intake (Berger *et al.*,1981), thus increasing negative energy balance.

Negative energy balance delays the onset of ovarian activity because mammary function apparently has metabolic priority over ovarian function through homeorhesis (Fonseca *et al.*,1983).

McGowan (1981) reported a negative relation between body condition at calving and the interval from calving to first oestrus.

Macmillan (1985a) showed that the conception rates were not affected by body condition scores at calving within the range of body condition score of 4.0-6.5 but, there was a decline in the conception rate at first service when the body condition at calving was below or above this range.

Cows which maintain body condition after calving have a shorter interval to first oestrus than those which lose body condition (Rutter and Randel,1984). Therefore, body condition scoring system is a useful management tool for relating suboptimal reproductive performance to inadequate nutrition in early lactation.

### c) Age

Two year old heifers had the highest percentage of inactive ovaries (85% of pre-service anoestrus), compared with 74% and 47% in the 3-year old and 4-year or older cows, respectively (Fielden *et al.*,1976). They also indicated that the two-year old heifers form a problem group in a herd and this was associated with stage of physical maturity, with nutrition and with social stress within the herd. Visser *et al.*,(1988) indicated that fertility increased by 6% from 2-5 years and then declined by 3% at ages 8-10 years.

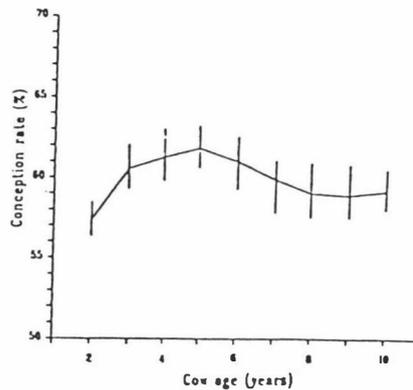


Fig 2.4 Conception rates for cows of different ages. From Visser *et al.*,(1988).

The young heifers had an interval from calving to first oestrus 10-16 days longer than the older cows in the herd (Macmillan and Clayton,1980). They also showed that in old Jersey cows the interval from planned start of mating to mean conception date was 23 days, compared with 36 days in 2-year old Jersey heifers.

### d) Breed effect

New Zealand farmers use four breeds of which Friesian and Jersey have the largest share in the national dairy herd, and Ayrshire and Milking shorthorns have small populations (Holmes and Wilson, 1987).

The pregnancy rate to first insemination was not different between Jersey and Friesian x Jersey cows, but the pregnancy to second and subsequent inseminations were higher in Friesian x Jersey crossbreds than Jersey cows (Macmillan and Clayton,1980).

In addition, Macmillan et al.,(1981) showed that the average interval from PSM to mean conception date for the crossbreds (Friesian x Jersey) was 3 days less than for the Jersey herd mates (23 days vs 26 days). Two year old cows ( irrespective of breed) took longer to commence ovulating than cows 3 years old (  $40.9 \pm 26.9$  vs  $27.1 \pm 14.1$  days) respectively (McDougall,1992).

#### e) Breeding index (BI)

The trend found in conception rate for the classes of breeding index (Fig 2.4.1) may be attributed to difference in fitness between animals of different breeding index. Under New Zealand conditions there is a lot of competition between cows, and selection on breeding index may include a correlated response in clinical fitness. Animals with high BI have a better fertility than animals with a low BI (Visser *et al.*,1988).

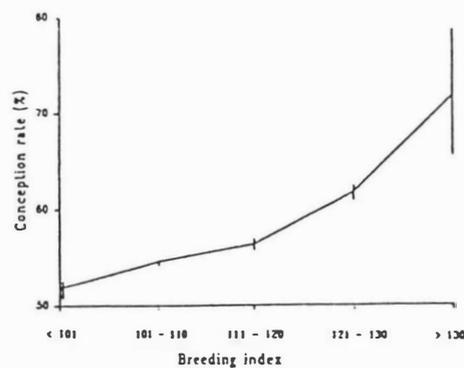


Fig 2.4.1 Conception rate for different classes of breeding index. From (Visser *et al.*,1988).

### **2:4:2 Environmental Factors Influencing Conception Rate**

Environmental factors may affect fertility. For example, pregnancy rates and conception rates during hot summer in USA were half of those for winter (24% vs 52%) (Badinga *et al.*,1985; Ron *et al.*,1984).

Results from a study of ovarian activity in post partum cows showed that the reproductive efficiency in spring-calving cows was higher than in autumn-calving cows in New Zealand. The percentage of the spring calving cows which showed oestrus at their first post-partum ovulation was higher than that of the autumn calving cows (62.9% vs 45.4%), intervals from PSM to conception and first service to conception was shorter in the spring herd  $28.3 \pm 1.5$  days and  $13.9 \pm 2.6$  days respectively, than in the autumn herd  $36.5 \pm 2.9$  days and  $18.5 \pm 2.6$  days, ( $P < 0.001$ ). These results were attributed to nutritional differences related to seasonal changes (Chaimongkol,1990).

High temperature on the day after insemination influenced pregnancy rate with significant reductions occurring when temperature exceeded  $30^{\circ}\text{C}$  (Gwazdauskas *et al.*,1981; Badinga *et al.*,1985).

Summer depression of reproductive performance of dairy cattle is a worldwide problem and inflicts heavy economic losses on the dairy industry. Many studies have documented the negative effects of high environmental temperature and humidity on fertility even when feed is freely available and its quality is not significantly affected by season, conception rate on first insemination may fall from about 50% in winter to about 15-20% in summer (Wolfenson *et al.*,1988).

High ambient temperature, acting through high body temperature sensors, may affect reproductive function either directly or indirectly. High Ambient temperatures are well known to reduce feed intake and induce a negative energy balance (Berman,1991).

In Holstein cows, monitoring of oestrus behaviour for 96 hours in winter and summer indicated that in cold weather oestrus behaviour as mounting activity was double than in hot weather in Indiana (28% vs 14%). Cows in hot weather interacted more by rubbing and licking than cows in cold weather (Pennington *et al.*,1985).

Dairy cattle tend to mate most frequently in late spring and summer, perhaps because of increasing day length that stimulates gonadotropin secretion, fertility level is lower in winter, when the days are short. Thus, responses to photoperiod are generally muted. For example, in sexually mature heifers neither photoperiod nor season affected the timing, amplitude or pattern or pre- ovulatory surges of LH or FSH or length of oestrus cycles (Tucker,1985).

### **2:4:3 Male Factors**

Male factors also play an important role in conception rates. Sire variation may be significant enough to cause problem. Davidson and Farver(1980) classified 18 sires, whose semen was used in a large 2550 cow herd, into three categories; low (38.2%), medium (55.7%) and high (66.1%) conception rates. Cows inseminated with semen from the high conception rate sires had an average calving to conception interval of 85 days compared with 109 days for the low group sires.

de Kruif and Brand (1978) suggested that there may be a high as 15% points variation in conception rate between bulls used in AI. They found that natural service provided higher conception rates at both the first and subsequent services. However, (Williamson *et al.*,1978) found little difference between natural service and AI.

The inseminator's ability is also a male factor that may affect conception rates. An analysis of New Zealand Dairy Board data (Visser *et al.*,1988) found variation in technician performance to be second to herd factors in a list of variables affecting subsequent calving rates to first service using liquid semen.

## 2:4:4 Management Factors Influencing Conception Rate

### a) Feeding level and supplementation effects

Supplementary feeding of grazing dairy cows may overcome the nutritional deficiencies of pasture and improve their reproduction performance. However, animal responses to supplementary feeding are influenced by a range of factors such as supplement type, supplement quality, stage of lactation, cow condition and pasture quality. In addition, cows may substitute supplements for pasture and this effect can decrease the economic response to supplement (Rogers, 1985).

Supplementary feeds are a crucial component of the average winter-milk producer's overall feeding strategy, providing about half of the herd's daily ration during winter, when pasture growth is slow (Holmes *et al.*, 1991).

The feeding of supplements is generally intended either to increase the cow's level of feeding and therefore increase her milk production, or to maintain the cow's level of feeding despite a limited supply of grazed pasture.

On most winter milk supply farms, the lactating cow would be severely underfed and the pasture would be severely overgrazed if supplements were not fed during winter. In these circumstances the supplements are likely to cause both short-term effects and long-term effects (Holmes *et al.*, 1991).

Silage supplementation to spring calving cows did not affect the percentage of animals ovulating or detected in behavioural oestrus before the start of the insemination period and did not affect the intervals from calving to first post partum ovulation, first oestrus or to conception (McDougall, 1994).

However, supplemented cows had a lower conception rate to first service than unsupplemented cows (37.5% vs 53.3%). The number of services per conception was higher in the supplemented (2.0 vs 1.5) than unsupplemented cows (McDougall, 1994). Actually the silage result is unexpected.

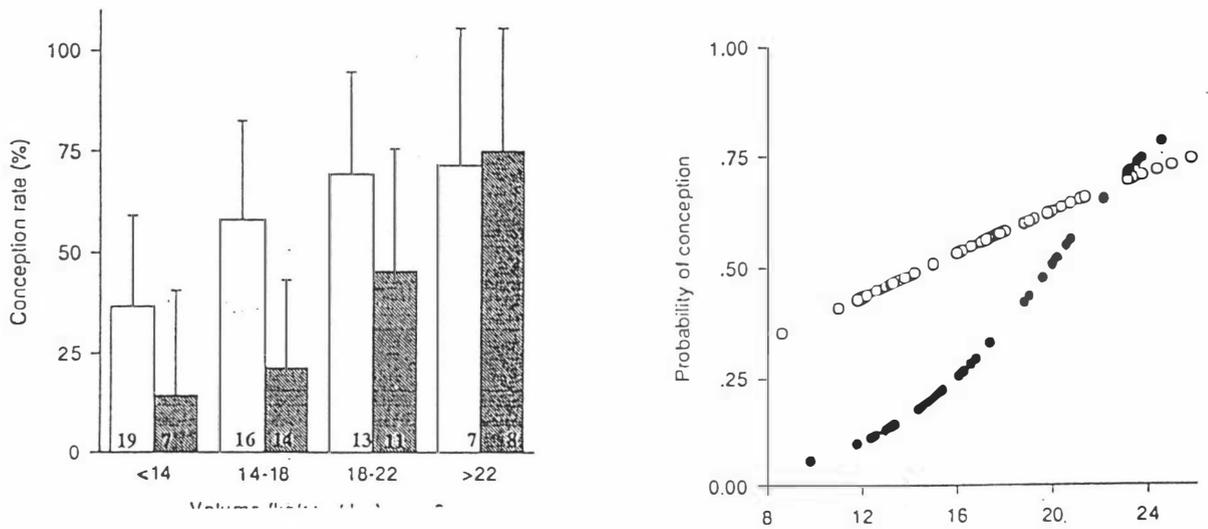


Fig 2.4.2 The estimated probability of conception (1.00= conception) at first service determined by logistic regression modelling (left) and the observed conception rate (right) (From McDougall *et al.*,1994).

The 37% conception rate in the silage-supplemented cows is below the 50% conception rate at which investigation of herd reproductive performance is recommended (Radostits,1985). Thus, the observed decrease in conception rate is statistically and biologically a significant result, and could be a very important effect in winter milk supply herds, if it does occur in these herds. Underfed post-partum cows, the interval between calving and first oestrus will be delayed and poor body condition are likely to be less fertile (Holmes *et al.*,1991). **Underfeeding in early lactation affects reproductive performance** (McCallum *et al.*,1994).

Milk production, liveweight, condition score and nutrient partitioning are interrelated and conception rate may be directly affected by changes in one or more of these factors induced by silage feeding.

Taylor and Leaver (1984b), working with cows fed high and low quality silage, found that calving intervals for the cows fed with high quality silage were significantly lower than those offered low quality silage. The authors attributed this effect to poor conception rates since days to first service were similar for both treatments.

Conception rate and reproductive efficiency from cows fed roughages/concentrates are reduced as a result of very high crude protein intake. Very high crude protein intake results in elevated levels of urea in the blood, milk and tissue fluids which include uterine secretions and vaginal mucus. These secretions may reduce sperm viability and reduce embryo survival (Elrod and Butler,1993). Hence, high intake of degradable protein in New Zealand pastures might adversely affect the reproductive performance of dairy cows. Direct evidence for this is however, equivocal (Williamson and Fernandez-Baca,1992).

In New Zealand, this effect was confirmed by Moller, (1991) who found high blood urea levels in herds with an anoestrus problem, especially around the time of mating. There are many factors affecting plant nitrogen levels. High pasture nitrogen levels can be induced by applying nitrogen fertilizer. Immature pasture has higher nitrogen levels than mature pasture, so rapid rotations in early spring may cause a problem.

#### **b) Accuracy of Oestrous Detection**

Accuracy of oestrous detection is the major factor affecting reproductive efficiency in dairy cattle (Esslemont,1974). Direct visual observation is the most common method used in detecting oestrus in most dairy herds.

The time spent observing oestrus is usually inadequate and many attempts have been made to develop oestrus detection methods in order to increase oestrus detection rates. Several techniques have been used to aid oestrus detection, taking into account ease of use, effectiveness, accuracy and cost for practical application. In addition, the duration

and intensity of oestrous behaviour is variable and behavioural interactions change continuously (Esslemont & Bryant,1976).

Tail painting is widely used as an aid in detecting oestrus in grazing cows with seasonal calving patterns (Macmillan & Curnow,1977a, Williamson,1980a) when many cows are in oestrus and sexually active groups (SAG) are formed.

Some studies used mounting activity of surgical vasectomised bulls or hormone-treated cows or steers (Sawyer & Fulkerson,1981, Stevenson and Britt,1977).

One method, not based on mounting activity,measured vaginal mucus electrical resistance (McCaughey and Peterson, 1981) to detect oestrus in cows staying in stanchion barns. Pedometers have also been used to measure the increased activity of cows at oestrus (Williams *et al.*,1981).

Milk progesterone techniques have been developed and have been widely used to detect post-partum ovulation events and oestrus in dairy cows (Mather *et al.*,1978).

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

Silent oestrus is common at the first ovulation soon after calving, and oestrus detection rates increase with the number of post-partum ovulations (Fonseca *et al.*,1983, Helmer and Britt,1985). For example, Fonseca *et al.*,1983 found that intervals to first ovulation were about 21 days for Holstein cows and only 12% of the first ovulations were associated with detected oestrus.

The detection rates increased by an average of 10% at each subsequent oestrus. Results from Moller, (1970) and King *et al.*, (1976) showed the percentages of cows that showed oestrus at first ovulation were 57% and 50%, respectively.

Additionally, results from Morris *et al.*, (1976) showed that by using a television system the percentage of cows in free-stalls showing oestrus symptoms at first, second and third ovulations were 39, 94 and 100 respectively which were higher than those of tie-stall cows (16, 50 and 61) respectively.

The lower detection rates at the first ovulation may be related to a true absence of oestrus, or reduced duration and or intensity of oestrus and or physiological, biochemical or environmental factors or interval from calving to first ovulation (short oestrus cycles post-partum preceded by expressed oestrus).

Malven (1984), proposed that the increased probability of behavioural oestrus with the number of post partum ovulations may result from:

- i) a longer period of recovery from pregnancy and or metabolic adjustments to lactational stress.
- ii) prior exposure to progesterone.

### **Factors Affecting the Expression of Oestrus:**

#### **1. Management and management activity in the herd**

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

Types of housing and feeding may affect the expression of oestrus. Britt *et al.*, (1986) showed that oestrus cows mounted more frequently and also stood more often when on a dirt lot than on clean grooved concrete. It was more difficult to detect oestrus in cows

kept tethered in tie-stall and free-stall areas, compared with cows which were allowed to graze.

Signs of oestrus other than mounting activity, such as bellowing, clear mucus from the vagina and restlessness can also be used to detect oestrous cows. Underfeeding delays puberty in animals. It also resulted in cessation of oestrus and ovarian activity in heifers that were already cycling (Bond *et al.*,1958).

## **2. Season and climate**

Pennington *et al.*,(1985) reported that climate can affect mounting and total sexual activity in lactating dairy cows. They showed that cows in hot weather were in oestrus for longer with less intensity of mounting than those in cold weather. Consequently, cows had more oestrus activity in cold temperatures than cows in hot temperatures. de Alba *et al.*,(1961) reported that heat stress reduced the intensity of oestrus in Zebu cattle and sometimes even in *Bos taurus* cattle raised in the tropics. Heavy rain stopped all oestrus activity, but only for a short period (Williamson *et al.*,1972b).

## **3. Number of animals in oestrus**

When the sexual active group (SAG) is formed in a herd, there is a greater mobility of the group around the paddock. Hurnik *et al.*,(1975) observed that the number of mounts per cow increased from 11.2 with only one oestrus cow to 52.6 with three cows in oestrus on the same day. Similar results were observed by Britt *et al.*,1986).

## **4. Breed effect**

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

## 5. The presence of a Bull in the herd

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

### Oestrous Detection

Oestrous detection is the most important part of reproductive management when AI is practiced. Poor oestrus detection causes low submission rates and consequently delays conception. There are many methods used to detect oestrus in cattle namely:

#### i) Visual aids

This method uses signs of oestrous behaviour such as standing to be mounted activity. Other behavioural features of oestrous cows have been reviewed. Only 50%-60% of the oestrous cows were observed in a herd when mounting activity was used to detect oestrus (Williamson *et al.*,1972b, Esslemont,1974).

Williamson *et al.*,(1972b), used continuous observation for 24 hours to detect all oestrous cows, while Fulkerson *et al.*, (1983), used 12 hour observation with a detection rate of 83%. However, continuous observation for oestrus cows in most dairy herds is unlikely to be practical.

Oestrus detection aids such as tailpainting, heat mount detectors and hormone-treated steers have been developed and used to improve oestrus detection rates in seasonal dairy herds (Macmillan and Curnow,1977). The use of one of these oestrous detection aids namely, tailpainting can produce high detection rates of more than 90% when combined with visual observation in well-managed New Zealand dairy herds.

From the visual method used for oestrous detection there are three main types of errors in oestrous detection and each has different effects on submission rate (SR) and conception rate (CR). These errors and their main effects are:

i) *Errors in omission* which occur when an oestrous cow is not detected. They reduce submission rate, need not reduce conception rate but will delay conception date.

ii) *Errors in diagnosis* which normally involve non-oestrous inseminations. They may increase submission rate but will reduce the conception rate. Their effect on conception date is variable.

iii) *Errors in identification* which occur when one cow in a herd is correctly diagnosed in oestrus but confused identity means a herdmate receives a non-oestrous insemination. They may not reduce submission rate, but will reduce conception rate and delay conception date.

Errors in diagnosis or identification usually produce return-to-service intervals which are less than 18 days and are randomly distributed between 1 and 18 days, whereas errors of omission decrease the proportion of returns to service of at least one cycle (18-24) days. Measures of detection efficiency in seasonal dairy herds have been described in detail in an extensive review (Macmillan,1979). A detection technique or oestrous observation routine must minimise the incidence of each of these errors.

## ii) Non-visual methods

### \* Rectal palpation

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

### \* Cervical or Vaginal mucus crystallisation

The crystallisation patterns of the mucus collected at different stages of the oestrous cycle can be used to detect oestrus (Goel and Rao,1971). The crystallisation patterns before and after oestrus were *fern-like* and were more visible near oestrus than during the luteal phase. Crystallisation patterns of vaginal mucus were less reliable indicators of oestrus than those of cervical mucus (Bane and Rajakoski,1961).

### \* Cervical and vaginal mucus resistance and conductivity

Changes in electrical resistance of mucus in the anterior vagina can be associated with oestrus in cattle. Electrical resistance was lower at oestrus than during dioestrus (Leidl and Stolla, 1976). This method was related to milk progesterone levels during the 4-days before oestrus (McCaughey and Patterson, 1981).

### \* Vaginal pH

It was reported that the intravaginal pH of a cow tends to decrease during oestrus. The pH was nearly constant during dioestrus, ranging from 6.86-6.98 at the cervix, from 7.26-7.38 at the mid part and from 7.0-6.72 one day before oestrus and further decreased to 6.54 at the beginning of oestrus (Schilling and Zust, 1968).

### c) Effect of Stocking Rate

Stocking rate was defined by Mott (1960) as the number of animals per unit area of land, irrespective of the amount of forage available. However, Holmes and Parker (1992) indicated that this definition can be misleading expression because it does not reflect the effective stocking rate of the farm, because differences in liveweight and productive potential can cause differences in herbage intake (Bryant, 1980).

Therefore, Holmes and Parker (1992) suggested the term *effective stocking rate* which can be calculated as the utilisation of pasture, that is total pasture eaten per hectare/total pasture grown per hectare calculated for a year.

White (1987), indicated that stocking rate is recognised as one powerful management tool in the New Zealand grazing system. A farm's stocking rate is positively correlated with the total economic return to the farm-owner ( $R^2=0.93$ , Deane, 1993) which has led to increases in stocking rate in many New Zealand farms.

The direct effect of stocking rate on animal production is through herbage intake per cow and per hectare. Increased stocking rates may be associated with reduced feed intake, condition score, liveweight and milk production for individual cows. This may also prolong the post-partum period however, pasture intake per hectare is increased as

well as pasture utilisation and more animal product per hectare is usually achieved. Therefore, increased animal production per hectare is achieved through increasing pasture utilisation.

Stocking rate can profoundly influence the productivity and profitability of a grazing system. Performance per animal decreases but performance per hectare increases as stocking rate increases. Stocking rate interacts with many of the physical, biological and economic components of any farming system, so that optimal stocking rate will be particular for a particular farming situation.

### **Reproduction**

Stocking rate affects animal liveweight and body condition score. However these two parameters have an important effect on reproductive efficiency, particularly at mating, since ovulation rate is closely associated with maternal liveweight (White,1987) and body condition score (McDougall,1992).

McDougall (1992) studied the effects of breed and stocking rate on the reproductive performance of grazing dairy cattle in New Zealand. Stocking rates were calculated such that the metabolic weights per hectare were similar among stocking rates irrespective of breed. The results showed that high stocking rate increased the interval to first ovulation by 11 days for Friesians and 6 days for the Jerseys as well as the interval to first oestrus by 18 days for Friesian and 8 days for the Jerseys. Thus, the percentage of cows that had shown oestrus by 50 days post-partum was reduced in cows at higher stocking rate. The adverse effect being more severe in the Friesians (38%) than in the Jerseys (85%) As a result of this, 3 week submission rate was reduced by high stocking rate. There were also significant negative correlations between the herd mean condition score and the herd mean interval from calving to first ovulation and to first oestrus (McDougall,1992).

Herd	% ovulated by			% detected in oestrus	
	d 45 pp*	d 50 pp*	PSM-7 d	d 50 pp*	PSM-7 d
LSJ	95.0	100.0	100.0	100.0	100.0
HSJ	88.2	89.4	94.7	84.9	100.0
LSF	87.5	87.5	94.1	90.9	90.9
HSF	47.4	50.0	90.0	37.9	89.7

(L: low, H: high) (J: Jersey, F: Friesian)

Table 1. The effect of stocking rate and breed on the percentage of animals having ovulated as determined by 3 times weekly milk progesterone assay and on the percentage of animals detected in oestrus by either 45 or 50 days post partum (d 45 pp, 50 pp) or by 1 week prior to the planned start of mating (PSM-7 d). \* Significant difference between herds ( $P < 0.005$ ), calving interval over the 1<sup>st</sup> 12 months of the experiment did not differ among sub-herds ( $p > 0.1$ ). Source: (McDougall 1992)

#### **d) Feeding (Nutrition) and Reproduction**

Feeding plays the most significant role in influencing both production and reproduction in dairy cattle. The major axis around which nutritional management of cattle revolves is the energy-protein input output relationships. The concept of infertility as a metabolic disease is inherent in understanding nutrition and fertility. For pasture based dairying systems nutrition is difficult to control due to the great fluctuations in pasture conditions and the economic constraints that often apply in regard to altering diet (Lean,1992).

The impact of nutrition on fertility is not limited to any particular stage of the reproductive cycle of the cow. Nutritional requirements of the dairy cow are calculated for a given stage and level of production.

#### **Energy and Fertility**

The major impacts of energy on fertility are in the period from the last trimester of pregnancy to the time when pregnancy is established. Both excesses and deficiencies of energy have been implicated in suboptimal reproductive performance (Lean,1992).

Cows which calve in higher body condition have lower appetites post calving (Garnsworthy,1988). Under conditions where dry matter intake is essentially ad-libitum (USA,Europe) these cows may lose the advantage of increased condition and be no more fertile than herdmates. This is reflected in greater energy deficit post calving for cows in heavier body condition and contrasts to the New Zealand situation where dry matter intake is often restricted post-partum and cows with greater body condition benefit from additional reserves (Lean,1992, Grainger *et al.*,1982).

Milk production responses to higher body condition scores will be dependant on tissue reserves and tissue mobilization which is favoured by diets high in undegradable nitrogen (escape/bypass protein) (Lean,1992). Thus, the influence of high protein diets may be through exacerbating an energy deficit in situations where energy levels are already marginal.

Under New Zealand conditions, the ability to increase intakes to achieve energy balance by feeding rations of high undegradable protein is likely to be severely limited by low pasture dry matter content and by an imposed restriction on pasture made available for grazing. Energy deficits *per se* have detrimental influences on fertility. Energy deficits in cows before calving can cause cows to calve in inadequate body condition. This is a major factor influencing the interval to oestrus after calving.

Post-partum energy levels also influence return to oestrus.

Energy status, body condition change and milk yield are widely believed to affect fertility. However, the evidence has been conflicting when these factors were examined around service. Improvements in condition and feeding in early lactation reduced the anoestrus interval after calving by 5.7 days for each additional condition score at calving and 1.2 day for each additional kg DM/cow/day fed over weeks 1-5 of lactation (Grainger *et al.*,1982). Cows with high energy status (high glucose and low FFA) took less time to begin cycling, had a better first service rate and required fewer services per conception (Whitaker,1995).

A 450 Kg cow producing 35 kg of milk requires three times more energy for production than for maintenance. The energy requirements are met through a combination of dietary intake and mobilization of body reserves. Excessive mobilization of body reserves has been associated with post partum fatty infiltration of the liver and reduced reproductive performance in high yielding cows (Saloniemi,1993).

Age of the cow has an influence on energy status-fertility relationship. Cows in their first lactation need energy for continued growing. First calvers have more treatments for anoestrus or sub-oestrus, but less treatments for ovary dysfunction and their conception rate is much better than that in older cows (Anon,1991). High yielding heifers, calved in autumn, have a high risk of treatment for anoestrus than old low yield cows calved in spring (Saloniemi *et al.*,1986).

## Protein and Reproduction

Increasing dietary crude protein (CP) intake will sometimes lead to increased milk production. However, in some studies, increasing dietary CP has resulted in a decrease in reproductive efficiency (table 2).

Trial	% CP	%UIP-CP <sup>1</sup>	4%-FCM	NO. COWS	% of NRC CP	% of NRC UIP	% DIP <sup>2</sup>	Conception Rate (%)
Roffler & Thacker, 1983	14	29	51.7	31	91.1	75.0	100.0	56
	17	32	58.4	38	116.1	104.5	122.5	53
Edwards et al., 1980	13	41	49.9	6	98.1	115.8	88.6	44
	15	40	57.0	6	107.6	123.8	100.0	39
	17	38	56.1	6	119.1	128.6	112.8	37
Carroll et al., 1988	13	36	53.9	29	85.0	85.0	85.0	67
	20	34	57.2	28	119.3	114.3	122.1	56
Howard et al., 1987	15	34	57.2	75	113.1	109.5	115.0	64
	20	36	61.7	71	143.1	147.8	140.5	68
Folman et al., 1981	16	37	74.3	20	77.6	81.5	75.5	69
	16	32	71.8	20	89.2	80.8	93.8	56
	20	32	71.0	20	111.0	100.0	117.0	44
Jordan & Swanson, 1979	13	31	64.2	15	73.1	62.3	79.1	68
	16	34	68.0	15	93.0	88.0	95.7	54
	19	36	70.8	15	108.2	107.7	108.5	41
Kaim et al., 1983	15-16	37	67.7	80	85.3	90.4	82.4	57
	19-20	37	67.4	89	108.6	112.0	105.8	43

Table 2. Summary of protein/reproduction trials<sup>1</sup>. From <sup>1</sup>Shaver, R (1989).

Three possible reasons that increasing dietary CP might result in a decrease in fertility are that excess dietary CP intake may result in :-

- 1) an increase in ammonia and its metabolites, which may be toxic to gametes and early embryos.
- 2) magnification of the effect of early post partum negative energy balance.
- 3) suppression of immune function.

Ferguson and Chalupa (1989) used logistic regression to generate a model to predict the impact of varying amounts of rumen DIP and UIP on fertility. Age and dietary energy concentration were also important in determining the impact of protein on reproductive efficiency. In addition, they reported that the conception rate in a herd was three times less when serum urea nitrogen (SUN) levels were  $>20$  mg/dl as compared to when SUN was  $<20$  mg/dl. Similarly (Canfield *et al.*, 1990) reported plasma urea nitrogen (PUN) levels were higher in animals which did not conceive (18.6 mg/dl) as compared to those that did conceive (15.7 mg/dl).

Elrod and Butler (1993) fed virgin Holstein heifers total mixed rations, which were formulated to provide 70% of the recommended ME daily and either met or exceeded the requirement for ruminally degradable protein. The first service conception rate was reduced from 82% to 61% in the heifers fed excess DIP. When they stratified the heifers based on plasma urea nitrogen (PUN), Elrod and Butler (1993) observed that fertility was markedly reduced in heifers with PUN levels  $> 16$ mg/dl.

The exact mechanism by which excess DIP may negatively impact fertility has not been elucidated, several studies have been conducted to evaluate potential mechanisms. In 1983, Jordan *et al.* reported that the concentration of Calcium, Magnesium, Phosphorus, Potassium and Zinc in uterine fluids aspirated at oestrus did not differ between cows fed either 12% or 23% CP rations. However, during the luteal phase of the oestrous cycle, uterine fluid Mg, P, K were reduced in cows fed the high protein ration.

Alteration of the uterine environment is further illustrated in the Holstein heifer study of Elrod and Butler (1993) in which a reduction of uterine pH on day 7 of the oestrous cycle occurred and a tendency for lower pH at oestrus in heifers fed excess ruminally DIP existed.

In the study of Elrod and Butler (1993), 7 of the 16 heifers fed excess DIP which did not become pregnant at first service, had an extended oestrous cycle ( $>25$  days), while none of the heifers in the control group had an extended oestrous cycle. This supports the hypothesis that one of the possible reasons for reproductive failure may be a negative

impact on embryo survival.

In a study in Ireland, (Armstrong *et al.*,1990) the feeding of a fish meal was shown to increase fertility significantly in a herd fed a rye grass silage based ration. The nitrogen intakes in all diets appeared high from the limited information provided. Crude protein in the silage was 16.6% and fish meal provided a source of undegradable rumen protein. However, the plasma urea level was increased in cows fed fishmeal, indicating that reducing the blood urea level may not be the only factor acting to improve fertility when undegradable rumen protein is fed to cows fed high crude protein diets.

Based on modelling work, experiments and observations (Ferguson *et al.*,1988) concluded that ruminally degradable protein and undegradable protein influence fertility independently and show interactions with the age of cows. Older cows in their fourth and late lactations are more susceptible to fertility depression due to high rumen degradable protein intake than younger animals while in young animals, there appears to be a negative influence of rumen undegradable protein on fertility, but there is an improvement in growth.

Conception efficiency in New Zealand dairy herds has been reported as being as high as 60%-68%, very high by world standards. New Zealand pastures are protein rich, with protein levels commonly above the 20% crude protein levels associated with infertility in other places, and reaching levels of as high as 36% crude protein. Pastures generally make up the total ration fed to cows in spring so the opportunity to balance rations with other ingredients to lower,more appropriate protein levels is generally absent. Thus, there is an apparent anomaly, with New Zealand having fertility levels which are probably the highest in the world, and also protein levels in pastures which are excessive by world standards and are hypothesized to cause infertility in other places (Williamson *et al.*,1992).

A New Zealand study related pasture nutrient values,blood metabolite levels and herd fertility (Moller,1991). He found that herds with highest urea levels had the highest levels of anoestrus. They grazed pastures with higher protein and lower soluble

carbohydrate levels. Also he observed that conception rate was lower when breeding occurred at the time of peak blood urea levels.

Overseas data (Bull,1990) support the evidence presented in New Zealand that spring pasture is protein high and sometimes carbohydrate low. However, (Williamson *et al.*,1992) concluded that there is a negative influence on fertility in the pasture based feeding regime of New Zealand, although the depression of fertility does not appear to be as severe as that reported in the northern hemisphere 5.55 mmol/l vs 7.0 mmol/l urea in blood reported by (Ferguson *et al.*,1988) in the USA.

### **Vitamins and Minerals**

Mineral imbalances are frequently thought to be associated with infertility in cattle. It is often clinically difficult to determine if a specific mineral/vitamin is responsible for a given infertility problem (Morrow *et al.*,1986).

Vitamin A, E and Selenium had long been known to affect fertility in cattle and may be necessary for reducing the incidence of retained foetal membranes . Calcium and phosphorus deficiencies affect reproduction, Vitamin D is an essential part in mineral metabolism but seems to be important also in endocrine and reproductive functions (Saloniemi,1993).

### **Calcium and vitamin D**

Calcium is needed for both growth of skeletal system and lactation. Its effect on reproduction appears to be primarily an indirect one. To prevent milk fever, it is important to restrict calcium intake during the dry period, particularly the last three weeks (Morrow *et al.*,1986). It was found that first service conception rates decreased as Ca:P ratios widened, and that conception rates decreased when vitamin D and phosphorus levels were low (Lean,1992).

**Phosphorus**

Phosphorus is necessary for normal energy and phospholipid metabolism as well as normal skeletal development and milk production. Signs of a deficiency may include a delayed onset of puberty, post partum oestrus and repeat breeding (Morrow *et al.*,1986, Holmes *et al.*,1987). Inadequate phosphorus intake also is associated with decreased intake of dietary energy through decreased appetite (Lean,1992).

**Selenium**

Deficiency signs include a muscular dystrophy known as *White muscle disease*, decreased fertility and an apparent increase in the incidence of retained foetal membranes (Morrow *et al.*,1986, Holmes *et al.*,1987).

**Iodine**

Iodine effects on fertility are related to the effects on the thyroid gland and hormone synthesis. Signs of an iodine deficiency related to reproduction include delayed puberty,cessation of oestrus activity and anovulatory oestrus periods. When an iodine-deficient diet is fed during pregnancy, cows may deliver weak or dead,hairless calves. Cows may also abort and have an increased incidence of retained foetal membranes and calves may be born with goiter (Morrow *et al.*,1986, Holmes *et al.*,1987).

**Copper**

The mechanism of impaired fertility due to copper deficiency is unknown but may be related to anemia and unthriftiness. Signs of copper deficiency related to reproduction in cattle are a general decline in fertility, an increased incidence of inactive ovaries and a greater incidence of retained foetal membranes have been reported in animals receiving inadequate copper (Morrow *et al.*,1986).

**Cobalt**

Signs of cobalt deficiency related to reproduction are delayed uterine involution, irregular oestrous cycles and decreased conception rate (Morrow *et al.*,1986). Dairy stock grazing pastures in New Zealand are clearly most susceptible to deficiencies of cobalt, copper, iodine and selenium, and mineral supplementation is often required.

Growing young stock and milking cows are usually considered to have the highest requirements for these trace elements. However, the pregnant cow, which is often restricted to a feeding level close to maintenance during the winter, may also be vulnerable to deficiencies. Thus problems such as abortions, retained foetal membranes, early embryonic loss and infertility may be anticipated in marginally deficient areas (Holmes *et al.*,1987).

Very few reliable data are available on the effects of mineral and vitamin nutrition on reproduction in dairy cows. A clinical deficiency of most vitamins and minerals will impair reproduction, but the effects of marginal deficiency are much less certain. In general, NRC recommendations appear adequate for most nutrients with respect to optimal reproduction.

### 2:5 Factors Affecting Milk Production In Winter Milk Supply Herds

Despite the differences in calving pattern between winter milk supply farms and seasonal milk producing farms, their productivities are affected by some common factors which have important effects on all pastoral dairy farms. These main factors are reviewed briefly here. In the New Zealand pastoral grazing system, the land is the most valuable resource. Therefore, milk produced per hectare is a most important economic factor of the profitability of a dairy farm (Holmes,1993). There are three main factors on which production efficiency depends:-

- i) the quantity and quality of the pasture grown per hectare (tDM/hectare), and its distribution during the year. It is affected by climate, soils, fertilisers, irrigation, plant species and management.
- ii) the proportion of the pasture consumed (harvested) by the stock, normally affected by stocking rate, management of surplus pasture growth.
- iii) the feed conversion efficiency (efficiency with which the feed eaten is converted into milk)

This New Zealand grazing system is affected by many factors Fig 2.6

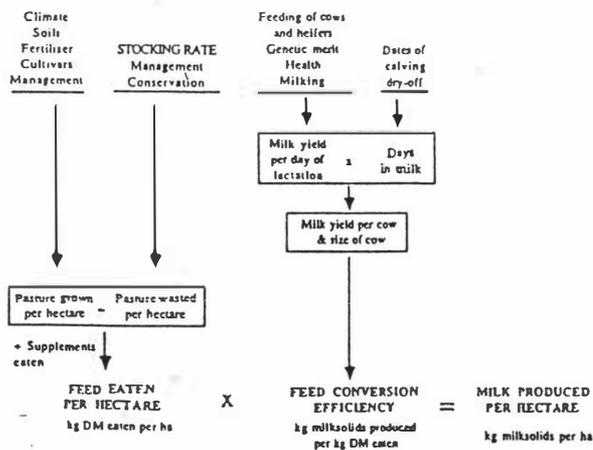


Fig 2.6 A simplified illustration of the main components of pastoral milk production systems (Holmes,1990).

The main important factors affecting milk production from pasture in winter milk supply farms are:-

- 1) stocking rate
- 2) pasture production
- 3) cow quality, date of calving and drying-off
- 4) management of feeds and feeding throughout the year which has the aim to satisfy the herds feed requirement throughout the year, but with particular emphasis on the first few months of lactation. Of all factors, stocking rate is dominant, linking the pasture and animal component of a grazing system, it has generally been increased in order to reduce the wastage of pasture per hectare, and hence to obtain greater efficiency, it cannot be considered in isolation from other factors in the system. It is important to distinguish between grazing management and the effects of stocking rate and good animal husbandry practices. Stocking rate is a framework under which management can work to balance pasture and animal production (Management of surpluses and deficits, date of calving and dry-off) (Holmes, 1993).

### 2:5:1 Pasture Utilization

Pasture utilization is the amount of herbage eaten by the animal, expressed as a percentage of total annual pasture yield (Holmes, 1987) found that the most important effect of increased stocking rate is to increase the annual harvesting efficiency. He reported feed utilization percentage of 80%-90% and of 40%-70% for New Zealand and British farms respectively.

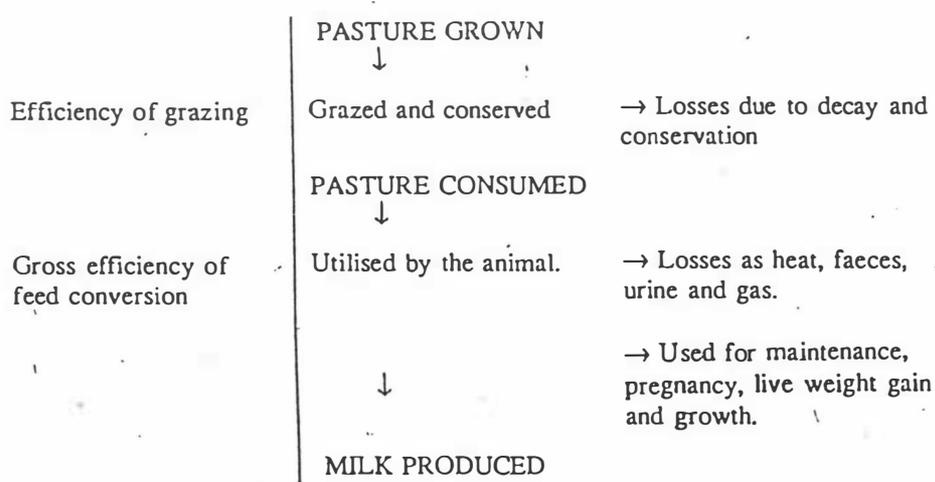


Fig 2.6.1 Diagram of pasture utilization (Bryant and Holmes, 1985).

### 2:5:2 Effect of stocking rate on pasture production

O'Sullivan (1983) found that high stocking rates reduce total annual dry matter production. This effect was explained as the result of an increase in defoliation caused by more intense grazing pressure, reduced interception of solar radiation, and hence lower photosynthetic activity in the sward and another cause could be that the pasture community becomes unsuitable and the system fails (White,1987).

Pasture growth rates can also be reduced at low stocking rates, because of increased senescence and a greater abundance of old leaves that are photosynthetically less efficient. Fig 2.6.2 shows the influence of stocking rate on rates of herbage growth, senescence and net production (Hodgson,1990)

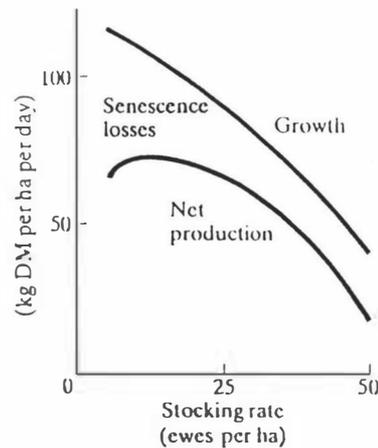


Fig 2.6.2 The influence of stocking rates on rates of herbage growth, senescence and net production (Hodgson,1990).

Digestibility of the herbage increased as stocking rate increased because increased defoliation of pasture lowered the fibre content, raising the digestibility (Baker and Leaver,1986). Although a high stocking rate ensures the maintenance of a high proportion of leaf in the total herbage, it may result in a depression in the digestibility of the herbage eaten because the chance for selective grazing is reduced (Holmes and Macmillan,1982).

### **2:5:3 Pasture intake per cow and per hectare and FCE**

Animal production depends partly on stocking rate, genetic potential, health of the stock and the managerial practices imposed (Campbell, 1966a).

The direct effect of stocking rate on animal production is on herbage intake by the grazing animal. When stocking rate is increased average herbage allowance is reduced and hence animal intake will also be reduced but, pasture eaten per hectare will be increased. The decrease in intake per cow will also usually cause a decrease in feed conversion efficiency (Holmes and Parker,1992). Milk production per cow is important for many reasons, including the fact that it is one determinant of the cow's gross feed conversion efficiency. Cows with higher yields of milk generally have higher values of feed conversion efficiency. The size or liveweight of a cow, will also affect her feed conversion efficiency through its effect on her maintenance requirement (Holmes,1993).

### **2:5:4 Milk fat production per animal and per hectare**

Many authors report that production per cow is decreased when a high stocking rate is reached. Holmes and Macmillan (1982) found that by increasing one cow per hectare there would be an increase of 70 kg milkfat per hectare and a reduction of 18 kg milk fat per cow. Increase in stocking rate causes increases in quantity of pasture eaten per hectare to a maximum value equivalent to about 90% of the quantity grown (Holmes,1993).

At lower stocking rates intake per cow is limited only by the cows ability to eat and utilize the feed. At the higher stocking rates used on most New Zealand dairy farms intake per cow is limited by the availability of pasture at sometimes of the year, the milk solids production per cow are decreased, liveweight is also decreased and yields of milk solids per hectare are increased (Holmes,1993).

Milk fat production per cow is likely to be affected in winter milk supply herds for the following reasons:-

1) Autumn calved cows are likely to consume less dry matter and less metabolisable energy per day in early lactation (during winter) than spring calved cows (in spring). This is because, during winter, the limited supply of pasture must be supplemented with silages or other supplements, most of which have lower metabolisable energy concentrations than the leafy pasture (O'Reilly and Holmes,1995), but the autumn calved cows when generously supplemented during winter time, they normally achieve long lactation period (more days in milk) despite low daily milk production than spring calved cows that are of high daily milk production with short lactation period. A recent study at Massey University has shown that cows fed pasture silage in late lactation were milked for an additional 54 days, producing an extra of 57 kg milk fat and 43 kg milk protein per tonne dry matter used (Holmes,1995).

A survey of 36 winter milk supply and 22 seasonal supply dairy farms in the Manawatu during 1988 revealed that winter milk supply farms were larger in area with slightly lower stocking rates. Winter milk supply herds produced 8% less milk fat per cow and 13% less milk fat per hectare than seasonal supply farms. From this survey the author agreed with the results of an earlier survey of winter milk supply farms and seasonal supply farms in South Auckland (Moffitt,1986), that winter milk supply farms can be expected to produce less milk fat per hectare, but require more supplementary feed per cow (Baldwin and Holmes,1989).

There is a possibility that winter milk supply farms may grow less feed due to:- 1) reduced regrowth of pasture associated with the need to graze pasture more intensively in spring in order to conserve more supplement (Fulkerson *et al.*,1987)

2) pasture damage from winter feeding out of supplements

3) shorter winter rotation length to achieve a high pasture allowance for lactating cows.

The requirement to meet quota on winter milk supply herds means that there is considerably less flexibility with regard to drying off date. Where feed supplies become scarce, seasonal supply farms will dry off late lactation cows producing at a low level

while a winter milk supply may be reluctant to dry off late lactation at critical times of the year because they must produce their quota (Holmes *et al.*,1990).

### **2:5:5 Animal genotype**

Friesians produce more milk per cow and per hectare than Jerseys. Therefore, Friesians have predominated in all winter milk herds. However, Friesians produce less milk fat and milk solids per hectare than Jerseys (Bryant,1992). Therefore, the benefit of extra volume from Friesians on winter milk farms may be achieved at the cost of a slightly reduced milk solids per hectare.

Cows of high genetic merit produce more milk and eat more feed during part of the lactation than the low genetic merit cows (Holmes and Macmillan,1982). Nevertheless, the high genetic merit cows converted their feed into milk more efficiently, losing condition during lactation, whereas the low genetic merit cows gained condition. Thus, to exploit all the genetic potential of high genetic merit cows, it is necessary to maintain them at lower stocking rates, so that feed allowance will not be restricted.

### **2:5:6 Grazing management**

Effective grazing management on a dairy farm must ensure that large quantities of good quality herbage are grown and consumed in order to fulfil the requirements of the cow and reduce pasture wastage.

The way pasture is offered and the interrelations between animals and pasture are important management issues. The aims of good grazing management are to ensure that:

- a) the stock are fed generously at each period of the year
- b) all pasture is eaten to prevent the accumulation of dead material in the pasture and wastage
- c) there is stimulation for the growth and survival of vigorous new tillers
- d) after each grazing, there is sufficient quantity of photosynthetic tissue left ungrazed to allow rapid regrowth of pasture (Holmes and Macmillan,1982). These objectives mentioned above lead to appropriate animal feeding throughout the year.

### 2:5:7 Grazing Methods

A general principle behind any grazing method is to match pasture supply to the feed requirements of the animals (Holmes, 1980). Use of either set stocking (continuous grazing) or rotational grazing methods has relatively little effect on milk production per hectare, when pasture production is sufficient to satisfy the cows feed requirements (Holmes *et al.*, 1987).

However, in New Zealand's intensive pastoral systems, where the cows are grazed on pasture throughout the year, it is often necessary to limit the cows daily pasture intake by restricting the area grazed each day. This can be done most easily with the **rotational** system, which is used on the majority of farms in order to achieve rational grazing management. There is no optimal rotation length for all seasons and conditions, and differences between rotational and continuous grazing methods are relatively small (Holmes *et al.*, 1987).

During winter, lactating cows are generally offered larger daily pasture allowances and areas per day than dry cows, even though their diet is supplemented with silage. Therefore, the grazing rotation is usually faster (40-60 day) on winter milk farms than on seasonal farms (60-120 days (Holmes *et al.*, 1987).

Fertilizers have a direct effect on soil fertility and pasture production, and a great number of factors affect the response of pastures to fertilizers including climate, soil nutrient levels, species composition, frequency of defoliation, grazing, presence of legumes and leaching (Frame, 1992).

In New Zealand, intensive grassland farming is based on N-fixation by clover, rather than N fertilization (Holmes *et al.*, 1987). Thus, N fertilizer is used in lower amounts. The application of N to grazed pastures usually results in an extra growth of between 10-25 kgDM/kg of N and Phosphate fertilizers of 20-50 kg/ha is mainly used to boost the clover (Holmes and Macmillan, 1982).

Even so, there are wide variations in the results obtained by other authors and these variations in response to N fertilizer may be explained by those factors mentioned.

The overall response of 1 kg of N was 9.9 litres of milk, of this 4.9 litres were directly related to the increase in N fertilizer and 4.5 litres were associated with an increase in stocking rate. This example indicated the need to increase stocking rate in order to maximise the extra response to N fertilizer (Hawkins and Rose, 1979).

### **2:5:8 Dairy cattle management relevant to winter milk production**

The most effective and simple system for the production of winter milk, particularly since the moves to a specific winter contract period, is to calve the cows in two distinct *seasonal herds* one in autumn and one in spring.

The number of cows in the autumn herd and their calving dates, must be planned carefully in relation to the winter contract (Holmes, 1993). The general aims should be to achieve compact calving patterns within both calving groups (eg with 90% calved in 7 weeks time). All the principles of mating management which apply to seasonal supply herds should be applied to both autumn and spring calving groups (which will be mated in winter and late spring respectively) (Holmes, 1993).

Drying -off dates in winter milk supply farms are important components of the farm's productivity as they determine the length of the herds lactation (days in milk) and therefore of the herd's full lactation yield and they determine the date at which the cows feed requirement can be reduced with consequent savings of pasture, other feeds and loss of body condition . Therefore, dry-off dates are an important component of the farm's autumn, winter and spring feed plan (Holmes, 1993). Despite the fact that in winter milk supply farms most individual cows have different dry-off dates as if too many cows are dried-off, the remaining cows may be unable to satisfy the daily contract volume. A rule of thumb mostly used by dairy farm operators is to dry-off two cows when one freshly calved cow enters the herd (Holmes, 1993).

**2:6 Summary:**

Milk for local consumption within New Zealand is produced in winter milk supply herds with mainly Friesian cows, that comprise 7% of all New Zealand dairy herds (Holmes *et al.*,1990). Milk has to be produced during the winter under special contract agreements which specify the minimum volume of milk to be supplied to the milk processor each day.

This contract system and its ramifications differentiate a winter milk herd from the seasonal herd (Wiseman,1988). To produce this daily contract within the same property a proportion of the herd (40%-45%) calves in autumn to ensure that winter milk production is adequate and a proportion (55%-60%) calves in spring to make efficient use of the spring flush of pasture and to ensure that summer milk production is adequate (in a few cases the entire herd calves in autumn). Hence, to achieve this winter milk production target under contract a regular autumn and spring calving pattern must be maintained and a careful organisation of the herd's calving dates is of paramount importance (Eede,1981).

The herd's calving date can influence the cows level of feeding in early lactation and also the days in milk (Holmes,1986). The autumn calved cows have lower daily milk yields due to the relative underfeeding in early lactation when compared to spring calved cows. These differences may be expected to affect the cow's daily milk production in winter and their fertility. However, autumn calved cows may have longer lactations which may allow them to achieve higher total lactation production despite lower milk production per day, while spring calved cows have high daily milk production but with fewer days in milk.

Due to the slower pasture growth rates during the autumn and winter season, winter milk supply herds use considerably more supplementary conserved feed (silage) for cows in milk and hay for dry and young stock. Therefore, during the autumn and winter seasons the stocking rate and animal production per hectare is normally low to facilitate grazing on the feed available (Holmes,1993).

To boost the winter pasture growth rates winter milk supply farms apply more nitrogen fertilizers at particularly in autumn or early spring in order to produce extra pasture at times of deficit. The additional pasture is likely to be cheaper than any other supplement available.

In some of the winter milk supply farms irrigation systems are utilised to boost pasture growth rates during the summer ( Holmes *et al.*,1987).

Significant seasonal differences are found in the reproductive performances of primarily Friesian cattle in winter milk supply herds. Autumn calved cows must be mated during winter, and the reproductive parameters of calving to first heat, submission rates, conception rates and heat detection efficiency are generally worse than those achieved in spring calving herds (Fielden *et al.*,1980; Fulkerson *et al.*,1985; Chaimongkol,1990). These results are probably due to a low plane of nutrition, and heat detection may be more difficult in winter milk supply herds because there are generally fewer cows in oestrous each day.

In addition winter is the period of the lowest temperatures and short daylength and fertility is lower in winter and higher in spring ( de Kruif and Brand,1978), while in tropical regions (Tanzania) fertility is higher in the rainy season when compared with the dry season. Furthermore, seasonal effects are greater under conditions of poor nutrition.

Compared with seasonal herds, where the events of any reproductive management programme are likely to be batched, a winter milk supply herd has cows at different stages of the reproductive cycle (Wiseman,1988).

## CHAPTER THREE

### Objectives and Methods

#### 3:1 Objectives of the study

The study analysed data from eight commercial winter milk supply herds, with Friesian cows, with the main objectives:-

- 1) To analyse lactational performances (days in milk per cow (DIM), milk fat and milk protein production (per cow) for cows which calved in autumn or in spring.
  
- 2) To analyse reproductive performances (calving interval, services per conception, conception rates (42 day non-return rates), 4 weeks submission rate (SR), 4 week calving rates and herd empty rates (MT) for cows which calved in autumn or spring.

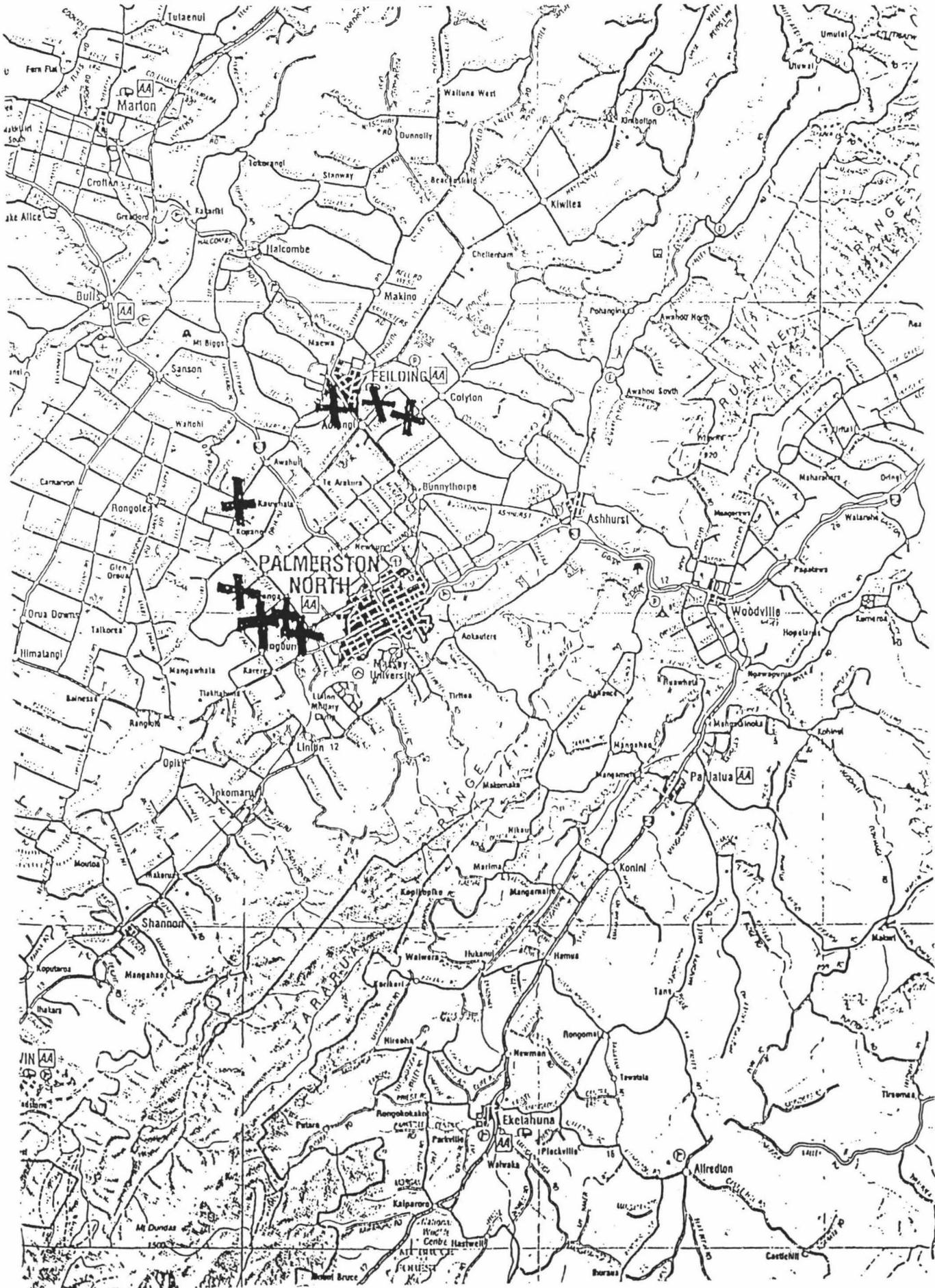
#### 3:2 Location of the farms, soils and management

Eight commercial winter milk supply herds around Palmerston North were studied, all had a calving spread condensed into two periods, autumn and spring. Locations of individual survey farms are shown on the Manawatu district map in figure 3.

Five of the farms were concentrated around Kairanga and three farms were located near Feilding. The Kairanga farms were located on silt loam soil which is generally described as alluvial, low lying river flats ranging from 9m-75m above sea level, while those near Feilding are located on Ohakea heavy silt loam with impervious clay subsoil (Cowie *et al.*,1972).

On some farms poor drainage is an integral part of the farming system. In Palmerston North district rainfall is well spread throughout the year with a noticeable winter maximum of 102 mm per month in June and July, a mean annual rainfall of 991 mm, mean annual temperature of 13.1°C (8.1°C- 33°C) and mean monthly soil temperature of 13°C (Burgess, 1988).

Figure 3. Location of eight winter milk supply farms. X= winter milk supply farms five of which are located in Kairanga and the remaining three near Feilding.



Fine chop pasture silage is the main supplementary feed. However, there is still some reliance on hay for the dry stock. A common feature to all the farms is the incorporation of a non-milking runoff area which gives the farmer flexibility with dry and young stock especially in winter.

Farms effective milking area averaged 72 hectares and with an average herd size of 105 cows calving during the autumn season and 122 cows calving during the spring season. The farms had daily milk winter contracts that ranged from 750 litres to 2960 litres (details in table 3).

### **3:3 Methods and Data collection**

A survey was undertaken during 1995 and data for 1993, 1994 and part of 1995 were obtained. There were 7689 calvings recorded involving 3787 cows which calved in 1993, 1994 and 1995. Details of the herds are given in appendices I; II; III; IV; V; VI; VII and VIII.

1) Data on pasture production (growth rates) and rainfall were provided by the winter milk supply farm located near Feilding (appendix I) and feed requirements for both autumn and spring calved cows are presented in appendix VIII.

2) Data for milk fat and milk protein production per cow and days in milk (DIM) per cow were collected from the Livestock Improvement herd test reports (lactation summaries). Data were recorded from the date each cow calved to its drying-off date, recognising the fact that in these herds individual cows had different drying off dates.

Days in milk less than 200 were excluded from the analysis. These accounted for 2% of the autumn calved cows compared to 0.8% of the spring calved cows in the same properties. Daily milk quota size, effective milking area and number of cows milked per season were obtained from the farm personnel appendix II and III.

**Table 3.0** Summary of data for eight commercial winter milk supply farms, averages for 1993 and 1994. Mean values of milking area (ha), number of cows (total milked, calved in autumn and spring), milk yields (milk fat and milk protein tonnes/farm), days in milk per cow (DIM) calved in autumn and spring and daily winter milk quota (litres/day, litres per autumn calved cow and per hectare).

FARM NO	1	2	3	4	5	6	7	8
Milking Area (ha)	85	90	90	70	44	70	63	62
Number of cows								
Autumn Herd	108	135	117	108	100	85	77	110
Spring Herd	127	190	143	132	84	89	93	121
Total	235	325	260	240	184	174	170	231
Days in milk/cow								
Autumn Cows	298	290	290	270	280	291	294	273
Spring Cows	271	269	275	231	264	253	282	220
Winter milk quota (litres/day)								
Total	1500	2960	2460	2000	750	1200	1270	1680
Per Autumn Cow	14	22	21	19	18	14	16	15
Per Hectare	18	33	27	28	17	17	20	27

3) Reproductive performances of autumn and spring calved cows for 1993 and 1994 are presented in appendix IV and V, lactational and reproductive performances of different age groups of autumn and spring calved cows are presented in appendix VI and VII respectively.

i) The calving interval in days (CI) per cow was calculated from the LIC herd test reports, using the calving dates of the cow for 1993, 1994 and 1995.

ii) Conception rates as 42 day non-return rates, were recorded as the 42 day first service non-return rate from LIC herd test reports (mating summaries) for each herd.

iii) 4 weeks submission rates (SR) were recorded as the number of cows in the herd which were mated for the first time during a period of 4 weeks, obtained from LIC herd test reports and from farm records.

iv) Services per conception/services per cow calving were recorded as number of all artificial breeding services per cow related to non-return rate from LIC herd test reports.

v) Calving dates and average number of cows due to calve per week in each herd were provided by farm staff and also extracted from the LIC herd test reports (mating and lactation summaries).

vi) 4 week calving rates were obtained from the LIC herd test reports (lactation summaries).

vii) Herd empty rate (MT) were obtained from the farm records (number of cows in the herd which were not pregnant at drying off or when culled).

### **3:4 Statistical procedures**

Difference in lactational and reproductive performances *within farm/herd* between autumn calved cows and spring calved cows data were statistically analysed using the Student-t test and the Mann-Whitney non parametric test.

## CHAPTER FOUR

### Results

#### 4:1 Milk production

The mean values for milk production and days in milk (DIM) are presented in tables 4.1 and 4.1.1 for the autumn calved cows (AC) and spring calved cows (SC) in both years, together with the ranges within each mean and the results of the analysis of variance. The average daily milk production for (AC) and (SC) on each test date for both years in (litres/cow/day) are presented in table 4.1.2 and in figure 4.1

The autumn calved cows (AC) produced more milk fat and milk protein per cow in whole the lactation period than the spring calved cows and they had longer lactations. The spring calved cows produced more milk fat ( $P < 0.05$ ) and milk protein (NS) per day of lactation than the autumn calved cows.

These herds are high producers relative to New Zealand average milk production data. New Zealand data by LIC 1994/95 indicated that an average Holstein-Friesian cow produced 161 kg milk fat and 126 kg milk protein per lactation length of 217 days or a daily milk fat production of 0.74 kg and 0.58 kg milk protein.

The autumn calved cows produced lower average daily yields during the second and third months of lactation, which indicated that these cows were on a lower level of feeding at this stage than the spring calved cows.

**Table 4.1**

Mean lactation values (with standard errors in brackets and ranges below) for autumn calved cows and spring cows in 1993 and 1994, number of cows (total milked), milk fat and milk protein production (Kg/cow/lactation), days in milk per cow (DIM) and daily milk fat and milk protein production (Kg/cow/day).

PARAMETER	1993		1994	
	AUTUMN	SPRING	AUTUMN	SPRING
Number of cows	109(±8) <i>74-155</i>	121(±13) <i>80-90</i>	101(±6) <i>68-117</i>	123(±12) <i>87-190</i>
<b>Lactation Yield (Kg/cow)</b>				
Milk Fat	217(±6) <i>185-226</i>	201(±7) <i>184-226</i>	202(±11) <i>186-210</i>	197(±9) <i>170-242</i>
Milk Protein	165(±4) <i>145-182</i>	160(±4) <i>148-173</i>	170(±3) <i>160-185</i>	159(±7) <i>130-189</i>
Days in milk/cow	286(±4) <i>270-298</i>	258(±8) <i>220-282</i>	277(±5) <i>262-301</i>	257(±7) <i>219-285</i>
<b>Average Yield/cow/day</b>				
Milk fat/cow/day	0.76(±0.02) <i>0.69-0.83</i>	0.78(±0.03) <i>0.69-0.84</i>	0.73(±0.07) <i>0.69-0.82</i>	0.77(±0.03) <i>0.63-0.83</i>
Milk protein/cow/day	0.58(±0.01) <i>0.54-0.78</i>	0.62(±0.02) <i>0.54-0.78</i>	0.61(±0.01) <i>0.57-0.67</i>	0.62(±0.02) <i>0.50-0.73</i>

**Table 4.1.1** Overall mean values of combined data for 1993 and 1994 (with standard errors in brackets and ranges below) for autumn calved cows and spring calved cows, number of cows (total milked), milk fat and milk protein production (Kg/cow/lactation), days in milk per cow (DIM) and daily milk fat and milk protein production (Kg/cow/day).

PARAMETER	Autumn Calved Cows	Spring Calved Cows	Significance of Difference
Number of cows	104(±12) 74-155	122(±12) 80-90	
<b>Lactation Yield</b>			
Kg milk fat prod/cow	206(±6) 185-236	199(±6) 170-242	NS
Kg milk protein prod/cow	166(±0.3) 145-185	160(±0.4) 130-189	NS
Days in milk/cow	282(±3) 262-301	258(±5) 219-285	P<0.05
<b>Average yield/cow/day</b>			
Kg milk fat/cow/day	0.73(±0.08) 0.69-0.87	0.77(±0.02) 0.63-0.99	P<0.05
Kg milk/protein/cow/day	0.60(±0.01) 0.54-0.78	0.62(±0.02) 0.50-0.78	NS

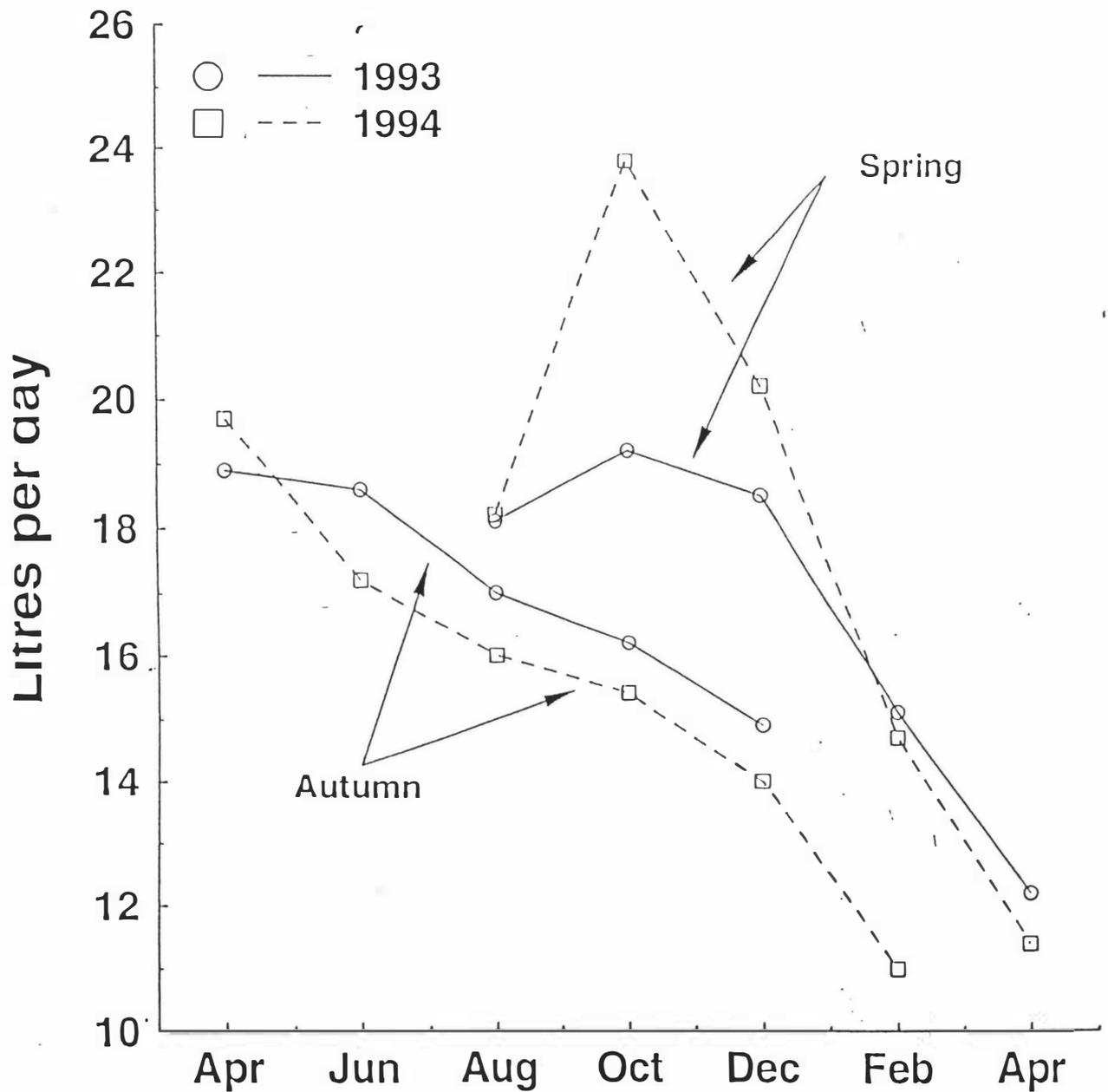
NS=Non Significant Difference

**Table 4.1.2** Average daily milk production, for autumn calved cows (AC) and spring calved cows (SC) on each test date for 1993 and 1994 (litres/cow/day).

AUTUMN CALVED COWS						
MONTHS OF TEST						
	April	June	Aug	Oct	Dec	Feb
1993	18.9	18.6	17.0	16.2	14.9	....
1994	19.7	17.2	16.2	15.4	14.0	11.0

SPRING CALVED COWS					
MONTHS OF TEST					
	Aug	Oct	Dec	Feb	April
1993	18.1	19.2	18.5	15.1	12.5
1994	18.2	23.8	20.2	14.7	11.4

**Figure 4.1** Average lactation curves for autumn calved cows and spring calved cows on each herd test date (litres/day) for 1993 and 1994.



#### **4:2 Reproductive performances**

The mean values for reproductive performances are presented in tables 4.2.1 and 4.2.2 for the autumn calved cows and spring calved cows in both years, together with the ranges within each mean and the results of the analysis of variance.

Significant differences between seasons were found in each of the reproductive performances measured, namely calving interval, 4 weeks submission rates, 42 day non-return rates, services per conception, 4 weeks calving rate and empty rates ( $P < 0.05$ ).

The autumn calved cows (AC) had lower values for all aspects of reproductive performance (391 days calving interval, 71% submission rate, 55% conception rate, 1.9 services per conception, 41% 4-week calving rate and 12% empty rate) than the spring calved cows (SC). This difference is probably due, at least partly, to the lower level of feeding for the autumn calved cows in early lactation. The calving patterns for the autumn calved cows and spring calved cows are presented in figure 4.2 and 4.2.1

On average the spring calved cows (SC) were high producers with average fertility, shorter calving interval (372 days), relatively high conception rate (64%), reasonable number of services per conception (1.6). This is probably due to relatively adequate feeding level during the early lactation and during the mating period.

**Calving interval(CI):**

The mean calving interval for autumn calved cows was 391 days (13 months) with 108 days service period, while the spring calved cows had a calving interval of 372 days (12.4 months) with 90 days service period (service period = calving interval- gestation period of 282 days). This difference in calving interval was significant ( $P<0.05$ ).

The long calving interval of the autumn calved cows (AC) means that on average each cow will calve on a date which is 25 days later in the next year than in the current year. It would be impossible in practice to maintain a satisfactory calving pattern for a winter milk herd with an average calving interval of 390 days.

**Submission rate (SR):**

The 4 weeks submission rate for the autumn calved cows was 71% compared to 81% for the spring calved cows in 1993 and 1994. The difference was significant ( $P<0.05$ ).

**42 Day non-return rate (NRR):**

The 42 day non-return for the autumn calved cows was 55%, while for the spring calved cows was 64%. This difference was significant ( $P<0.05$ ).

**Services per conception:**

Services per conception for the autumn calved cows was 1.9 services per cow, while for the spring calved cows had an average of 1.6 services per conception.

The difference was significant ( $P<0.05$ ).

**4 Week calving rate:**

The 4 week calving rate for the autumn calved cows was 41%, while for the spring calved cows was 54%. This difference was significant ( $P<0.05$ ).

**Empty rate (MT):**

Empty rate for the autumn calved cows was 12%, while the spring calved cows had an average of 10% empty rate. The difference was significant ( $P<0.05$ ).

**Table 4.2.1** Mean reproductive values (with standard errors in brackets and ranges below) for autumn calved cows and spring calved cows 1993 and 1994, number of cows (herd size), calving interval (days/cow), 4 weeks submission rate (% of the herd), 42 day non-return rate (% of the herd), services per conception/cow, 4 week calving rate (% of the herd) and empty rate (% of the herd).

PARAMETER	1993		1994	
	AUTUMN	SPRING	AUTUMN	SPRING
Number of cows	109(±8) <i>40-155</i>	121(±13) <i>80-190</i>	101(±6) <i>68-117</i>	123(±11) <i>87-190</i>
Calving Interval (days/cow)	392(±4) <i>380-410</i>	372(±1) <i>369-374</i>	390(±4) <i>371-390</i>	372(±2) <i>366-377</i>
4 Wks Submission Rate (%)	71(±0.2) <i>70-72</i>	75(±0.1) <i>75-76</i>	84(±0.01) <i>82-83</i>	87(±0.1) <i>85-87</i>
42 day non-Return Rate (%)	56(±0.01) <i>50-56</i>	63(±0.1) <i>60-64</i>	58(±0.1) <i>53-58</i>	62(±0.1) <i>60-64</i>
Services/Conception	1.9(±0.02) <i>1.8-2.0</i>	1.6(±0.02) <i>1.6-1.7</i>	1.9(±0.03) <i>1.8-2.0</i>	1.6(±0.02) <i>1.5-1.7</i>
4 Week Calving Rate (%)	36(±0.2) <i>32-40</i>	45(±0.1) <i>43-47</i>	45(±0.2) <i>42-48</i>	54(±4) <i>50-56</i>
Empty Rate (%)	13(±0.8) <i>12-18</i>	10(±0.1) <i>10-11</i>	11(±0.1) <i>10-11</i>	10(±0.1) <i>10-11</i>

**Table 4.2.2** Overall mean reproductive values of combined data for 1993 and 1994 (with standard errors in brackets and ranges below) for autumn calved cows and spring calved cows, number of cows (herd size), calving interval (days/cow), 4 weeks submission rate (% of the herd), 42 day non-return rate (% of the herd), services per conception/cow, 4 week calving rate (% of the herd) and empty rate (% of the herd).

PARAMETER	Autumn Calved Cows	Spring Calved Cows	Significance of Difference
Number of cows	104(±2) 74-155	122(±12) 80-90	
Calving Interval (days/cow)	391(±3) 371-410	372(±86) 369-390	P<0.05
4 Wks Submission Rate (%)	71(±0.02) 70-83	81(±0.02) 75-87	P<0.05
42 day non-Return Rate (%)	55(±0.3) 50-58	64(±0.3) 60-66	P<0.05
Services/Conception	1.87(±0.02) 1.8-2.0	1.62(±0.02) 1.5-1.7	P<0.05
4 Week Calving Rate (%)	41(±1.2) 40-48	54(±0.2) 43-57	P<0.05
Empty Rate (%)	12(±0.4) 10-18	10(±0.2) 10-11	P<0.05

NS=Non Significant Difference

**Figure 4.2** Calving pattern for the autumn calved cows (AC) in eight commercial winter milk supply herds for 1993 and 1994.

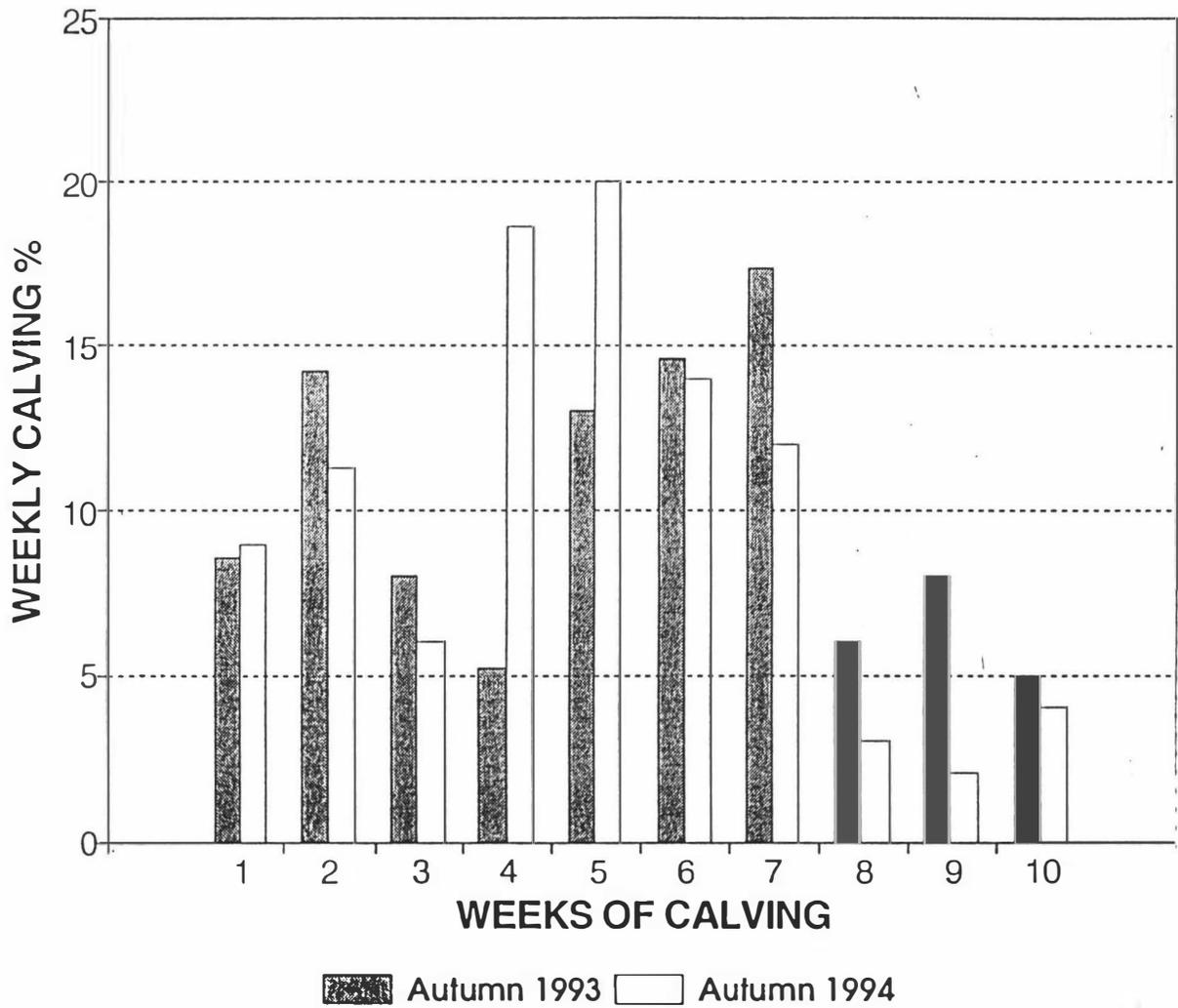
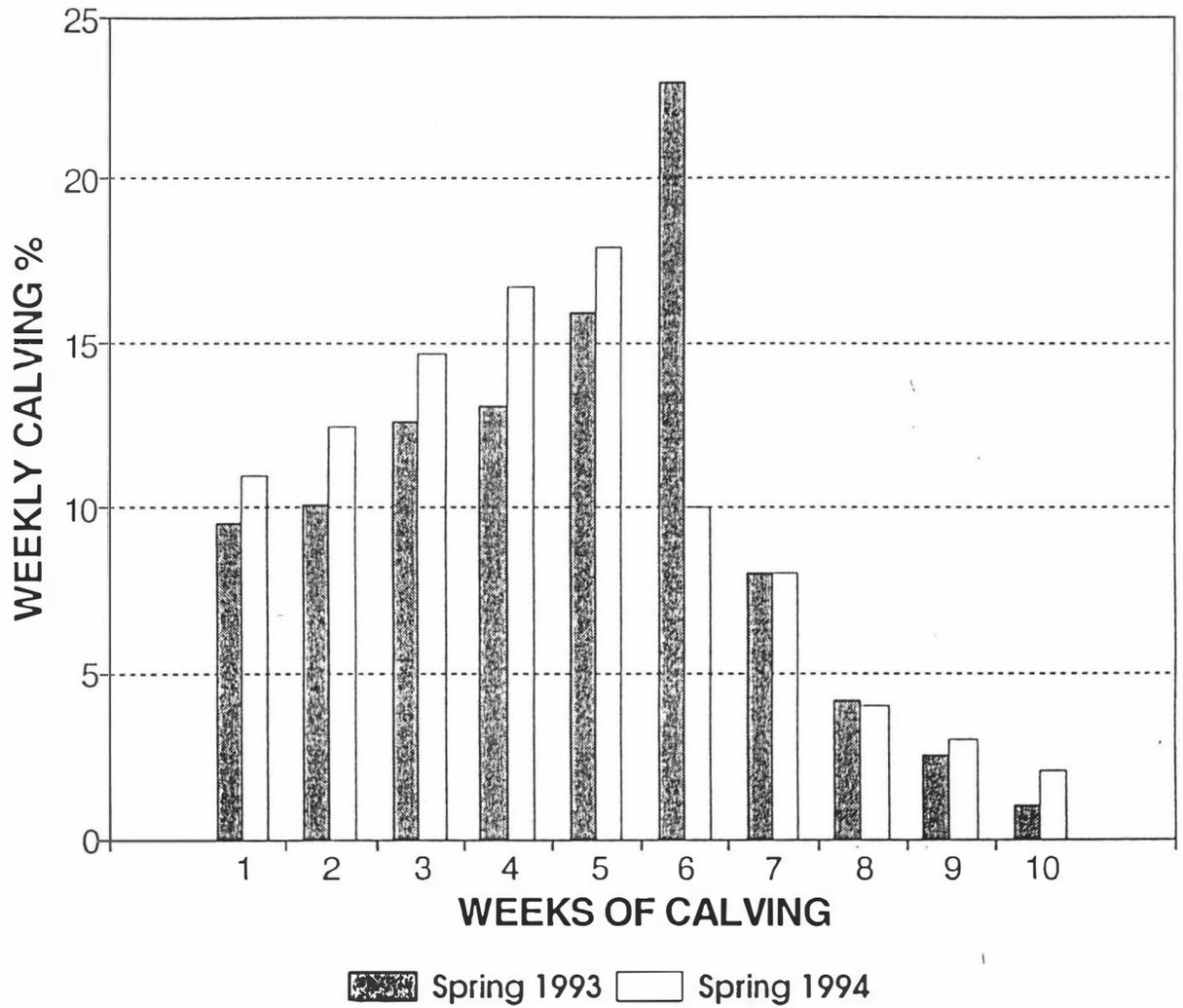


Figure 4.2.1 Calving pattern for the spring calved cows (SC) in eight commercial winter milk supply herds for 1993 and 1994.



**4:3** The Lactational and reproductive performances for the different age groups of autumn and spring calved cows (average milk yield, days in milk, breeding index and reliability, calving intervals) are presented in table 4:3 and 4:3.1. Milk yield was highest in the older age groups (four years and older), that comprised 46% to 57% of the herd.

The most efficient reproductive performance occurred with the four year old cows (376 days calving interval during the autumn season and 372 days calving interval during the spring season) and the least efficient performance occurred with the two year old cows (394 days calving interval during the autumn season and 390 days calving interval during the spring season).

There was a tendency for reproductive performance to decline with increasing age after five years of age.

**Table 4.3**

Mean values of milk production and reproductive performance of the different age groups of autumn calved cows in eight commercial winter milk supply herds

<b>Age</b>	2yrs	3yrs	4yrs	5yrs	6yrs	7yrs	8yrs	9yrs	10yrs
<b>% in the Herd</b>	22	15	11	7	10	7	11	6	11
<b>KgMF/cow/lactation</b>	170	180	220	240	220	212	210	200	208
<b>KgMF/cow/day</b>	0.60	0.67	0.76	0.83	0.77	0.70	0.74	0.75	0.78
<b>KgMP/cow/lactation</b>	142	149	175	190	175	179	167	170	161
<b>KgMP/cow/day</b>	0.50	0.56	0.60	0.66	0.61	0.59	0.59	0.63	0.61
<b>Days in Milk</b>	282	268	290	289	286	303	282	268	266
<b>Calving Interval (days)</b>	401	392	383	385	388	387	393	393	397
<b>Breeding Index/Avg. Rel.</b>	132/39	131/45	129/44	128/42	125/35	124/34	123/35	123/35	123/35

**Table 4.3.1**

Mean values of milk production and reproductive performance of the different age groups of spring calved cows in eight commercial winter milk supply herds

<b>Age</b>	<b>2yrs</b>	<b>3yrs</b>	<b>4yrs</b>	<b>5yrs</b>	<b>6yrs</b>	<b>7yrs</b>	<b>8yrs</b>	<b>9yrs</b>	<b>&gt;10yrs</b>
<b>% in the Herd</b>	21	13	25	13	9	3	7	4	4
<b>KgMF/cow/lactation</b>	157	171	206	227	194	211	199	217	216
<b>KgMF/cow/day</b>	0.61	0.71	0.82	0.89	0.75	0.81	0.73	0.84	0.81
<b>KgMP/cow/lactation</b>	117	142	150	175	156	160	148	157	175
<b>KgMP/cow/day</b>	0.45	0.59	0.60	0.69	0.60	0.61	0.54	0.61	0.66
<b>Days in Milk</b>	258	241	251	255	258	261	272	258	267
<b>Calving Interval (days)</b>	382	374	364	368	374	371	372	371	372
<b>Breeding Index/Avg. Rel.</b>	135/45	133/48	130/50	131/50	127/35	130/54	127/46	128/53	120/50

## CHAPTER FIVE

### Discussion

#### 5:1 Milk production.

The autumn calved cows produced 206 kg milk fat/cow and 166 kg milk protein/cow per 282 days in milk, while the spring calved cows produced 199 kg milk fat/cow and 160 kg milk protein per 258 days in milk. The autumn calved cows had a longer lactation period (24 extra days in milk) than the spring calved cows ( $P < 0.05$ ). The average daily milk fat produced by the autumn calved cows was 0.73 kg milk fat while the spring calved cows produced 0.77 kg milk fat ( $P < 0.05$ ). The autumn calved cows produced 372 kg milk solids per lactation period while, the spring calved cows produced 359 kg milk solids per lactation. New Zealand milk production data (Dairy statistics, 1994/95), indicated that the average Holstein-Friesian cow produced 161 kg milk fat and 126 kg milk protein per lactation length of 217 days or 0.74 kg milk fat and 0.58 kg milk protein per day and 16.7 litres per day in an average seasonal farm. Therefore, the present herds are relatively high producers compared with the average for the New-Zealand herds, due mainly to longer lactation.

The difference in milk yield between cows which calved at different times of the year probably reflect different levels of feeding at different times of the year. Autumn calved cows spend their early and mid lactation in winter on a relatively low level of feeding, on a diet which includes relatively large proportion of silage, hence having a lower daily milk production 18.0 litres and 17.0 litres during the second and third months of lactation whereas spring calved cows produced a daily average of 22.0 litres and 19.0 litres during the second and third months of lactation and normally spend their early lactation on plentiful pasture in spring and their late lactation in summer when pasture may be less plentiful (*refer 2:6:4 literature review*).

A comparison of the present study with other published data for milk production data in winter milk supply herds is presented in table 5.1

PARAMETER	AUTUMN CALVED COWS	SPRING CALVED COWS	REFERENCE
KgMF/cow/ lactation	157 214 206	164 183 199	Fulkerson '87 Thomas'85 <i>present study</i>
KgMF/cow/day	0.73	0.77	<i>present study</i>
KgMP/cow/day	0.60	0.62	<i>present study</i>

Table 5.1 Comparison of the present study with other data for milk production data in winter milk supply herds.

Unquestionably underfeeding in early lactation significantly reduces cow performance (Grainger *et al.*,1979; Bryant, 1982; Baldwin and Holmes, 1990;Fulkerson *et al.*,1987; Holmes *et al.*,1991; Carruthers and Penno,1995; King, 1968), and this is a probable explanation of lower daily yields by the autumn calved cows in early lactation, and averaged across the whole lactation (*refer 2:2 (i) literature review*).

By contrast, spring calved cows are normally well fed in early lactation but underfed in summer due mainly to slower pasture growth and a decline in the availability and quality of feed from December onwards (Thomson and Holmes,1995).

## 5:2 Fertility

The initiation of milk production depends on the establishment of pregnancy and the accomplishment of normal parturition. Reproductive efficiency is therefore, an important determinant of how effectively and economically a herd is capable of producing milk. This is particularly true in situations where the timing of calving is a critical factor ( e.g before the period of winter contract). The basic reproductive performances measured in

this survey were summarised in table 4.2. The autumn calved cows had the following average values:- calving interval 391 days (13 months), submission rate of 71%, non-return rate 55%, 1.9 services per pregnancy, 41% 4 week calving rate and an empty rate of 12%. While the spring calved cows had an average values of calving interval of 372 days (12.4 months), 81% submission rate, non-return rate 64%, 1.6 services per pregnancy, 55% 4 week calving rate and 10% empty rate.

A comparison of the present study with other published data for fertility performances in winter milk supply farms is presented in table 5.2

PARAMETER	AUTUMN CALVED COWS	SPRING CALVED COWS	REFERENCE
Submission rate %	73	74	McKay '88
	72	87	Fulkerson '85
	71	81	<i>present study</i>
Non-return rate%	55	75	Fulkerson '85
	61	65	McKay '88
	55	64	<i>present study</i>
Services per conception	1.9	1.5	Fielden '80
	1.9	1.6	<i>present study</i>
Empty rate %	17	16	McKay '88
	12	10	<i>present study</i>
Calving interval (days)	384	377	Fielden '80
	391	372	<i>present study</i>

Table 5.2 Comparison of present study with other authors in fertility performances in winter milk supply farms.

The data presented above show significant differences in reproductive performances measured between autumn calved cows and spring calved cows in commercial dairy farms and it can be concluded that performances during the spring season were better than during the autumn season (Chaimongkol, 1990; Shrestha, 1978; Fielden *et al.*, 1980; de Kruif and Brand, 1978; Fulkerson, 1985; McKay, 1988; O'Farrell *et al.*, 1994). The relatively poor performances during the autumn season are probably influenced by the low level of feeding (*refer 2:4:2 literature review*), that also affects the lactational performances during the early lactation and during winter.

### **Submission Rate (SR)**

Both of the average values 71% and 81% respectively for the autumn and spring calved cows are relatively low when compared to recommended figures for New Zealand seasonal dairy herds of 3 weeks submission rate of 90% and 6 weeks submission rate of 95% (Macmillan *et al.*, 1973). Low values of submission rates may be due to the cows failing to cycle normally, or ineffective detection of oestrus (Fulkerson *et al.*, 1985) (*refer 2:3 literature review*).

Submission rate is affected by several factors including the previous year's calving pattern, efficiency of oestrus detection, level of nutrition and deferred services (Brightling *et al.*, 1990). Low level of feeding is likely to be a factor for autumn calved cows that leads to delay of first heat and reduces the herd's fertility particularly through effects on the submission rate (Grainger *et al.*, 1982).

### **42 Day Non-Return Rate (Conception rate) and services per conception**

The average non-return rate for the autumn calved cows was 55% while that for the spring calved cows was 64%. Both values are relatively low when compared with conception rates reported by Macmillan, (1985) (65%-68%). The higher incidence of missed heats in winter milk supply herds is likely to have a greater influence on herd's in calf rate than is the submission rate (Grimmett, 1985) (*refer 2:4 literature review*).

This statistic is closely related to the actual pregnancy rate to first insemination, but in extensive trials in New Zealand dairy herds, the average pregnancy rate to first

insemination as confirmed by palpation of the foetus *in utero* was about 5% lower than the average 42 day non- return rate (conception rate) (Macmillan,1985).

Conception rate is affected by **underfeeding**. A low level of feeding in early lactation caused delays in conception, due to delayed return to oestrus and possibly reduced conception rate (Grainger *et al.*, 1979; McDougall,1992; Patchell, 1957; King, 1968). Nutritional deficiencies influencing reproductive performances have been discussed in an earlier section (*refer 2:3:3 literature review*).

For the autumn calved cows, the average number of services per pregnancy was 1.9 while the average number of services per pregnancy for the spring calved cow was 1.6 ( $P<0.05$ ). Number of services per conception may be higher in winter milk supply herds where repeat breeders can be carried over from one herd to another (Macmillan,1985). A lower feeding level normally causes a prolonged anoestrus interval,therefore more cows will be mated to first heat post-partum, and have low conception rates. This may have contributed to the higher average number of services per pregnancy in winter milk supply herds (Grainger *et al.*,1979; Broster, 1973; Macmillan, 1985; McClure, 1970).

### **Calving Rate and Calving pattern**

The calving pattern depends at least partly on what the farmer wants to achieve. Due to their winter contract agreement with the local milk company, these farmers wanted to calve their herds into two compact groups. There was significant difference in 4 week calving rates between autumn calved cows and spring calved cows in this particular study (41% vs 55%), although there were differences in submission rate percentages.

From this particular study on average 41% of the autumn cows calved within 4 weeks period while 50% of the herd took on average 28 days to 39 days to calve despite the relative low submission rate and non-return rate their calving spread was poorly distributed (fig 4.2), and 54% of spring cows calved within 4 weeks period and their calving spread was relatively skewed distributed (fig 4.2.1; 4.2.3). Both values are relatively high when compared with interval between the planned start of calving date to the mean calving date reported by Macmillan, (1985) of 22( $\pm 3.7$ ) days for 50% of

the herd to calve (*refer 2:2 (ii) (literature review)*).

Hughes (1984), suggested that an interval of 15 days (PSC-MCD) or less reflected high submission rates and satisfactory conception rates to first insemination of the previous season's breeding programme. This interval is a major contributor to the wide variation in the total calving spread.

A compact calving pattern is an advantage for an autumn calving herd as well as for a spring calving herd because mating is restricted to a short period (Macmillan,1985), because start of calving for the autumn herd can be delayed until closer to the start of the contract period, and all the cows can be in early-mid lactation during the winter, with maximum potential for milk production during this critical stage of the year.

Spread calving patterns tend to extend the calving period from year to year, a situation which can only be corrected by use of induced calving or culling of late calvers or allowing very short service periods (Holmes *et al.*,1987). However, a spread calving pattern can be useful in winter milk supply herds which have a high daily quota for the whole year but not for short periods of winter contract (*refer 2:2 (i) literature review*).

#### **Empty Rate (MT) (Non-pregnant rate)**

The autumn calved cows had an average value for empty rate of 12% while the spring calved cows had an average value of 10%.

These figures reported are higher than average values for New Zealand dairy herds empty rates of about 3%-4% over many years. It was relatively low in young cows (3%) increasing to 6%-8% in older cows (Macmillan,1985).

Prolonged mating periods (e.g an average of 13 weeks recorded in this study) in winter milk supply herds will also increase the total percentage of cows which conceive and reduce the percentage which remain empty. For example a 10 weeks mating period was associated with 7% empty rate, a 15 weeks mating period was associated with 5% empty rate, a 20 weeks mating period was associated with 3% empty rate and a 25 weeks mating period was associated with 2% empty rate (Macmillan *et al.*,1976).

Lower values were reported for 3354 Friesian heifers in 125 herds (5.4%) compared to 10% for the 1855 Jersey heifers in 62 herds and the Friesian x Jersey heifers in 73 herds were 8.1% (Macmillan,1994). A herd with relatively low fertility performances (e.g the autumn calved herds) is likely to have a relatively high percentage of empty cows.

### **Calving Interval (CI)**

The average calving interval for the autumn calved cows was 390 days (13 months) and 372 days (12.4 months) for the spring calved cows ( $P < 0.05$ ). These results are similar to the data of Fielden *et al.*, (1980) and Wiseman who reported the same figures in 1988 but, these figures are considerably higher than 364 days and 363 days reported by Macmillan and Moller (1977) for seasonal milk supply herds in New Zealand.

The greatest variation from one herd to another in days open, calving to first oestrus and calving to first service has been attributed to differences in practices for detection of oestrus (Bozworth *et al.*,1972). These factors then could be assumed to be of some importance in determining the length of the calving interval especially for the autumn calved herds.

Many factors have been implicated in the longer calving interval of the autumn calved cows namely seasonal and environmental factors (Gwazdauakas *et al.*,1973), inadequate feeding (Grimmett, 1985; Bryant,1982; Grainger *et al.*, 1979), poor body condition after calving (McDougall,1995, Grainger *et al.*, 1982; Baldwin and Holmes, 1990) and inefficient heat detection methods in small herds where sexual active groups, showing vigorous heat signs, are frequently not formed (Macmillan,1985).

Nutritional deficiencies were frequently stated to be a major cause of infertility and extended calving interval in dairy cows. The general explanation given for the lowered fertility in autumn and winter is the difficulties in detecting oestrus due to short day length (Macmillan,1985). This information supports the results of the present study and of the and other authors showing relatively low reproductive performances for the autumn calved herds compared to spring calved cows (*refer table 5:2*).

The calving interval in winter milk supply herds is an important factor in the system which is the consequence of all other managerial aspects leading to out of season milk production. A long calving interval (e.g 390 days for the autumn calved cows) means that on average each cow will calve on a date which is 25 days later in the next year. Unless the herd manager intervenes, for example by inducing premature calving, it would be impossible in practice to maintain a satisfactory calving pattern for a winter milk herd with an average calving interval of 390 days (*refer 2:1 literature review*).

### **5:3 Feed requirements related to feed supply**

On winter milk supply farms, because some cows are lactating in every month of the year, there is less variation of the herd's feed requirements between months than on seasonal milk supply farms (Holmes *et al.*,1987) (*refer 2:6 literature review*).

From this particular study a winter milk supply farm near Fielding provided monthly pasture growth rates and supplement production on the farm. The annual pasture production was 12,000 KgDM/ha (*refer appendix I*) and each cow consumed 4432 KgDM with a stocking rate of 2.6 cows/ha. The calculations were based on average values for calving date, liveweight, milk yield per day and total metabolisable energy required (for milk production and for maintenance) and the energy value per (KgDM) of the pasture consumed per day for a Holstein-Friesian cow (Holmes *et al.*,1987), taking into consideration that autumn and spring calved cows were grazed in the same property with different feed requirements (*refer appendix VIII*).

### **5:4 The influence of season on lactational and reproductive performances**

New Zealand pastoral agriculture is mainly a legume-based pasture system, with year-round grazing. Pasture supply is highly seasonal, with approximately 70% of annual feed production occurring in the five months from September to January. Bryant (1990) considered that the productivity and profitability of an individual dairy enterprise depended fundamentally on the degree of success in coping with seasonality of feed supply.

The influence of calving season on lactational and reproductive performances was shown in (tables 4.1; 4.1.1; 4.1.2; 4.2.1; 4.2.2 and figure 4.1). Performances during the spring season were better than during the autumn season (Chaimongkol, 1990; Shrestha, 1978; Fulkerson, 1985; McKay, 1988; Baldwin and Holmes, 1990; de Kruif and Brand, 1978).

The most important effect of the seasonal variations on the dairy farm's productivity is on the growth and development of pastures. Pasture growth during winter is slow due to the low temperatures and lack of sunshine, but faster in spring and summer due to the warmer temperatures provided that rainfall is adequate (Holmes *et al.*, 1987).

In a pasture based system dietary energy intake is likely to be most limiting factor (Phillips, 1994). Therefore, low submission rates, conception rates, long calving intervals, higher average numbers of services per conception, and low daily milk production by the autumn calving dairy cows may be attributable to a negative energy balance and generally these parameters do not compare favourably with target figures accepted for spring calving dairy herds. These effects on fertility and on milk production are probably associated with the problem of underfeeding (Baldwin and Holmes, 1990; McCallum *et al.*, 1994; Holmes *et al.*, 1980; Grainger *et al.*, 1982).

Undernutrition, or the inadequate intake of nutrients relative to demand, is a major factor contributing to prolonged post partum anoestrous, particularly among cows depending upon natural forage for most, if not all of their requirements (McDougall, 1992).

Other factors that may be put forward as contributing to the seasonal variation in reproductive performance are ambient temperature and day length. In colder climates the negative energy balance in cows at pasture may be exacerbated by the greater energy demands to maintain body heat. (Peters *et al.*, 1990) demonstrated a negative correlation between daylight hours during late pregnancy and the onset of ovarian cycles post partum. The photoperiodicity response may be a mechanism derived from feral cattle that predisposes to calving in late spring and early summer when feed supply is optimal. However, these factors are probably less important than the relative underfeeding of the autumn calved cows in winter, compared with the spring calved cows in spring.

## 5:5 Conclusions

On average these herds achieve high milk production relative to New Zealand average milk production mainly due to longer than average lactation period. Autumn calved cows produced 372 kg milk solids per lactation and an average of 15.8 litres per day, while spring calved cows produced 359 kg milk solids per lactation and an average of 17.2 litres per day.

Reproductive performances were lower in the autumn/winter season than in the spring season. This was seen in the data for calving interval, submission rate, 42 day non-return rate (conception rate), services per conception and empty rate.

The most likely cause of the poorer fertility of autumn calved cows was their relative underfeeding in early lactation (winter), when their diet composed a large proportion of conserved feeds.

The present results indicate that, even in well managed winter milk supply herds, autumn calved cows are likely to have slightly poorer performances than spring calved cows under New Zealand pastoral production conditions. Large quantities of high quality supplementary feeds would be required to overcome this effect.

## Appendix I.

Pasture production, rainfall and supplement fed for one winter milk supply herd near Feilding.

Daily pasture growth rates (KgDM/ha) and Rainfall (mm) data for 1993 and 1994.

Month	1993		1994		Actual Supplement Fed during 1994 (t/DM/month)
	Daily Pasture Growth Rate (KgDM/ha)	Monthly Rainfall (MM)	Daily Pasture Growth Rate (KgDM/ha)	Monthly Rainfall (MM)	
June	14	75	15	109	30
July	17	116	9	89	30
Aug	19	18	30	88	30
Sep	45	68	50	128	30
Oct	72	67	40	75	10
Nov	45	66	55	186	0
Dec	34	70	25	23	15
Jan	23	107	10	15	20
Feb	37	23	20	51	27
Mar	28	142	34	126	30
Apr	44	54	63	110	0
May	40	54	39	80	12
Total	13 tonne DM/year Av. 34.8 KgDM/day	860(mm)	12 tonne DM/year Av. 32.0 KgDM/day	1080(mm)	234 (tonneDM) Av. 0.64tDM/day

**Appendix II.**

Data for eight commercial winter milk supply farms, effective milking area, number of cows (total milked, autumn calved cows and spring calved cows), lactation yields, milk fat and milk protein (Kg/cow), days in milk per cow (DIM) of autumn and spring calved cows and daily winter milk contract (litres/day) for 1993.

<b>FARM NO</b>	1	2	3	4	5	6	7	8
<b>Milking Area (ha)</b>	82	90	90	70	38	70	60	62
<b>Number of cows</b>								
Autumn Herd	104	155	117	108	90	100	74	120
Spring Herd	127	190	143	132	80	88	90	121
Total	231	305	260	240	170	188	164	241
<b>Daily/winter milk contract (litres/day)</b>	1500	2960	2460	2000	550	1200	1130	1930
<b>Days in milk/cow</b>								
Autumn Cows	298	290	290	270	280	291	294	273
Spring Cows	271	269	275	231	264	253	282	220
<b>Lactation Yields (Kg/Cow)</b>								
<b>Milk Fat</b>								
Autumn Cows	233	212	228	185	218	201	232	228
Spring Cows	219	191	192	170	213	184	226	217
<b>Milk Protein</b>								
Autumn Cows	182	165	176	153	165	145	179	173
Spring Cows	173	148	148	133	167	147	173	172

**Appendix III.**

Data for eight commercial winter milk supply farms, effective milking area, number of cows (total milked, autumn calved cows and spring calved cows), lactation yields, milk fat and milk protein (Kg/cow), days in milk per cow (DIM) of autumn and spring calved cows and daily winter milk contract (litres/day) for 1994.

<b>FARM NO</b>	1	2	3	4	5	6	7	8
<b>Milking Area (ha)</b>	87	90	90	70	44	70	66	62
<b>Number of cows</b>								
Autumn Herd	112	155	117	108	110	68	80	100
Spring Herd	127	190	143	132	87	90	95	120
Total	239	305	260	240	197	158	175	220
<b>Daily/winter milk contract (litres/day)</b>	1500	2960	2460	2000	950	1200	1400	1430
<b>Days in milk/cow</b>								
Autumn Cows	262	280	287	264	270	280	301	275
Spring Cows	219	242	271	260	260	263	285	259
<b>Lactation Yields (Kg/Cow)</b>								
<b>Milk Fat</b>								
Autumn Cows	220	202	219	206	201	196	206	238
Spring Cows	182	170	200	165	186	189	229	242
<b>Milk Protein</b>								
Autumn Cows	169	162	174	162	160	155	173	185
Spring Cows	146	138	160	130	143	165	184	189

**Appendix IV.**

Reproductive data for eight commercial winter milk supply herds, number of cows in the herd per season, calving interval (days) per cow, conception rate or 42 day non-return rate (% of the herd), 4 weeks submission rate (% of the herd), services per conception per cow, 4 week calving rate (% of the herd) and empty rate (% of the herd) of autumn and spring calved cows for 1993.

<b>FARM NO</b>	1	2	3	4	5	6	7	8
<b>Herd Size</b>								
Autumn Herd	104	155	117	108	90	100	74	120
Spring Herd	127	190	143	132	80	88	90	121
<b>Calving Interval (days/cow)</b>								
Autumn Cows	385	410	400	392	380	382	395	387
Spring Cows	369	372	377	370	369	371	374	370
<b>4 Weeks Submission Rate (%)</b>								
Autumn Herd	69	71	68	70	64	60	73	72
Spring Herd	75	76	74	73	69	71	75	70
<b>42 Day Non-Return Rate (%)</b>								
Autumn Herd	56	50	55	56	52	55	52	55
Spring Herd	60	61	62	64	63	64	62	61
<b>Services/Conception</b>								
Autumn Herd	1.9	2.0	2.0	1.8	1.8	1.8	2.0	1.8
Spring Herd	1.6	1.6	1.7	1.6	1.7	1.6	1.6	1.6
<b>4 Week Calving Rate (%)</b>								
Autumn Cows	39.0	36.0	37.0	36.0	32.0	33.0	38.0	40.0
Spring Cows	45.0	46.4	46.0	47.0	43.5	45.4	47.0	43.0
<b>Empty Rate (%)</b>								
Autumn Herd	11.5	12.3	17.9	12.0	12.2	12.0	12.2	11.6
Spring Herd	10.2	10.0	9.8	9.8	10.0	10.2	10.0	9.9

**Appendix V.**

Reproductive data for eight commercial winter milk supply herds, number of cows in the herd per season, calving interval (days) per cow, conception rate or 42 day non-return rate (% of the herd), 4 weeks submission rate (% of the herd), services per conception per cow, 4 week calving rate (% of the herd) and empty rate (% of the herd) of autumn and spring calved cows for 1994.

<b>FARM NO</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
<b>Herd Size</b>								
Autumn Herd	112	155	117	108	110	68	80	100
Spring Herd	127	190	143	132	87	90	95	120
<b>Calving Interval (days/cow)</b>								
Autumn Cows	371	382	384	382	385	390	382	381
Spring Cows	372	366	376	372	374	376	367	377
<b>4 Weeks Submission Rate (%)</b>								
Autumn Herd	80.0	81.0	79.0	82.0	78.0	83.0	80.0	82.0
Spring Herd	84.0	86.0	83.0	87.0	88.0	82.0	85.0	87.0
<b>42 Day Non-Return Rate (%)</b>								
Autumn Herd	55	54	53	58	56	57	56	58
Spring Herd	64	60	65	64	63	66	65	66
<b>Services/Conception</b>								
Autumn Herd	1.8	1.8	1.9	1.8	1.8	1.9	2.0	1.8
Spring Herd	1.6	1.5	1.7	1.6	1.6	1.7	1.5	1.7
<b>4 Week Calving Rate (%)</b>								
Autumn Cows	44.0	43.7	42.0	48.0	44.0	47.3	45.0	48.0
Spring Cows	54.0	52.0	54.0	56.0	55.0	54.0	55.0	57.0
<b>Empty Rate (%)</b>								
Autumn Herd	10.7	11.0	11.0	11.0	10.9	10.3	11.3	11.0
Spring Herd	10.2	10.0	9.8	9.8	10.3	10.0	10.5	10.0

Mean values for weekly calving patterns for cows which calved in autumn and spring 1995 in eight winter milk supply herds. (Average number of calved cows/herd, weekly calving % and cumulative %).

Week No.	AUTUMN (n=922)			SPRING (n=932)		
	Average no of Calved cows	Weekly Calving %	Cumulative Calving %	Average no of Calved cows	Weekly Calving %	Cumulative Calving %
1	79	8.6	8.6	89	9.5	9.5
2	131	14.2	22.8	94	10.1	19.6
3	74	8.0	30.8	117	12.6	32.2
4	48	5.2	36.0	123	13.1	45.3
5	120	13.0	49.0	149	16.0	61.3
6	135	14.6	63.6	214	23.0	84.3
7	160	17.4	81.0	75	8.0	92.3
8	55	6.0	87.0	39	4.2	96.5
9	74	8.0	95.0	23	2.5	99.0
10	46	5.0	100.0	9	1.0	100.0

Mean values for weekly calving patterns for cows which calved in autumn and spring 1994 in eight winter milk supply herds. (Average number of calved cows/herd, weekly calving % and cumulative %).

**AUTUMN (n=943)**

**SPRING (n=990)**

<b>Week No.</b>	<b>Average no of Calved cows</b>	<b>Weekly Calving %</b>	<b>Cumulative Calving %</b>	<b>Average no of Calved cows</b>	<b>Weekly Calving %</b>	<b>Cumulative Calving %</b>
1	85	9.0	9.0	109	11.0	11.0
2	107	11.3	20.3	124	12.5	23.5
3	56	6.0	26.3	145	14.7	38.2
4	176	18.7	45.0	166	16.8	55.0
5	189	20.0	68.0	178	18.0	73.0
6	132	14.0	82.0	99	10.0	83.0
7	113	12.0	91.0	79	8.0	91.0
8	28	3.0	94.0	40	4.0	95.0
9	19	2.0	98.0	30	3.0	98.0
10	38	4.0	100.0	20	2.0	100.0

**Appendix VIII** Feed requirements for the autumn and spring calved cows in a winter milk supply herd.

Autumn calved cows:

Assumptions:-

- a) Lw 450 kg
- b) Average days in milk 282 days
- c) Average milk production/lactation 4840 litres
- d) Calving date 20/3
- e) Drying off date 27/01

<b>Month</b>	<b>Milk yield/day</b>	<b>Maintenance Requirements MJ/ME/day</b>	<b>Milk Requirements MJ/ME/day</b>	<b>Total MJ/ME</b>	<b>KgDM /day</b>
Apr/May	19.3	58.0	104.2	162	15.4
Jun/July	17.9	58.0	96.7	154	14.7
Aug/Sept	16.6	58.0	89.1	147	14.0
Oct/Nov	15.8	57.8	85.3	143	13.6
Dec/Jan	14.45	57.0	73.3	135	12.9
Feb/March	11.0	57.0	59.4	116	11.1

Spring calved cows:

Assumptions:-

- a) Lw 450 kg
- b) Average days in milk 258 days
- c) Average milk production/lactation 4122 litres
- d) Calving date 1/08
- e) Drying off date 20/04

Month	Milk yield/day	Maintenance Requirements MJ/ME/day	Milk Requirements MJ/ME/day	Total MJ/ME	KgDM/day
Aug/Sept	18.2	58.0	98.0	156	14.8
Oct/Nov	21.5	58.0	116.1	174	16.5
Dec/Jan	19.4	58.0	104.5	162	15.5
Feb/March	14.9	57.8	80.5	138	13.2
Apr/May	11.9	57.0	64.5	121	11.6

## REFERENCES

**de Alba J.; Corta EV and Ulloa GC (1961):** Influence of natural service on length of oestrus in the cow.

*Animal Production* **3**:327-330

**Anon (1991):** Fertility in dairy cattle.(in Finnish). Ed. Alamko,N.

*Report for Finnish Herd Health Board. Helsinki*

**Armstrong JD.; Goodall EA.; Gordon FJ.; Rice DA and McCaughey WJ (1990):** The effect of levels of concentrate offered and inclusion of maize gluten or fish meal in the concentrate on reproductive performance and blood parameters of dairy cows.

*Animal Production* **50**:1-10

**Badinga L.; Collier RJ.; Thatcher WW and Wilcox CJ (1985):** Effects of climatic and management factors on conception rate of dairy cattle in subtropical environment.

*Journal of Dairy Science* **68**:78-85

**Baker AM and Leaver JD (1986):** Effect of stocking rate in early season on dairy cow performance and sward characteristics.

*Grass and Forage Science* **41**:333-340

**Bane A and Rajakoski E (1961):** The bovine oestrous cycle.

*The Cornell Veterinarian* **51**:77-95

**Bauman DE and Currie WB (1980):** Partitioning of nutrients during pregnancy and lactation. A Review of the mechanisms involving homeostasis and homeorhesis.

*Journal of Dairy Science* **63**:1514-1529

**Berger PJ.; Shanks RD.; Freeman AE and Laben RC (1981):** Genetic aspects of milk yield and reproductive performance.

*Journal of Dairy Science* **64**:114-122

**Berman A (1991):** Reproductive responses under high temperature conditions. Animal husbandry in warm climates. *Proceedings of the international symposium on animal husbandry in warm climate.*

*European Association for Animal Production Publication* **55**:23-30

**Bond J.; Wiltbank JN and Cook AC (1958):** Cessation of oestrus and ovarian activity in a group of beef heifers on extremely low levels of energy and protein. *Journal of Animal Science* **17**:192 (Abstract)

**Brightling P.; Larcombe MT and Malmo J (1990):** Investigating shortfalls in reproductive performances in Dairy herds. *Dairy Research Council, Melbourne.*

**Britt JH.; Scott RG.; Armstrong JD and Whitacre MD (1986):** Determinants of oestrous behaviour in lactating Holstein cows. *Journal of Dairy Science* **69**:2195-2202

**Britt JH.; Kittok RJ and Harrison DS (1974):** Ovulation, oestrus and endocrine response after GnRH in early post-partum cows. *Journal of Animal Science* **39**:915-919

**Bozworth RW.; Ward G.; Call EP and Bonewitz ER (1972):** Analysis of factors affecting calving intervals of dairy cows. *Journal of Dairy Science* **55**:334-338

**Broster WH (1973):** Liveweight change and fertility in the lactating Dairy cow : A Review. *Veterinary Record* **93**:417-420

**Bryant AM (1980):** A comparison of three systems of wintering dairy cattle. *Proceedings of the Ruakura Farmers' Conference* **32**:181-188

**Bryant AM (1982):** Development in dairy cow feeding and pasture management. *Proceedings of the Ruakura Farmers' Conference* **34**:75-81

**Bryant AM (1992):** Information sheet for the Waikato field trip. *Farm Management II. Massey University*

**Bryant AM (1990):** Present and future grazing systems. *Proceedings of New Zealand Society of Animal Production* **50**:35-38

**Bryant AM and Holmes CW (1985):** Utilisation of pasture on dairy farms. In: *The Challenge: Efficient Dairy Production Australia and New Zealand Society of Animal Production, Albury-Wodonga*

**Bryant AM and Trigg TE (1981):** Progress report on the performance of Jersey cows differing in breeding index.  
*Proceedings of the New Zealand Society of Animal Production* **41**:39-47

**Bulman DC and Lamming GE (1978):** Milk progesterone levels in relation to conception, repeat breeding and factors influencing acyclicity in dairy cows.  
*Journal of Reproduction & Fertility* **54**:447-458

**Bull IS (1990):** Using new knowledge of protein nutrition in dairy rations.  
*Jersey Journal* **9**:46-54 USA

**Burgess SM (1988):** The climate and Weather of Manawatu.  
*New Zealand Meteorological Service* **18**:21-36

**Butler WR.; Everest RW and Coppock CE (1981):** The relationships between energy balance, milk production and ovulation in post partum Holstein cows.  
*Journal of Animal Science* **53**:742-748

**Chaimongkol C (1990):** Studies on reproductive performance of dairy cows in New Zealand and some factors which may influence reproductive performance.  
*Master of Veterinary Science Thesis. Massey University*

**Call EP (1978):** Economics associated with calving intervals.  
*In Large Herd Dairy Management (ed) Wilcox, C.J. University Press Florida USA*

**Campbell AG (1966a):** Grazed pasture parameters. I. Pasture dry matter production and availability in a stocking rate and grazing management experiment with dairy cows.  
*Journal of Agricultural Science* **67**:199-210

**Cowie JD and Kear BS (1972):** Soil map of Kairanga county, North Island, New-Zealand.  
*New Zealand Soil Bureau Map 102.*

**Canfield RW and Butler WR (1990):** Energy balance and pulsatile LH secretion in early post partum dairy cattle.

*Domestic Animal Endocrinology* **7:323-330**

**Carruthers TD and Hafs HD (1980):** Suckling and four-times daily milking: Influence on ovulation, oestrus and serum LH, glucocorticoids and prolactin in post-partum Holsteins.

*Journal of Animal Science* **50:919-925**

**Carruthers VR and Penno JW (1995):** Energy and protein supplementation in spring.

*Proceedings of the Ruakura Farmers Conference* **47:53-58**

**Davidson JN and Farver TB (1980):** Conception rates of Holstein bulls for artificial insemination on a California dairy.

*Journal of Dairy Science* **63:621-626**

**Deane TH (1993):** The relationship between milk fat production per hectare and economic farm surplus on New Zealand dairy farms.

*Proceedings of the New Zealand Society of Animal Production* **53:51-53**

**de Kruif A and Brand A (1978):** Factors influencing the reproductive capacity of a dairy herd.

*New Zealand Veterinary Journal* **26:178-189**

**Dillon P.; O'Farrell K and Crosse S (1994):** Why calving date and compact calving are so important to profitable dairying.

*Irish Grassland and Animal Production Association Journal* **28:3-8**

**Eddy RG (1980):** Analysing dairy herd fertility. *In Practice* **2:25-30**

**Eede JR (1981):** Calving pattern and their relation to production planning.

*New Zealand Milk Board Publication. Hamilton*

**Elrod CC and Butler WR (1993):** Reduction of fertility and alteration of uterine pH in heifers fed excess ruminally degradable protein.

*Journal of Animal Science* **71:694-701**

**Erb HN.; Smith RD.; Oltenacu PA.; Guard CL.; Hillman RB.; Powers PA.; Smith MC and White ME (1985):** Path model of reproductive disorders and performance, milk fever, mastitis, milk yield and culling in Holstein cows.  
*Journal of Dairy Science* **68**:3337-3349

**Erb HN and Smith RD (1987):** The effects of periparturient events on breeding performance of dairy cows. *Veterinary Clinics of North America*.  
*Food Animal Practice* **3**:501-511

**Esslemont RJ (1974):** Economic and husbandry aspects of the manifestation and detection of oestrus in cows. III. The detection of oestrus.  
*Journal of the Agricultural Development and Advisory Service-Quarterly Review* **15**:83-95

**Esslemont RJ (1992):** Measuring dairy herd fertility.  
*Veterinary Record* **131**:209-212

**Esslemont RJ and Eddy RG (1977):** The control of cattle fertility; The use of computerised records.  
*British Veterinary Journal* **133**:346-355

**Esslemont RJ and Bryant MJ (1976):** Oestrous behaviour in a herd of dairy cows.  
*Veterinary Record* **99**:472-475

**Esslemont RJ and Ellis PR (1974):** Components of a herd calving interval.  
*Veterinary Record* **95**:319-320

**Etherington WG.; Martin SW.; Dohoo IR and Bosu WTK (1985):** Interrelationships between ambient temperature, age at calving, post partum reproductive events and reproductive performance in dairy cows: A path analysis.  
*Canadian Journal of Comparative Medicine* **49**:254-260

**Fagan JG and Roche JF (1986):** Reproductive activity of post partum dairy cows.  
*11<sup>th</sup> International Congress of Animal Reproduction and Artificial Insemination*  
*Dublin, Ireland*

**Ferguson JD.; Blanchard T.; Galligan DT and Hoshall DC (1988):** Infertility in dairy cattle fed a high percentage of protein degradable in the rumen.

*Journal of American Veterinary Medical Association* **192:659-662**

**Ferguson JD and Chalupa W (1989):** Impact of protein nutrition on reproduction in dairy cows.

*Journal of Dairy Science* **72:746-766**

**Fielden ED.; Macmillan KL and Watson JD (1973):** The anoestrous syndrome in New Zealand dairy cattle. 1. Preliminary investigation.

*New Zealand Veterinary Journal* **21:77-81**

**Fielden ED.; Harris RE.; Macmillan KL and Shrestha SL (1980):** Some Aspects of Reproductive Performance in Selected Town Supply Dairy Herds.

*New Zealand Veterinary Journal* **28:131-132**

**Fielden ED.; Macmillan KL and Moller K (1976):** The pre-service anoestrous syndrome in New Zealand dairy herds.

*Bovine Practitioner* **11:10-14**

**Fonseca FA.; Britt JH.; McDaniel BT.; Wilk JC and Rakes AH (1983):**

Reproductive traits of Holsteins and Jerseys. Effect of age, milk yield and clinical abnormalities on involution of cervix and uterus, ovulation, oestrous cycles, detection of oestrus, conception rates and days open.

*Journal of Dairy Science* **66:1128-1147**

**Frame J (1992):** Improved Grassland Management. *Farming Press Books, UK*

**Francos G and Mayer E (1988):** Analysis of fertility indices of cows with extended post-partum anoestrus and other reproductive disorders compared to normal cows.

*Theriogenology* **29:399-412**

**Fulkerson WJ.; Franks DR and Michell P (1987):** Comparison of autumn and spring calving management strategies.

*Elliott Research station. Interim Report. Tasmania*

**Fulkerson WJ.; Sawyer GT and Crothers I (1983):** Fertility management in dairy cattle  
*Collins, London, U.K*

**Galina CS.; Calderon A and McCloskey M (1982):** Detection of signs of oestrus in the Charolais cow and its Brahman cross under continuous observation.  
*Theriogenology 17:485-498*

**Garnsworthy PC (1988):** The effect of energy reserves at calving on performance of dairy cows. In : Nutrition and Lactation in the dairy cow.(Ed) Garnsworthy, P.C  
*Proceedings of the 46<sup>th</sup> Congress. University of Nottingham*

**Goel VG and Rao MVM (1971):** Studies on the reproductive behaviour of Zebu and crossbred farm animals.  
*Annual Report. National Dairy Research Institute. Karnal India*

**Grainger C.; Wilhelms GD and McGowan AA (1982):** Effect of body condition at calving and level of feeding in early lactation on milk production of dairy cows.  
*Australian Journal of Experimental Agriculture and Animal Husbandry 22:9-17*

**Grainger C and Wilhelms GD (1979):** Effect of duration and pattern of underfeeding in early lactation on milk production and reproduction of Dairy cows.  
*Australian Journal of Experimental Agriculture and Animal Husbandry 19:395-401*

**Grimmet JG (1986):** Achievement of calving date and pattern in seasonal dairy herds.  
*Dairy Farming Annual. Massey University 40:82-87*

**Grimmet JG (1985):** Reproductive program monitoring in seasonal dairying.  
*The Challenge: Efficient Dairy Production. Australia and New Zealand Society of Animal Production*

**Gwazdauskas FC.; Thatcher WW and Wilcox CJ (1973):** Physiological, environmental and hormonal factors at insemination which may affect conception.  
*Journal of Dairy Science 56:873-877*

**Gwazdauskas FC.; Lineweaver JA and Vinson WE (1981):** Rates of conception by artificial insemination of dairy cattle.  
*Journal of Dairy Science 64:358-362*

**Hawkins SW and Rose PH (1979):** The relationship between the rate of fertilizer nitrogen applied to grassland and milk production, and analysis of recorded farm data.

*Grass and Forage Science* **34**:203-208

**Helmer SD and Britt JH (1985):** Mounting behaviour as affected by stage of oestrous cycle in Holstein heifers.

*Journal of Dairy Science* **68**:1290-1296

**Hodgson J (1990):** Grazing Management, Science into Practice.

*Longman Scientific and Technical, Essex, England.*

**Holmes CW and Parker WJ (1992):** Stocking rate and its effects on dairy farm productivity.

*Dairy Farming Annual. Massey University* **44**:4-15

**Holmes CW and Macmillan KL (1982):** Nutritional management of the dairy herd grazing in pasture. In Macmillan, K.L., Taufa, V.K (eds).

*Dairy Production From Pasture. Clark and Matheson Ltd. Hamilton*

**Holmes CW.; Brookes IM and Wilson GF (1991):** Supplementary feeds for winter milk production. Information for winter milk producers.

*Bulletin 4:1. Massey University*

✧ **Holmes CW (1986):** Calving dates and their importance to the dairy farmer and the dairy industry.

*Dairy Farming Annual. Massey University* **40**:54-67

**Holmes CW and Mclenaghan RJ (1980):** Results of some studies in Dairy production.

*Department of Animal Science. Massey University.*

**Holmes CW and Wilson GF (1987):** Milk Production From Pasture.

*Butterworths New Zealand LTD*

**Holmes CW and Baldwin GW (1990):** The performance and problems of winter milk dairy farms.

*Dairy Farming Annual. Massey University* **42**:59-63

**Holmes CW (1982):** The effect of fertilizer nitrogen on production of pasture and milk on dairy farmlets :1971-1974.  
*Proceedings of the New Zealand Grassland Association* **43:53-57**

**Holmes CW (1993):** Reproduction, fertility, mating, calving and dairy herds productivity.  
*Study guide. Department of Animal Science. Massey University*

**Holmes CW (1990):** Principles and practices of profitable dairy farming.  
*Proceedings of Ruakura Farmers' Conference* **42:60-67**

**Holmes W (1980):** Grazing management. In W Holmes (Ed).  
*Grass: Its production and utilization. Blackwell, London* **12:51-75**

**Hughes TP (1984):** Definition and objectives of reproduction in Dairy cows. Dairy cattle reproduction.  
*Animal Industry Workshop. Lincoln College (Ed) Barrell, G.K*

**Hughes TP (1992):** Manipulating feed supply. Feed planning for dairy farmers.  
*Animal Industries Workshop. Lincoln University.*

**Hurnik JK.; King GJ and Robertson HA (1975):** Oestrous and related behaviour in post partum Holstein cows.  
*Applied Animal Ethology* **2:55-65**

**Hutton JB (1968):** Farming two cows per acre: At Ruakura, three seasons. Intensive Dairy Production.  
*Proceedings of the Ruakura Farmers' Conference* **20:215-227**

**Imakawa J.; Day ML.; Garcia-winder M.; Zalesky DD.; Kittok RJ.; Schanbacher BD and Kinder JE (1986):** Endocrine changes during restoration of oestrous cycles following induction of anoestrus by restricted nutrient intake in beef heifers.  
*Journal of Animal Science* **63:565-571**

**Jansen J.; Dijkhuizen AA and Sol J (1987):** Parameters to monitor dairy herd fertility and their relation to financial loss from reproductive failure.  
*Preventive Veterinary Medicine* **4:409-418**

**Jordan ER .; Thomas EC.; Swanson LV and Donald WH (1983):** Relationship of dietary crude protein to composition of uterine secretions and blood in high-producing post partum dairy cows.

*Journal of Dairy Science* **66:1854-1862**

**Kilgour R.; Skarsholt BH.; Smith JF.; Bremner KJ and Morrison MCL (1977):** Observations on the behaviour and factors influencing the sexually active group in cattle.

*Proceedings of New Zealand Society of Animal Production* **37:128-135**

**King GJ.; Hurnik JF and Robertson HA (1976):** Ovarian function and oestrus in dairy cows during early lactation.

*Journal of Animal Science* **42:688-692**

**King JOL (1968):** The relationship between the conception rate and changes in bodyweight, yield and SNF content of milk in Dairy cow.

*Veterinary Record* **83:492-494**

**Lamming GE and Bulman DC (1976):** The use of milk progesterone radioimmunoassay in the diagnosis and treatment of subfertility in dairy cows. *British Veterinary Journal* **132:506-517**

**Lean IJ (1992):** Nutrition and Reproduction.

*Proceedings of the Society of Dairy Cattle Veterinarians of the New Zealand Veterinary Association*

**Leidl W and Stolla R (1976):** Measurement of electric resistance of the vaginal mucus as an aid for heat detection.

*Theriogenology* **6:237-246**

**Livestock Improvement Corporation (1989/90):** Dairy statistics

**Livestock Improvement Corporation (1994/95):** Dairy statistics

**Lucy MC.; Staples CR.; Thatcher WW.; Erickson PS.; Cleale RM.; Clark JH.; Murphy MR. ; Brodie BO and Firkins JL (1992):** Influence of diet composition, dry matter intake, milk production and energy balance on time of post partum ovulation and fertility in dairy cows.

*Animal production* **54:323-331**

**Macmillan KL (1985):** Objectives of a breeding programme. The Challenge : *Efficient Dairy Production by Australia and New Zealand Societies of Animal Production, Albury-Wodonga*

**Macmillan KL and Clayton DG (1980):** Factors influencing the interval to post partum oestrus, conception date and empty rate in an intensive managed dairy herd. *Proceedings of New Zealand Society of Animal Production* **40:236-239**

**Macmillan KL and Curnow RJ (1977b):** Factors influencing AB conception rates. XI. Variation in sire fertility.

*New Zealand Journal of Experimental Agriculture* **5:279-285**

**Macmillan KL and Curnow RJ (1977a):** Tailpainting : A simple form of oestrus detection in New Zealand dairy herds.

*New Zealand Journal of Experimental Agriculture* **5:357-361**

**Macmillan KL.; Day AM.; Taufa VK.; Henderson HV and Allison PA (1987):** Some effects of injecting a PGF<sub>2</sub> $\alpha$  (Lutalyse) during the post-partum period on the subsequent fertility of dairy cows.

*Proceedings of New Zealand Society of Animal Production* **47:65-68**

**Macmillan KL (1979):** Factors influencing conception rates to AB in New Zealand dairy herds. A Review.

*Proceedings of New Zealand Society of Animal Production* **39:129-137**

**Macmillan KL and Curnow RJ (1976):** The application of oestrous synchronisation in New Zealand dairy herds.

*Proceedings of New Zealand Society of Animal Production* **36:50-57**

**Macmillan KL and Watson JD (1974b):** Factors influencing conception rates to AB in New Zealand dairy herds. V. Cow age and stage of oestrus at insemination.

*New Zealand Journal of Experimental Agriculture* **3:29-35**

**Macmillan KL and Peterson AJ (1993):** A new intravaginal progesterone releasing device for cattle (CIDR-B) for oestrous synchronisation, increasing pregnancy rates and treatment of post partum anoestrus.

*Animal Reproduction Science* **33**:1-25

**Macmillan KL and Moller K (1977):** Aspects of reproduction in New Zealand dairy herds. II. Calving interval, breeding period and non-pregnancy rates.

*New Zealand Veterinary Journal* **25**:220-224

**Macmillan KL and Watson JD (1975e):** Fertility differences between groups of sires relative to the stage of oestrus at the time of insemination.

*Animal Production* **21**:243-249

**Macmillan KL and Curnow RJ (1976a):** Aspects of reproduction in New Zealand dairy herds. I. Gestation length.

*New Zealand Veterinary Journal* **24**:243-252

**Macmillan KL.; Taufa VK and Pearce MG (1984):** Calving patterns and their effects on herd production.

*Proceedings of Ruakura Farmers' Conference* **36**:25-28

**Macmillan KL (1985a):** Achieving high conception rates in dairy cattle.

*The University of Sydney. Post Graduate Committee in Veterinary Science (Dairy Cattle Production) Proceedings* **78**:55-61

**Macmillan KL (1985b):** Dairy herd breeding management.

*The University of Sydney. Post Graduate Committee in Veterinary Science (Dairy Cattle Production) Proceedings* **78**:62-66

**Macmillan KL.; Duganzich DM and Bryant AM (1981):** Production differences between Jersey and Friesian x Jersey cows in commercial dairy herd.

*Proceedings of New Zealand Society of Animal Production* **41**:48-52

**Macmillan KL (1975):** Factors influencing conception rates in AB dairy herds. Differences in records of inseminating technicians.

*New Zealand Journal of Experimental Agriculture* **3**:15-19

**Macmillan KL (1994):** Empty heifers.

*Proceedings of Ruakura Farmers' Conference* **46:43-48**

**Macmillan KL and Watson JD (1973):** A.B. in New Zealand Dairy herds.II.

Interactions between conception rate and submission rate on the proportion of the herd reported in calf to A.B.

*New Zealand Journal of Experimental Agriculture* **1:309-314**

**MacDonald KA and Macmillan KL (1993):** Condition score and liveweight in Jersey and Friesian cows.

*Proceedings of the Ruakura Farmers' Conference* **45:47-53**

**Malven PV (1984):** Pathological physiology of the puerperium. Definition of the problem.

*Proceedings of the 10<sup>th</sup> International Congress Animal Reproduction and Artificial Insemination* **IV:III-1**

**Marion GB.; Norwood JS and Gier HT (1968):** Uterus of the cow after parturition. Factors affecting regression.

*American Journal of Veterinary Research* **29:71-75**

**Mather EC.; Camper PM.; Vahdat F.; Whitmore HL and Gustafsson BG (1978):** Assessment of ovarian activity in the post partum dairy cow by using a milk progesterone assay.

*Theriogenology* **10:119-129**

**McCaughey WJ and Patterson AD (1981):** Vaginal electrical resistance in cow. II. Relationship of milk progesterone concentrations during the reproductive cycle.

*Veterinary Research Communication* **5:77-84**

**McClure TJ (1970):** An experimental study of the causes of nutritional and lactational stress infertility of pasture fed cows, associated with loss of bodyweight at about the time of mating.

*Research in Veterinary Science* **11:247-254**

**McCallum D.; Thomson NA.; and Clough J (1994):** Meal feeding at high stocking rates at Waimate West demonstration farm.

*Dairy Farming Annual. Massey University* **46:50-54**

**McDougall S (1992):** The effect of stocking rate, breed and prepartum nutrition on post partum anoestrus.  
*Proceedings of 1<sup>st</sup> International Conference of Society of Dairy Cattle Veterinarians of the New Zealand Veterinary Association Noumea*

**McDougall S (1994):** Post partum anoestrus in the pasture grazed New Zealand Dairy cow.  
*Doctor of Philosophy Thesis. Massey University.*

**McDougall S.; Clark DA.; Macmillan KL and Williamson NB (1994):** Effect of silage supplementation in pasture fed Dairy cows on reproductive performance.  
*Proceedings of the New Zealand Society of Animal Production 54:95-98*

**McDougall S.; Leijnse P.; Day AM.; Macmillan KL and Williamson NB (1993):** A case study of anoestrus in New Zealand dairy cows.  
*Proceedings of New Zealand Society of Animal Production 53:101-103*

**McGowan AA (1981):** Effect of nutrition and mating management on calving patterns.  
*Proceedings of New Zealand Society of Animal Production 41:34-38*

**McKay BJ (1988):** The recording and analysis of animal health data on New Zealand dairy farms.  
*Master of Veterinary Science Thesis. Massey University*

**McMeekan CP and Walshe MJ (1963):** The inter-relationships of grazing method and stocking rate in efficiency of pasture utilization by dairy cattle.  
*Journal of Agricultural Science 61:147-166*

**Moller K (1978):** Planned animal health and production service in New Zealand dairy herds.  
*Bovine Practitioner 13:26-30*

**Moller K and MacDiarmid SC (1981a):** The reproductive performance of New-Zealand dairy cows after induction of calving.  
*New Zealand Veterinary Journal 29:172-173*

**Moller S (1991):** Nutritional balance and reproductive efficiency in dairy cows on spring pasture - A preliminary study.

*Dairy Cattle Society of the New Zealand Veterinary Association* **9:3-9**

**Moller K (1970):** Uterine involution and ovarian activity after calving.

*New Zealand Veterinary Journal* **18:140-145**

**Morris RS (1976):** Diagnosis of infertility syndrome in large dairy herds.

*The University of Sydney. Post Graduate Committee in Veterinary Science (Dairy cattle Production-mastitis). Proceedings* **28:183-194**

**Morris CA.; Hurnik JF.; King GJ and Robertson HA (1976):** A cost- benefit analysis for monitoring systems to detect oestrus in cows.

*Canadian Journal of Animal Science* **56:291-298**

**Morrow DA and Gerloft BJ (1986):** Effect of nutrition on reproduction in dairy cattle.

In: *Current Therapy in Theriogenology*, (eds) Morrow, D.A and Sanders, W.B. Philadelphia USA

**Mott GO (1960):** Grazing pressure and the measurement of pasture production.

*Proceedings of the 8<sup>th</sup> International Grassland Congress, Reading*

**New Zealand Dairy Board (1951):** 27<sup>th</sup> farm production report. Farm production division Wellington

**O'Farrell KJ and Ryan D (1994):** Research in reproductive management of Dairy herd.

In: *Murphy J (Ed) Dairying improving the competitive edge, Teagasc Dublin*

**O'Reilly J and Holmes CW (1994):** Feeds, Feeding and daily milk yield during June and July in ten high producing winter milk farms.

(unpublished observations)

**O'Sullivan M (1983):** Some aspects of pasture utilization by the grazing animal.

*Irish Grassland Animal Production Society*

**Patchell MR (1957):** The influence of undernutrition of Dairy cows in the yield and composition of milk.

*New Zealand Journal of Science and Technology* **38A:682-688**

**Payne JM and Payne S (1987):** The metabolic profile.

*Text Oxford University Press*

**Pelissier CL (1976):** Dairy cattle breeding problems and their consequences.

*Theriogenology* **6:575-583**

**Pennington JA.; Albright JL.; Diekman MA and Callaham CJ (1985):** Sexual activity of Holstein cows : Seasonal effect.

*Journal of Dairy Science* **68:3023-3030**

**Peters AR and Lamming GE (1990):** Lactational anoestrus in farm animals.

*Oxford Reviews of Reproductive Biology* **12:246-287**

**Phillips T (1994):** If there were no problems there would be no opportunities.

*Large Herd Conference*

**Radostits OM and Blood DC (1985):** Herd health.

*Saunders, W.B. Philadelphia USA*

**Rhind SM.; Martin GB.; Mcmillan S.; Tsonis CG and McNeilly AS (1989):** Effect of level of food intake of ewes on secretion of LH and FSH and on the pituitary response to gonadotropin-releasing hormone in ovariectomized ewes.

*Journal of Endocrinology* **121:325-330**

**Rogers GL (1985):** Pasture and supplements in the temperate zones.

In: *The Challenge: Efficient Dairy Production* (ed) Phillips, T.I. Australian Society of Animal Production

**Ron M.; Bar-anan R and Wiggans GR.; (1984):** Factors affecting conception rate of Israel Holstein cattle.

*Journal of Dairy Science* **67:854-860**

**Rutter LM and Randel RD (1984):** Post partum nutrient intake and body condition effect on pituitary function and onset of oestrus in beef cattle.  
*Journal of Animal Science* **58**:265-274

**Rutter LM, and Manns JG (1987):** Hypoglycemia alters pulsatile luteinising hormone secretion in post partum beef cow.  
*Journal of Animal Science* **64**:479-488

**Saloniemi H (1993):** Reproductive disturbances related to feeding.  
*Acta Veterinaria Scandinavia Supplementary* **89**:71-74

**Saloniemi H.; Grohn Y and Syvajarvi J (1986):** An epidemiological and genetic study on registered diseases in Finnish Ayrshire cattle. II. Reproductive disorders.  
*Acta Veterinaria Scandinavia* **27**:196-208

**Sauvant D (1994):** Modelling homeostatic and homeorhetic regulations in lactating animals.  
*Livestock Production Science* **39**:105-113

**Sawyer GJ and Fulkerson WJ (1981):** The effectiveness of steers and heifers treated with oestrogen or testosterone to detect oestrus in cattle.  
*Journal of Reproduction Science* **3**:259-269

**Schilling E and Zust J (1968):** Diagnosis of oestrus and ovulation in cows by pH measurements *Intra vaginam* and by apparent viscosity of vaginal mucus.  
*Journal of Reproduction and Fertility* **15**:307-311

**Shrestha SL (1978):** Reproductive efficiency in Town supply Dairy herds in New Zealand.  
*Master of Philosophy in Veterinary Science Thesis. Massey University.*

**Shaver RD (1989):** Role of blood urea nitrogen (BUN) as an indicator of dietary protein status : relationship to reproductive performance.  
*Veterinary Nutrition Symposium. Madison WI*

**Simmonds JG (1985):** Factors influencing calving date of seasonal supply dairy herds in New Zealand.

In: *The challenge: Efficient Dairy Production (ed) Phillips, T.I. Australia and New Zealand Society of Animal Production*

**Smith JF.; Payne E.; Tervit HR.; McGowan LT.; Fairclough R.; Kilgour R and Goold PG (1981):** The effect of suckling upon the endocrine changes associated with anoestrus in identical twin dairy cows.

*Journal of Reproduction and Fertility Supplementary 30:241-249*

**Smith JW and Legates JE (1962):** Relation of days open and days dry to lactation, milk and fat yields.

*Journal of Dairy Science 45:1192-1198*

**Smith JF and Macmillan KL (1978):** Dairy cattle breeding management: Tail painting, shortening the AB period and AB in heifers.

*Ruakura Farmers' Conference FPP 127*

**Slama H.; Wells ME.; Adams GD and Morrison RD (1976):** Factors affecting calving interval in dairy herds.

*Journal of Dairy Science 59:1334-1339*

**Staples CR.; Thatcher W and Clark JH (1990):** Relationship between ovarian activity and energy status during the early post partum period of high producing dairy cows.

*Journal of Dairy Science 73:938-947*

**Stevenson JS and Britt JH (1977):** Detection of oestrus by three methods.

*Journal of Dairy Science 60:1994-1998*

**Stevenson JS and Call EP (1983):** Influence of early oestrus, ovulation and insemination on fertility in post-partum Holstein cows.

*Theriogenology 19:367-375*

**Taylor W and Leaver JD (1984b):** Systems of concentrate allocation for dairy cattle 2. A comparison of two patterns of concentrate allocation for autumn-calving cows offered two qualities of grass silage *ad-libitum*.

*Animal Production 39:325-333*

**Thomas GW.; Mathews GL and Wilson DG (1985):** Effect of calving date on milk production and economic returns.

In: *The challenge. Efficient Dairy Production (ed) Phillips, T.I. Australian Society of Animal Production*

**Thomson NA and Holmes CW (1995):** Supplementary feeding for increased milk production.

*Dairy Farming Annual. Massey University* 47:20-27

**Tucker HA (1985):** Photoperiodic influence on milk production in dairy cows.

*Recent Advances in Animal Nutrition. Ed, Haresign, W and Cole, D.J.A. Butterworths*

**Visser A.; Shannon P and Wickham BW (1988):** Factors affecting AB conception rates in cattle.

*Proceedings of the New Zealand Society of Animal Production* 48:61-63

**Visek WJ (1984):** Ammonia: Its effects on biological systems, metabolic hormones and reproduction.

*Journal of Dairy Science* 67:481-498

**White DH (1987):** Stocking rate:

In: *Snaydon, R.W (ed) Managed Grasslands, Elsevier, Amsterdam*

**Whitaker D (1995):** Fertility and nutrition.

*Irish Farmers' Journal (Dairying Sept)*

**Williamson NB (1980a):** Tailpaint as an aid to detection of oestrus in cattle.

*Australian Veterinary Journal* 56:98-100

**Williamson NB.; Morris RS.; Blood DC and Cannon CM (1972b):** Study of oestrous behaviour and oestrus detection methods in a large commercial dairy herd. I. The relative efficiency of methods of oestrus detection.

*Veterinary Record* 91:50-57

**Williamson NB.; Blood DC.; Morris RS.; Cannon CM and Cannon RM (1978):** A health program for commercial dairy herds I. Objectives and methods.

*Australian Veterinary Journal* 54:207-215

**Williamson NB (1987):** The interpretation of herd records and clinical findings for identifying and solving problems of infertility.  
*New Zealand Compendium on Continuing Education for the Practicing Veterinarians* 9:15-23

**Williamson NB and Fernandez-baca E (1992):** The role of dietary protein and energy in dairy herd fertility.  
*Proceedings of the New Zealand Dairy Cattle Veterinary Association*

**Williams WF.;Yver DR and Gross TS (1981):** Comparison of oestrus detection techniques in dairy heifers.  
*Journal of Dairy Science* 64:1738-1741

**Wiseman PR (1988):** The reproductive performance of autumn calving dairy herds.  
*Proceedings of the 5<sup>th</sup> Semminar of Dairy Cattle Society of the New Zealand Veterinary Association*

**Wolfenson D.; Flamenbaum I and Berman A (1988):** Hyperthermia and body energy store effects on oestrous behaviour, conception rate and *Corpus luteum* function in dairy cows.  
*Journal of Dairy Science* 71:3497-3504