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THE WINTERING AND CALVING OF ANGUS BEEF
COWS ON A SANDUST PAD

A thesis presented in partial fulfilment of
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ABSTRACT

A system of wintering and calving beef cows on a sawdust cattle pad was compared with the traditional method of wintering unsupplemented cows on hill country pasture. Comparisons were made over four years, beginning in 1970.

Two herds of Angus beef cows were used in the experiment. One herd was originally the Massey University Stud herd, which included approximately 50 cows aged from three to ten. Three-year-old replacements were added to this herd each year. This herd was designated the Stud herd. The other herd designated the Commercial herd, was based on 67 yearling heifers bought in 1969. These cows were all of the same age, and no replacements were added. In 1969 25 cows from this herd were mated to calve at two-years-of-age. The two herds were run together as one unit during the trial, distinction only being made for the purpose of statistical analysis.

The pad consists of two yards with sawdust packed on top of tile drains. A concrete apron runs along the side where the feeding racks are situated. A stand of pampas grass protects the pad from the prevailing wind. Half gates were installed, and the bottom rails of the yard were removed to allow the calves to get out and creep feed on the adjoining pasture.

Three weeks before calving begins cows were allotted to the pad or the hill treatment using a table of random numbers. In 1971, 1972, 1973 a switchover design was adopted, whereby some animals alternated between the two treatments in successive years, while others wintered on the same treatments.

Over 1970 the cows were confined all the time. In 1971 the cows on pad I were allowed to break feed saved pasture over a week. In 1972 and 1973 the cows and calves were removed from the pad for three and four days after birth respectively. This enabled the calf to obtain colostrum without interference, allowed the cow to build up reserves of vitamin A, helped form a bond between the calf and its mother, and enabled the calf to have the benefit of a healthier environment for the first days of its life. This practice appeared to have some merit in reducing the incidence of calf scours.

While confined the cows were fed hay, barley straw, and barley meal. In 1970 some experimentation in feeding levels was necessary, and in 1971, 1972 and 1973, 4.3 kg hay, 2.3 kg barley straw and 0.6 kg of barley meal per head per day were fed.

In 1972 and 1973 feeding once a day was compared with feeding the same ration once every second day.

Before the cows were confined the top three inches of sawdust was removed and the sawdust and timberwork sprayed with a 10% solution of formalin. In 1973 the concrete apron was scraped off weekly with a tractor and blade.

Milk determinations were made by the weigh-nurse-weigh method following a 16 hour separation.

The cows entered the pad about the second week in July, and remained there until the end of September, when they joined their contemporaries on the hill.

Generally the cows wintered on the pad lost more weight than the cows grazed on the hill, although the magnitude of the weight lost varied considerably between years.

Birth weights of the calves born on the pad were generally about 2 kg below that of the calves born on the hill. However, there were no clear differences between treatments for the weaning weights. Limited information gathered on the cow milk production indicated that although milk weights of the cows on the pad were lower during confinement, handicapping the growth of their calves, there appeared to be a surge of milk production in these animals upon their release to the hill pasture, in some years. This resulted in an increased growth rate of the calves from the pad at this time.

Reproductive performance of the three-year-old and mature cows as measured by their calving interval was unaffected by the winter treatments.

The performance of the first calving two-year-old heifers from the Commercial herd in 1970 was adversely affected by the pad treatment. Birth weights and weaning weights were reduced and 26.5% of the heifers failed to rebreed the following season. Nevertheless

subsequent performance demonstrated no further effect of calving at two-years-of-age under adverse conditions.

There was no effect on the calf performance of feeding every day against feeding every second day. Neither was calf performance affected by any of the switching treatments imposed between years.

Differences due to the effect of sex and age of dam were similar to those reported in the literature for birth weight and weaning weight. As the four-year-old dams performed surprisingly well in this study an age-of-dam \times treatment interaction was suspected. There was an indeterminate effect of sex on the milk yield of the dam.

Regressions involving the age of the calf on the weight at various points revealed a strong association of growth with climatic variables. Since the period under study included stormy weather and long droughts this complicated the evaluation of calf growth data.

It was concluded that the pad system of wintering and calving beef cows can be operated as a commercial system in the manner described. A discussion of pad husbandry is given, and recommendations are made.

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LIST OF TABLES

<u>Table</u>		<u>Page</u>
1.1	The correlation between the gestation length of the dam and the birth weight of the calf.	6
1.2	Gestation length of the dam and birth weights of the male and female calves.	8
1.3	The correlation between the weight of the dam and the birth weight of the calf.	9
1.4	Effect of the age of the dam (years) on the weaning weight of the calf (kg).	22
1.5	The effect of sex on the weaning weight of the calf of different breeds.	25
1.6	The repeatability of the dam for calf weaning weight.	31
1.7	Correlation coefficients between milk production of the cow and growth of its offspring.	39
1.8	The average daily gain (A.D.G.) of the calves and the milk yield of their dams and the correlations between them.	46
1.9	The milk yield (kg) of beef cows on different levels of feeding.	57
1.10	The milk yield (kg) for beef cows fed at different levels of energy and protein.	59
2.1	The number of cows on each treatment in each year of the trial.	75
3.1	The least square differences between sexes in each herd-year for the birth weight of the calf.	82

<u>Table</u>		<u>Page</u>
3.2	The least square differences between sexes in each herd-year for the weaning weight of the calf (200-day adjusted)	85
3.3	The least square differences between sexes for the milk consumption of the calf.	87
3.4	The least square means for the effect of the age of the dam (years) on the birth weight of the calf (kg).	89
3.5	The least square differences for the effect of the age of the dam (years) on the weaning weight of the calf (kg)	91
3.6	The least square differences for the effect of the age of the dam on the amount of milk consumed by the calf.	93
3.7	The least square differences for the effect of the parity of the dam on the birth weight of the calf.	95
3.8	The least square differences for the effect of the parity of the dam on the weaning weight of the calf.	97
3.9	The least square differences for the effect of the parity of the dam on the milk consumption of her calf.	99
3.10	The least square differences for the effect of the treatments on the birth weight of the calf.	101
3.11	The least square differences between the treatments for the adjusted weaning weight of the calf.	103
3.12	The least square differences for the effect of the treatment on the milk consumption of the calves.	106

<u>Table</u>		<u>Page</u>
3.13	The regression coefficients for the time of calving (days) on the birth weight (kg).	109
3.14	The least square regression coefficients for the effect of the time of calving on the 200-day adjusted weaning weights.	111
3.15	The least square regression coefficients for the effect of the time of calving on the milk consumption of the calf.	113
3.16	The least square differences between the liveweights of the cows according to winter treatment when they were removed from the pad.	115
3.17	The least square differences for the effect of the sex of the calf on the liveweight of the dam at the end of winter.	117
3.18	The least square differences for the effect of the parity of the cow on her liveweight at the end of the winter.	118
3.19	The least square regression coefficients for the effect of the autumn liveweight of the cow on her liveweight at the end of the winter.	120
3.20	The least square regression coefficients for the effect of the time of calving of the cow on her liveweight at the end of the winter.	121
3.21	The least square means for the effect of the treatment on calf weight at birth and three weekly intervals post pad.	123
3.22	The least square differences for the effect of sex on calf weight at birth and at three weekly intervals post pad.	125

<u>Table</u>		<u>Page</u>
3.23	The linear and quadratic regression coefficients of calf age on weight at birth and three weekly intervals post part.	127
3.24	The minimums of the quadratic regressions of calf age on calf weight at three weekly intervals post part.	128
3.25	The least square differences for the effect of treatment on the calving interval of the cows.	131
3.26	Climatological data.	135

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1.1	Beef cow lactation curves as reported by various workers.	53
2.1	Treatments imposed each year.	75
3.1	The graph of calf liveweight y calf age at each three-weekly weight for the 1973/74 calves.	129
A.1	The normal equations	164

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	ii.
ACKNOWLEDGEMENTS	vi.
LIST OF TABLES	vii.
LIST OF FIGURES	xi.
INTRODUCTION	1.
<u>REVIEW OF LITERATURE</u>	3.
PART I CALF PERFORMANCE	3.
The Birth Weight of the Calf	3.
The Gestation Period	5.
The Weight of the Dam	7.
The Age of the Dam	10.
The Sex of the Calf	12.
The Sire of the Calf	12.
Time of Birth	14.
Repeatability of Birth Weight	15.
PART II CALF PERFORMANCE	16.
The Weaning Weight of the Calf	16.
The Weight of the Dam	20.
The Age of the Dam	21.
The Sex of the Calf	24.

	<u>Page</u>
The Effect of the Sire	27.
The Year and Season of Birth	28.
The Repeatability of Weaning Weight	29.
PART III THE EFFECT OF NUTRITION OF THE DAM OVER THE PERIOD OF GESTATION ON THE BIRTH WEIGHT OF ITS CALF	 32.
PART IV MILK PRODUCTION OF THE BEEF COW	38.
Breed Considerations	48.
The Lactation Curve	50.
Nutrition and Milk Yield	52.
Milk Constituents and Calf Performance	60.
The Efficiency of Milk Conversion to Liveweight Gain	64.
Age of Dam Effects	65.
The Sex of the Calf	67.
Conclusions	70.
<u>MATERIALS AND METHODS</u>	71.
Husbandry	71.
The Experimental Design 1970 to 1972/73	75.
Biometrical Analyses	77.
<u>RESULTS AND DISCUSSION</u>	81.
THE EFFECT OF THE SEX OF THE CALF	81.
(a) Birth Weight	81.
(b) Weaning Weight	84.
(c) Milk Production	86.

	<u>Page</u>
THE EFFECT OF THE AGE OF THE DAM	88.
(a) Birth Weight	88.
(b) Weaning Weight	90.
(c) Milk Consumption of Calves	93.
THE EFFECT OF PREVIOUS CALVINGS	94.
(a) Birth Weight	94.
(b) Weaning Weight	96.
(c) Milk Consumption	98.
THE EFFECT OF THE WINTERING TREATMENT	98.
(a) Birth Weight	98.
(b) Weaning Weight	102.
(c) Milk Consumption	105.
THE EFFECT OF TIME OF CALVING	108.
(a) Birth Weight	108.
(b) Weaning Weight	110.
(c) Milk Consumption	112.
THE LIVELINE CHANGE OF THE COWS OVER WINTER	114.
(a) Treatment	114.
(b) Sex of Calf	116.
(c) Parity of the Cow	116.
(d) The Autumn Liveweight of the Cow	119.
(e) The Time of Calving	119.

Page

THE GROWTH OF THE 1973/74 CALVES	119.
(a) Winter Treatment	119.
(b) The Sex of the Calf	124.
(c) The Effect of the Time of Birth	126.
THE CALVING INTERVAL	130.
GENERAL DISCUSSION AND CONCLUSION	133.
LIST OF REFERENCES	148.
APPENDIX I	163.

INTRODUCTION

This study was concerned with only a part of the analysis of data collected during the operation of a new system of management of beef cows and their young calves. This system involved the confinement of breeding cows on a sawdust pad over the earlier part of the winter, from about three weeks before calving, until about eight weeks after calving. The rationale behind the use of this technique involves a consideration of the problems in the winter of much of New Zealand's hill country. Because of wetness of this country it is unwise to attempt to graze large numbers of cattle since it will contribute to erosion and pugging, and the difficulty involved in providing supplementary feed for cattle. However because of economic considerations this land should be devoted to breeding, thus tying its productivity to the number of capital stock which it can overwinter.

The supply of store stock for finishing will become the limiting factor in the expansion of New Zealand's beef industry, since breeding loses attractiveness to investors because of a longer cycle, and a greater risk compared to a finishing policy. It thus seems that any major increase in cattle numbers must be the result of herd expansion

in the hill country. But to achieve this the problem of wintering the animals in this environment must be overcome.

The present investigation analyses the feasibility of overcoming the winter problem by removing the breeding cows from the hills, and confining them to a sawdust pad until the spring. A similar group of cows remained on the wet hills of Tuapaka where they did not receive any supplementary feed and these acted as controls. To this end a number of questions were raised:

1. How was the birth weight of the calf affected?
2. How was the weaning weight of the calf affected?
3. How was the milk yield of the cow affected?
4. How was the calving interval of the cow affected?
5. How was the weight of the cow affected?

This thesis is not intended to be an exhaustive study of the system. Further data which are available must be analysed to clarify certain aspects, particularly those associated with the liveweight changes of the cow.

In addition a number of females in the trial were calved at two-years-of-age, thus adding further information to the literature already published on this practice.

It is believed that this work will be of value to the New Zealand beef cattle industry, and that a number of the points raised will stimulate further experimentation and lead to discussion and adoption of the techniques by producers.

PART I

CALF PERFORMANCE

The Birth Weight of the Calf

Birth is the point at which the calf commences independent growth. Health and vigour is of prime importance at this point to enable the calf to adapt to its new, and less desirable environment. These two attributes have some connection with the development of the calf, and one measure of this is its weight at birth.

Furthermore an advantage in weight at birth would be generally expected to continue, and be positively correlated with certain economic traits such as weaning weight. The heaviest calf at birth is that which has grown most rapidly as a foetus. Outside the uterus, growth rate will be affected by variables such as the milking and mothering ability of the dam, climatic factors, the amount and type of feed available, as well as genotype-environment interactions. The degree to which these variables operate to modify the rate of growth is measured by the strength of the correlation between birth weight and weaning weight.

Koch et al. (1973) using 3,462 Hereford calves found a correlation between birth weight and weaning weight (at 200 days) of $r = 0.43$.

Gregory et al. (1950) reported the comparable correlation for Herefords to be $r = 0.27$ and $r = 0.60$ ($P < 0.01$) for two localities for 205-day weaning weight to be $r = 0.35$ for Angus and $r = 0.40$ for Hereford calves in Mississippi. Dawson et al. (1947) working with 402 Beef Shorthorn calves from 112 dams, found the correlation between birth weight and the time required for the calves to reach a weight of 225 kg. to be $r = -0.58$ indicating that the heavier calves at birth took less time to grow to 225 kg. Heyns (1959) in South Africa studied Africander cows and calves and noted that for every 4.5 kg. increase in birth weight, calves weighed 45.0 kg. more at weaning, while Niemann, and Heydenrych (1965) also with Africanders in South Africa showed 11.7% of the variation in calf weaning weights could be explained as being due to the effect of birth weight.

Hohenboken et al. (1971) found a correlation between birth weight and pre-weaning gain of $r = 0.53$ with Herefords, while Rogoni and Pasti (1958) reported $r = 0.283$ for 154 Brown Alpine calves. Although Auriol et al. (1963) found a highly significant correlation between birth weight and calf weight at nine months for the Charolais breed they considered that calf birth weight gave a poor indication of pre-weaning growth rate. Koch et al. (1973) and Dawson et al. (1947) reported that birth weight had a closer correlation with post-weaning weight gains than it did with pre-weaning weight gains.

The evidence indicates that calf birth weight has some association with latter weights, the degree of association depending largely on the environmental conditions operating.

Birth weight is a function of: (i) Gestation length, (ii) Genetic potential of the calf to grow, (iii) The material environment. These variables are interrelated and depend upon such influences of the age of the dam, the sire, the calf sex, and the time of birth. These will be considered in turn.

The Gestation Period

Calf production begins with conception and continues with the growth of the foetus in utero. This phase of growth before birth is the gestation period. Since the foetus grows continually though at varying rates through pregnancy, it is clear that the birth weight of the calf will be a function of the gestation length. This is supported by the positive correlations between gestation length and birth weight shown in Table 1.1.

Burris and Blunn (1952) using 502 Hereford, Angus, and Short-horn calves found the regression of gestation length on birth weight to be 0.16 kg/day ($P < 0.01$). Reynolds et al. (1965) dealing with 438 matings of Angus, Brahman, Brangus and Africander-Angus calves showed birth weight increased 0.29 kg with each day increase in gestation. O'Connor et al. (1968) working with data from 851 Friesian calves showed that the regression of birth weight on

Table 1.1 The correlation between the gestation length of the dam and the birth weight of the calf.

Correlation Coefficient	Number of Animals	Breed	Reference
0.35	650	Simmental	Brogner <u>et al.</u> (1970)
0.44 (genetic)	414	Hereford	Lasley <u>et al.</u> (1961)
0.25	402	Beef Shorthorn	Dawson <u>et al.</u> (1947)
0.22	53	Meuse-Rhine-Yssel	Jordao and De Paula Assis (1951)
0.42	None given	Unspecified	Tudor (1972)

gestation length was 0.225 kg/day. Forrest (1964) found a regression for Friesians of 0.22 kg/day. Lawson and Peters (1964) with 219 calves of the Highland and Hereford breeds found an increase of 0.059 kg/day ($P \leq 0.01$). Although it is not strictly correct to report the association of two continuous variables as a regression these values do give some idea of the trend. The rapidly growing breeds such as the Friesian gain more per day increase in gestation than do the less rapidly growing breeds. This is to be expected, and indicates more opportunity in the former breeds to affect calf birth weights by reducing the gestation period.

It will be noted from Table 1.2 that the Angus has one of the shortest average gestation lengths for the beef breeds. The Friesian tends to be shorter than the Angus while the large exotic breeds, Simmental and Charolais recently introduced into New Zealand exhibit longer gestation periods. Animals of Bos indicus breeding are characterised by a long gestation period, of an order greater than 290 days.

The Weight of the Dam

In all reports the weight of the dam is positively associated with the calf birth weight (Table 1.3). The correlation for the younger, immature dams (two- three- and four-year olds) is normally lower than that for mature dams. This supports the contention that dam body weight per se has little to do with calf birth weight beyond an obvious genetical association.

Table 1.2 Gestation length of the dam and birth weights of the male and female calves.

Breed	Gestation Length (days)	Male B.W. (kg)	Female B.W. (kg)	Reference
Hereford	-	32.9	31.8	Rice <u>et al.</u> (1954)
Hereford	-	31.4	29.5	Hallman (1965)
Hereford	-	34.1	28.6	MacDonald (1954)
Angus	-	26.1	23.7	Hallman (1965)
Angus	-	31.3	27.0	MacDonald (1954)
Sindhi	283	15.3	18.9	Dave (1950)
Meuse-Rhine-Yssel	277	40.3	38.0	Jordao and De Paula Assis (1951)
Simmental	286	46.3	42.7	Petrovic (1952)
South Devon	287	45.8	44.6	Joubert (1957)
Charolais	-	50.2	45.9	Dumont <u>et al.</u> (1959)
Charolais	-	45.8	42.7	De Vree (1961)
Sahiwal	286	23.8	21.6	Singh and Dutt (1961)
Simmental	285	-	-	Belic (1949)
Shorthorn	281	-	-	Dawson <u>et al.</u> (1947)
Angus	283	-	-	Livesay and Ural (1945)
Hereford	285	-	-	Livesay and Ural (1945)
Hereford	287	-	-	Lasley <u>et al.</u> (1961)
Hereford	289	-	-	Rife <u>et al.</u> (1943)
Angus	273	-	-	Rife <u>et al.</u> (1943)

Table 1.3 The correlation between the weight of the dam and the birth weight of the calf.

Correlation Coefficient	Number of Animals	Breed	Reference
0.40	None given	Unspecified	Tudor (1972)
0.24	502	Hereford	Alexander <u>et al.</u> (1960)
0.27	73	Unspecified heifers	Balika (1965)
0.54	64	Unspecified second calvers	Balika (1965)
0.38	323	Africander	Niemann and Heydenrych (1965)
0.30	708	Bulgarian Red	Balabanov <u>et al.</u> (1970)
0.17	783	Friesian	Afifi and Solimon (1971)
0.24	463	Angus x Milking Shorthorn	Drewry <u>et al.</u> (1972)

The Age of the Dam

This effect is a measure of differences in the maternal environment as the dam ages. At younger ages, notably the two- and three-year-olds, the developing foetus must compete with active growth 'sinks' for resources, as at these ages the dam itself is still growing. Furthermore, skeletal limitations of the dam may constrain the calf's growth. At the older ages - greater than eight years-of-age - efficiency declines due to the aging process, and no doubt factors such as sub-clinical disease play a greater role.

Values reported for the reduction in performance in younger cows compared with mature cows (normally five- to seven-year olds) are remarkably consistent. Alexander et al. (1960) with 244 Herefords found first-calf heifers to drop calves 1.8 kg lighter than those of mature cows while Bennett (1958) found calves from Hereford and Shorthorn dams to be 2.7 kg lighter from the two-year-old dams, and 1.8 kg lighter for the three-year-old dams from those from cows four years and over. Meyer (1964) reported the average birth weight of calves from heifers was 10% less than from mature dams.

However the older dams appear to be much more variable as far as the birthweight of their calves are concerned. This is consistent with environmental influences playing a greater role. Also the values obtained for older dams can be biased by culling. Many authors failed to make it clear whether or not this practice had occurred when reporting their results. Koch and Clark (1955)

analysing the records of 5,952 Herefords found that calf birth weight increased with cow age between three- and six-years then declined. Niemann and Heydenrych (1965) using Africanders found a positive curvilinear relationship between birth weight and the age of the dam up to six or seven years. Bosman and Harwin (1966) with 662 calves of the Bonsmara, Africander, and South Devon breeds showed that cows aged three, four or eleven years produced calves that were 3.6 kg lighter than those produced by cows of other ages. Hewitt (1951) working with Red Polls and Friesians noted no decrease in calf birth weight until the eleventh calf, while Singh (1969) found that eight- to twelve-year olds had the heaviest calves at birth.

On a more general theme, Dawson et al. (1947) found calf birth weight to be 0.09 kg heavier for each month increase in dam age. Similarly Singh and Dutt (1961) showed that a one month increase in the dam's age increased birth weight by 0.068 kg in males, and 0.096 kg in females, for Sahiwal calves. Vial and More O'Ferrall (1965) found the regression of calf birth weight on age of dam to be approximately linear and equal to 0.59 kg/year, for Shorthorns and Friesians. Foote et al. (1960) calculated the regression of birth weight on parity of the dam as 0.18 kg/year for the Angus, and 0.15 kg/year for the Shorthorn.

The question as to whether the age of the dam affects the gestation period, and thus the birth weight indirectly has come

under consideration. The age of the dam had no effect on gestation length in the studies of Lasley et al. (1961), Reynolds et al. (1965) and Tudor (1972). Foote et al. (1959) noted that gestation length increased with age of dam for 250 Friesian cows, although the differences between ages were not significant.

The Sex of the Calf

Male birthweights are higher than those of female calves according to almost all studies (Table 1.2).

Male calves are generally carried in utero for a longer period, as well as being heavier at birth. However, that the increase in male birth weight is due to an effect over and above that of the increase in gestation length is shown by the results of O'Connor et al. (1968). They found that male calves had a 1.6 day increase in gestation period and a birth weight of 4.0 kg higher than females although the regression of birth weight on gestation length was 0.23 kg/day. Evidence was also provided by Foote et al. (1960) who showed that female Shorthorn calves were in utero longer than were the males, although the birth weights favoured the males.

The Sire of the Calf

Since the sire contributes a sample half of his genes towards the genetic makeup of the calf, differences between sires of the

same breed as the dams, for the birthweight of the progeny are to be expected. Thus significant differences between sires were noted by Brown and Calvez (1969) and Brakel et al. (1952). Brown and Calvez (1969) found that sire effects accounted for 20% of the variation in Hereford calves, and 9% in the Angus. Niemann and Heydenrych (1965) noted differences of 4.1 kg between sires for calf birth weight. Foote et al. (1959) found differences of up to 5.9 kg between six sires used on 250 Friesian cows. However, no significant sire effect was found by Abelein and Ritter (1959), or Singh (1969).

The sire effect will depend not only upon the relative genetic merit of a sire for foetal growth rate, but also upon the degree of genetic difference between the sire and dam, which may give rise to either heterosis, (between lines within a breed), or inbreeding depression.

Brogner et al. (1970), and Wheat and Riggs (1952), have reported a significant effect of sire on gestation period. Rice et al. (1954) with 443 Hereford cows mated to eight bulls found that offspring of the different sires varied from 284 to 289 days ($P < 0.01$), Willet (1950) using 20 Groningen bulls observed a high, positive, correlation ($r = 0.82$) between the gestation period of individual bulls and the average gestation period of their progeny. This sire effect lends support to the hypothesis that the calf plays a determining role in the initiation of parturition.

Time of Birth

Dickinson, (1961), examined the effect of month of calving, and found a decrease in gestation length when cows calved in the summer. There was also a short decrease in April (northern spring) which appeared to be associated with the cows going out onto pasture. O'Connor et al. (1968), with British Friesian cattle found significant differences between areas for gestation length. Calves from the North and Wales had shorter gestation periods than those in the Midlands and South East. However there were no differences between the corrected birth weights.

Bosman and Harwin (1966), found birth weight to increase by 0.05 kg/day and 0.07 kg/day in each of two herds as the calving season progressed. Young (1970) found 0.06 kg/day ($P < 0.01$) and 0.063 kg/day ($P < 0.01$) for Angus, while Lawson and Peters (1964) calculated a 0.05 kg/day for Highland and Hereford cattle. The latter authors attributed this gain to a superior pre-calving range environment for the late cows, although all studies were confounded by gestation length. Bracher (1951) studying gestation length found no effect of calving sequence on birth weight.

Repeatability of Birth Weight

Repeatability may be calculated in either of two ways, but neither takes account of variations in gestation length.

1. Intraclass correlation between calves by the same cow.
2. Regression of subsequent records on earlier records by the same cow.

Botkin and Whatley (1953) calculated $r = 0.18$ for the first method and $r = 0.14$ for the second for 620 Hereford calves. A second herd with only two calving records gave $r = 0.25$.

Taylor et al. (1957) with 350 calves from 103 Hereford cows found $r = 0.18$ and with 900 calves from 364 Angus, Hereford and Shorthorn dams $r = 0.30$. Alexander et al. (1960) using 502 calves from 244 Hereford cows found $r = 0.25$ while Singh and Dutt (1961) in India with 177 Sahiwal calves calculated $r = 0.11$.

Since repeatability is affected by many unconsidered variables such as age, sire and gestation length, estimates calculated as above cannot be expected to be high.

PART II

CALF PERFORMANCE

The Weaning Weight of the Calf

Weaning is an arbitrary point determined by the cattleman at which the cow and calf are separated. Initially the cow provides food and maternal influence necessary for the calf's survival, but as the calf develops and grows its diet changes, and the need for supervision decreases, so the cow becomes increasingly competitive with its calf. Eventually a stage arrives where the growth of the calf is likely to be enhanced by removing the cow. The location in time of this point varies according to the environmental conditions, and the degree of technology available. It can be as long as 300 days as on some New Zealand high country stations, or as short as three or four days on intensive dairy farms. However most reports concerned with run cow beef units put the average time of weaning at around 200 days of age.

Because of the different birth dates and a managerial need to wean all calves at one time, calves differ in their ages at weaning. Thus to make any inferences about weaning, the weights of all calves must be adjusted to a common age. This is normally done by the use of the formula:

$$\begin{array}{l} \text{Weaning weight (W.W.)} \\ \text{Birth weight (B.W.)} \end{array} \left(\frac{\text{W.W.} - \text{B.W.}}{\text{age(days)}} \right) \times \text{common age (days)} + \text{B.W.}$$

Common age is normally given as 180, 200, 205 or 210 days.

This formula assumes that growth rate up to the weaning age has been linear. Brown (1960) noted linear growth between 60 and 240 days for Hereford and Angus steers, as did Pahnish (1958) with 661 Herefords between the ages of 121 and 323 days. Burns and Alexander (1956) at Brian Pastures in Queensland, Australia, reported a linear growth rate of 0.68 kg/day for Herefords over the first eight months until the pasture deteriorated. Marlowe et al. (1965) showed linear growth for Angus and Hereford calves from 120 days until weaning. Linear growth to weaning was assumed for the calculations reported in the papers of Green and Buric, (1965), Koch et al. (1959) and Rollins and Guilbert (1954).

However Elings et al. (1971) investigated the effect of average daily gain of calves to weaning for Hereford cattle, using two herds, with 4,612 observations in herd A, over 28 years, and 1,324 observations in herd B over 14 years. They found that between 180 and 292 days the regression coefficients of age on average daily gain (A.D.G.) indicated an average decrease of 0.0009 kg/day for bulls, and 0.00084 kg/day for heifers. Similar evidence for a curvilinear effect was provided by Creek, (1964), working in Jamaica with Zebu, Angus, Red Poll and Charolais calves from eight farms.

In a systematic comparison of estimates with real weights, he found that estimates taken before 210 days overestimated the 210-day weight while estimates taken after 210 days underestimated the 210-day weight. Loganathan et al. (1965) using 667 Hereford calves found that males grew 1.07 times as fast as females through to July, and 1.11 times as fast from July to weaning. Swiger et al. (1962) calculated a linear growth rate from birth to 130 days, but a pronounced curvilinear effect of age on gain from 130-200 days of age, ($P < 0.05$), for beef calves at each of two separate locations. Older and younger calves appeared to gain more slowly than calves near the average age over this period. Minyard and Dinkel (1965), observed 1,915 Hereford, and 436 Angus calves from 20 private herds in the period 1951-1957. The average weaning age in these herds of 203 days was adjusted to 190 days. They discovered that the linear correction factor appeared to overadjust weight for the extreme age groups. The younger age groups were adjusted too high, and the older groups too low. Cundiff et al. (1966) reported a significant month of birth x type of management interaction for weaning weight. Similarly Harwin et al. (1966) found a significant year x age of calf interaction for weaning weight in Hereford calves. Creek (1964) studied calf growth during a period of drought in Jamaica. During the acute period of the drought, the younger calves gained at a rate of 0.11 kg/day, and the older calves at 0.46 kg/day

($P < 0.01$). Lehmann et al. (1962) using 2,802 calves, which were weighed four times at 28-day intervals, calculated the regression of average daily gain on the age of the calf to be significantly concave for creep-fed calves, and significantly convex for non-creep fed calves.

The evidence indicates that linear adjustment of calf weaning weights to a constant age could be subject to error if between birth and weaning one or more components of the environment undergo a marked change. Such changes may occur during a drought. The different environmental conditions cause a departure from linear growth. The extent of departure from linearity appears to affect different ages of calves differently, and may have something to do with the relative proportions of milk to grass which the calf has been consuming.

In an investigation into the effect of age correction factors, Johnson and Dinkel (1951), showed the growth curve to be straight up to 155 days, thereafter increasing at a decreasing rate. However, they found a linear correction factor to be more accurate than a quadratic one. Nevertheless they counselled caution in applying a correction factor to calves where the weaning weight has been taken much more than 30 days preceding, or following the standard weaning age.

The situation becomes serious when age adjusted weaning weights from a large range of ages is used to compare the effect of different treatments. This aspect, and its relationship to the present work will be discussed in detail later.

The Weight of the Dam

The advantage established at birth, reported as a positive correlation between the weight of the dam and the weight of the calf (see earlier discussion on birth weight), continues to weaning. Urick et al. (1971) reported the correlation between cow weight and 205-day weaning weight of the calf as $r = 0.21$ for 534 cows of the Angus, Charolais, and Shorthorn breeds. Niemann and Heydenrych (1965) using 321 Africander calves calculated that 1.2% of the total variation in weaning weight was accounted for by the weight of the dam. Neville (1962) working with 135 calves from 61 Hereford dams calculated an extra weaning weight of 3 kg for every 45 kg increase in dam weight, ($P < 0.01$). Godley and Tennant (1969), showed that the weight of Angus cows was positively correlated with the weaning weight of their calves, but this was not true for Hereford cows. Tanner et al. (1965), using 385 Hereford calves, from 153 dams, and 518 Angus calves from 250 dams found a linear relationship between cow weight and calf weaning weight in

the Angus, (4 kg/45 kg), and a curvilinear association in the Hereford. Benyshek and Marlowe, (1972) working with 1,011 observations from 15 herds of Hereford cattle made over two years, calculated adjusted average daily gain to increase linearly with adjusted cow weight at the rate of 0.29 to 0.46 g/day.

The Age of the Dam

A similar pattern to that observed for birth weight emerges (Table 1.4). A major factor in the maternal environment to weaning is the milking ability of the dam. In a review of this subject Barton (1971) presents correlations between the milk production of the cow and the growth of its offspring for the Angus, Hereford and Charolais breeds. Values range from $r = 0.13$ to $r = 0.85$, with a majority of values $r = 0.45$ to 0.65 . Milk yield and its relationships will be dealt with separately.

Two- and three-year-old dams wean noticeable lighter calves than those in the mature age groups of five to seven years. This effect of the younger dam seems to be fairly consistent with large increases in production, occurring between the second and third, and third and fourth years. Pahnish (1958) showed age of dam to exert a curvilinear influence on age adjusted weaning weights as did Niemann and Heydenrych (1965), from three to seven years of age.

Table 1.4 Effect of the age of the dam (years) on the weaning weight of the calf (kg).

Preston and Willis (1971)

Weaning Age (days)	Weaning Weight (kg)	<u>Age of Dam (years)</u>										Reference
		2	3	4	5	6	7	8	9	10		
Not given	Not given	- 7	2	2	2	10	10	10	- 5	- 5	Burgess <u>et al.</u> (1964)	
180	151	-16	- 5	- 2	0	0	0	0	0	0	Clum <u>et al.</u> (1956)	
180	170	-17	-17	- 6	0	1	0	1	- 1	- 1	Brown (1960)	
240	204	-	-14	-10	- 5	- 2	0	0	0	-	Mahmud and Cobb (1963)	
190	189	-25	- 9	- 2	2	10	11	12	8	5	Minyard and Dinkel (1965)	
200	176	- 6	- 6	2	2	5	5	5	5	2	Harwin <u>et al.</u> (1966)	
205	189	-12	-12	0	3	6	7	8	8	7	Cundiff <u>et al.</u> (1966)	
205	202	-18	-18	-10	0	0	0	0	0	0	Meade <u>et al.</u> (1959)	

Singh (1969), working with Herefords (Herd A), and Warren et al. (1965) with 28,493 Hereford, Angus and Santa Gertrudis calves found that weaning weight increased significantly with age of dam up to seven years of age.

An interesting result obtained by Singh (1969) using 244 steers and 189 heifer calves from the Hereford breed (Herd B) was that the calves from the four-year-old dams were heaviest at weaning despite the fact that calves from the eight-to-twelve year old age groups were heaviest at birth.

On the other hand the decline in production of cows at the older age groups is much more variable. This may be due to the degree of selection operating, as well as differing environmental influences. Sewell et al. (1963) using the 180-day weaning weight of 1,066 Hereford calves, Clum et al. (1956) and Marlowe and Gaines (1958) working with Angus, Hereford, and Shorthorns, showed that there was no fall off in production until the tenth year. Marlowe et al. (1965) observed no fall off in calf weaning weights until a herd of Angus and Hereford cows reached their eleventh year. However Creek and Nestal (1964) found the 210-day weight of 2,358 Zebu type calves in Jamaica (a tropical climate) to decline when dam age reached eight years.

An illustration of the variable effect of the environment was demonstrated by Mathis and Kothmann (1970), when they compared

four-year-old, and eleven-year-old Hereford cows under three rates of stocking. As expected the lightest calves were weaned under the heaviest stocking rates for both ages of cows. Under all treatments, the younger cows weaned consistently lighter calves, however the difference increased with reduced stocking rate, showing a greater effect of the less favourable environment on the older cows. It is easy to imagine a relationship favouring the younger cows becoming more important as topography and climate tend to extremes. Further evidence of this nature was provided by Harwin et al. (1966) with Herefords, and Eftekhari-Shahroudi (1972) with Angus and Herefords, who found significant year x age of dam interactions. The latter found this interaction to account for 10.7% of the variation in weaning weight.

The Sex of the Calf

Consideration of the effect of sex on weaning weight involves a third classification, namely steers. Bulls are heavier than heifers at weaning, with steers intermediate (Table 1.5). Problems of interpretation are involved in using steer data, since the time of castration is often not stated.

Male calves have an advantage at birth, (see earlier discussion under birth weight) but they also appear to grow faster to weaning. Pahnish (1958) gives an extra growth rate of 0.1 kg/day for males.

Table 1.5 The effect of sex on the weaning weight of the calf of different breeds.

Preston and Willis (1971).

<u>Breed</u>	<u>Weaning Age (days)</u>	<u>Male Weight (kg)</u>	<u>Female Weight (kg)</u>	<u>Reference</u>
Hereford	180	182	171	Brinks <u>et al.</u> (1961)
Hereford	200	193	176	Gregory <u>et al.</u> (1966)
Hereford	200	181	171	Harwin <u>et al.</u> (1966)
Hereford	210	170	158	Lasley <u>et al.</u> (1961)
Hereford	240	210	193	Mahmud and Cobb (1963)
Hereford	205	175	165	Meade <u>et al.</u> (1959)
Hereford	230	218	202	Pahnish <u>et al.</u> (1964)
Angus	200	198	176	Gregory <u>et al.</u> (1966)
Angus	205	188	177	Meade <u>et al.</u> (1959)
South Devon	180	158	148	Joubert (1957)
Shorthorn	200	195	176	Gregory <u>et al.</u> (1966)

Koch et al. (1959) gave 0.05 kg/day, Mahmud and Cobb (1963) gave 0.05 kg/day, Singh (1969) gave 0.05 kg/day and Jamison (1967) gave 0.07 kg/day. Marlowe and Gaines (1958) reported steers grew 3% faster than heifers and 5% less than bulls.

The extent to which the males have the advantage depends upon how near the optimum the environmental conditions are for growth. This leads to sex x environment interactions. Creek and Nestal (1964), reported that male calves from mature dams were markedly heavier than those from younger or older dams, while dam age had little effect on the 210-day weight of females. Pahnish (1958) also demonstrated that the age of the dam had a greater influence on bull calves than on heifer calves. Further sex x age of dam interactions were noted by Urick et al. (1971) for 534 cow-calf pairs of Angus, Charolais and Hereford breeds. This was also noted by Cordellino and Frahm (1971) and Harwin et al. (1966). Cundiff et al. (1966) found no significant sex x age of dam effect, although there was a significant sex x management interaction.

Marlowe et al. (1965) studied 111 Angus, and 82 Hereford calves and showed non-creep fed bulls to grow 6.5% faster than heifers, and creep fed bulls to grow 9.7% faster than heifers. Similarly Cundiff et al. (1966) demonstrated bulls to benefit more from creep feeding than either steers or heifers for 13,937 Hereford and Angus calves.

The Effect of the Sire

The sire contributes a genetic influence to the weight of the calf. Environmental variation between birth and weaning could diminish the influence of the sire in weaning weight as compared with birth weight. This may make the sire influence in weaning weight more difficult to assess, especially when only small numbers of animals are involved. In this respect Neville (1962) found no significant sire effect using 135 animals. Miguel and Lagos (1967) working with 145 Hereford calves the progeny of six bulls did not find a sire effect, although from the abstract report of this experiment the authors do not appear to have removed variation due to the age of dam effect. Rovira et al. (1967) with only 97 Hereford calves by eight different bulls detected no sire influence. Singh (1969) working with 432 calves in eight sire groups found no sire effect, but in a second herd having 619 calves in 13 sire groups, a significant sire influence was reported.

Significant effects on weaning weight due to the sire were noted by Bosman and Harwin (1956), who calculated the difference between extremes to be 29 kg. They also observed the ranking for sires at weaning were different to that at birth. Brown (1961) found the difference between the best and poorest sire to be 53 kg for 287 Herefords, 35 kg for 334 Angus in one herd and 37 kg for 271 Angus in another herd. Rice et al. (1954) studying 443 Hereford cows and eight bulls calculated the

extreme differences between sire groups to be 19.5 kg.

As pointed out under birth weight some heterotic effect may occur if the genetic make up of the sire and dam are dissimilar. Brinks et al. (1972) estimated this by crossing two lines of Hereford cattle. They found a heterotic effect of 5.4% for pre-weaning daily gain, and 4.7% for weaning weight.

The Year and Season of Birth

Differences between years for weaning weight were significant in the studies of Bosman and Harwin (1966); Brown (1961), who showed that the year of birth accounted for 6-8% of the variation in weaning weight; Burgess et al. (1954) who found weaning weights of 546 Hereford calves to vary 20 kg over five years; Eftekhari-Shahroudi (1972), using 530 Angus and Hereford calves showed weaning weight to vary by 23 kg over eight years. However neither Green and Buric (1953) using 62 Angus and Hereford calves, nor Miguel and Lagos (1967) who studied 145 Hereford calves, noted any significant year effect.

Actual year effects due to climatic variations are difficult to compute accurately because year and age at weaning are confounded. As pointed out earlier, linear adjustment of calf age for weaning weight can lead to errors due to non-linear growth rate under some conditions, and this would inflate or deflate the estimates.

Seasonal influences have also been established. As expected calves born in the spring have heavier weaning weights (Marlowe et al., 1965 ; Clum et al. 1956). . Calves born in the winter have the lightest weaning weights, (Burgess and Bowman, 1964 ; Marlowe et al., 1965). Warren et al. (1965) reported that the heaviest calves were born in late winter (February), although this was in Georgia under a tropical climate.

Niemann and Heydenrych (1965) showed weaning weight to be significantly correlated with date of birth ($r = -0.88$) for Africanders, while Bennett (1958) found late-born Hereford and Shorthorn calves to be 17 kg lighter than those born mid-season. However Neville (1962) working with 135 calves born to 61 Hereford dams reported that for every day later in the season that birth occurred, calves weighed a significant 0.1 kg more at four months of age, although the difference was negligible at eight months.

The Repeatability of Weaning Weight

As with birth weight, repeatability of weaning weight may be calculated in either of two ways:

1. Intra-class correlation between calves of the same cow.
2. Regression of subsequent records between calves of the same cow.

Repeatability of weaning weight is generally higher than that calculated for birth weight (Table 1.6). This reflects the strength of influence of some major source of variation, probably milk-yield (see later). Meade et al. (1959) found repeatability of birth weight for Herefords to be 28%, but repeatability for weaning weight to be 42%. Botkin and Whatley (1953) working with 603 calves of 151 Hereford cows found birth weight $r = 0.18$, but weaning weight $r = 0.43$. Similarly Taylor et al. (1957) calculated $r = 0.18$ for birth weight, and $r = 0.30$ for weaning weight.

Values are high enough to enable prediction of a cow's worth to be made early in its life, although Cunningham and Henderson (1965) having analysed 4,838 records of beef cattle indicated that earlier records were a poor basis for prediction of performance more than two years removed.

Table 1.6 The repeatability of the dam for calf weaning weight.

Repeat-ability	Age (Days)	Number of Animals	Breed	Reference
0.44	180	3342	Hereford	Kress and Burfening (1972)
0.46	210	603	Hereford	Botkin and Whatley (1953)
0.66	210	98	Hereford	Botkin and Whatley (1953)
0.52	180	1066	Hereford	Sewell <u>et al.</u> (1963)
0.42	200	693	Hereford	Kilkenny (1968)
0.39	200	607	Angus	Kilkenny (1968)
0.49	200	896	Lincoln Red	Kilkenny (1968)
0.45	-	260	Hereford/Angus	Lueker <u>et al.</u> (1963)
0.30	-	330	Hereford	Taylor <u>et al.</u> (1957)
0.30	-	900	Hereford/Angus/ Shorthorn	Taylor <u>et al.</u> (1957)
0.48	240	159	Hereford	Rollins and Gilbert (1954)
0.52	-	745	Hereford	Koch (1951)
0.44	205	439		Drewry and Hazel (1966)
0.16	205		Angus	Meade <u>et al.</u> (1959)
0.42	205		Hereford	Meade <u>et al.</u> (1959)

PART III

THE EFFECT OF NUTRITION OF THE DAM OVER THE PERIOD OF GESTATION UPON THE BIRTH WEIGHT OF ITS CALF

The issue as to whether the birth weight of the calf can be influenced directly by the level of nutrition of the dam over the period of gestation is currently of interest in the beef cattle industry. The introduction of exotic breeds such as the Charolais, Simmental, and Limousin has produced new potential for traits such as size, liveweight gain per day, and heavy muscling. However, the incidence of foetal dystocia has been high when these breeds have been crossed with the smaller British beef breeds (Angus, Hereford and Shorthorn) which predominate in New Zealand. This is a factor which has reduced the profitability of utilising these animals in New Zealand, and elsewhere.

The birth weight of the calf has been shown to influence calving difficulty (Bellows et al., 1971), Brogner et al. (1970), Laster et al. (1973), Monteiro (1969), Naude (1967), Nelson and Huber (1971). Belic and Menissier (1968) reported a correlation of $r = 0.64$ between calf birth weight, and dam's calving difficulty score. If birth

weight could be reduced by nutrition then a valuable managerial tool would be available to help to overcome the problem of foetal dystocia where the large breeds are concerned. The question is whether or not restricting the energy intake of the dam during gestation will improve overall productivity in the herd. This means considering other aspects such as dam's reproductive efficiency, and her milk production besides the possible reduction in the calf birth weight.

Calf birth weight can be effectively reduced by severely restricting the winter nutrition of the cow. Wiltbank et al. (1962) reduced the birth weights of the progeny of 24 Hereford cows by 4.95 kg by reducing dam's liveweight to 17-20% of that in the autumn. Similarly Hight (1966) in New Zealand fed Angus cows so that they lost up to 25% of their autumn liveweight at calving to produce calves which were 5.4 kg lighter at birth than the controls whose dam's only lost 1% of their autumn liveweight. Both these feeding regimes increased the period of anoestrus in the nutritionally stressed cows. Furthermore, Hight (1968) showed that the calves from these cows had a lower weaning weight than the calves from the control cows. Bellows et al. (1972) succeeded in feeding one group of Angus-Hereford cross first-calf heifers to gain 14% of autumn liveweight, the other group to lose 14% of autumn liveweight. Calf birth weight was significantly ($P < 0.05$) lower for the low plane

group (28.6 kg v 26.8 kg). However, the period of anoestrus was 20 days longer for these cows on the low plane of nutrition.

Thus the effects of restricted pre-calving nutrition of the dam upon reproduction and milking ability - both important economic parameters - confine the manipulation of dam pre-calving nutrition to rather narrow limits. Lamond (1970) recommends that mature beef cows should lose no more than 15% of their autumn liveweight during the winter.

Of these workers who confined their investigations within narrower limits, Pinney et al. (1972) in evaluating the lifetime performance of range beef cows wintered at different levels of nutrition, reported that birth weights were unaffected by any of the treatments. Scarth and Dalton (1972), compared 30 females which gained 23.3 kg over three months prior to calving with 35 heavily stocked cows which lost 17.2 kg over the same period. Differences in birth weight were small and non-significant. On the other hand, McGinty and Ray (1973) using two groups of cows, the first gaining 11 kg, the second losing 23 kg over the 54 days prior to calving, found calf birth weights to be lower for the second group. However the presence of first calving two-year-old heifers in this trial may have influenced the results.

A different situation would apply to heifers since these animals are still growing while carrying their first calf. Clanton et al. (1967) working with bred yearling heifers found a calf birth weight difference of 4 kg between those which lost 4.5 kg and those which

gained 52.2 kg over the winter. This difference was not significant (only 16 animals were involved). Similarly Christensen et al. (1967) fed 58 yearling heifers, over a 140-day pre-calving period. One group gained 35.5 kg, the second group lost 2.2 kg. The difference in birth weight of the calves from each group was 3.3 kg (29.9 kg v 26.6 kg). But this difference became 4.6 kg at two weeks, 5.9 kg at four weeks, 6.6 kg at six weeks, 13.6 kg at eight weeks. Milk production was found to average 1.0 kg lower for the low plane group. It would appear that the energy restriction in the work of Christenson et al. (1967) was mild, and thus the results emphasise the cost in terms of calf weaning weight from attempting to restrict first calving heifers. To what extent this applies to mature cows remains to be determined, but it would appear that any restriction in nutrition sufficient to affect the birth weight of the calf is almost certain to adversely affect the milk yield of the dam, - at least over the first two months post-partum (see section on milk yield).

The evidence indicates that a reduction in the birth weight of the calf due to nutritional restriction is possible. However, it is open to doubt whether the reduction is sufficient to affect the ease of calving when overfatness on the part of the dam is not the reason for a large foetus. It is noteworthy that although the

studies of Young (1970), Ryley (1961), Bellows et al. (1972) reported reduced calf birth weights among the group with a lower energy intake, none of these authors found foetal dystocia to occur any less frequently. Furthermore, the data of Smithson et al. (1966) from a study of 45 cows through seven calf crops indicated that considerable adaptation could occur among cows which lost up to 20% of their autumn liveweight, so that after four years of treatment the birth weight of their calves was similar to those of cows which lost only 5% of their autumn liveweight before calving.

The possibility that the gestation length might be affected by the nutritional regime has been raised by Tudor (1972). He fed sub-maintenance rations to Hereford cows under Queensland conditions during the last trimester of pregnancy, and significantly reduced calf birth weight by 6.8 kg. But he also lowered the mean gestation length by 5.4 days, when compared to cows on an above-maintenance ration. This aspect does not appear to have been considered by other workers. If it is true then the nature of the diet may have some importance in affecting the time of parturition.

The use of controlled nutrition as a management tool by influencing the birth weight of the calf seems to be limited by its effect on other variables such as milk yield, and the period of anoestrus. Furthermore, reducing birth weight by two or

three kilograms may be insufficient to lower the frequency of dystocia. One is led to conclude that the depth of research in this field is insufficient. Too often the results reported have been obtained as a by-product of the main investigation, and thus there has been no follow up to determine the effect upon other variables. The effect of mild energy restriction to give an autumn liveweight loss of less than 15% in mature cows before calving, needs to be investigated to find its effects upon dam's milk yield and reproductive efficiency. A large-scale factorial experiment using a number of energy levels needs to be carried out to better identify areas of interest and importance to the understanding of the problem. Until this, or similar work, is done the field remains undefined, and progress will not be made.

PART IV

MILK PRODUCTION OF THE BEEF COW

There exists a high correlation between the liveweight gain of the calf, and the milk production of its dam during the preweaning period. Barton (1971), has reviewed the literature and tabulated the correlations obtained by various workers (Table 1.7).

The most common method of evaluating the milk production of a cow is by the weigh-nurse-weigh (W.N.W.) method. The calf is separated from the cow for a period, weighed, allowed to nurse, then weighed again immediately after nursing. The difference between the two weights is assumed to be the amount of milk produced by the cow. Actually the figure is a measure of the calf's appetite at the time, rather than the cow's capacity to yield milk. Barton (1971) points out that errors may arise due to an interaction between the cow and calf, which may depend on such factors as the sex of the calf, its birthweight and subsequent weight changes, its vigour, breed, and its ability to stimulate the cow's let-down process. Furthermore Dickey et al. (1971), using 977 observations of milk yield on Angus and Hereford cows reported that the figure obtained by the W.N.W. method was significantly ($P < 0.05$) dependent on the time for which the cow and calf were separated before suckling.

Table 1.7 Correlation coefficients between milk production of the cow and growth of its offspring.

After Barton (1971)

Breed	Age of Cow (years)	Number of Cow/Calf pairs	Age of Offspring (months)	Correlation Coefficient	Reference
Hereford	2 to 8	50	1	0.52 **	Gifford (1953)
			2	0.66 **	
			4	0.67 **	
			6	0.65 **	
			8	0.60 **	
Hereford	2 to 8	20	8	0.82 **	Gifford (1953)
			12	0.69 **	
			24	0.53 **	
			36	0.55 **	
Hereford	3 to 6+	135	2	0.74 **	Neville (1962)
			4	0.63 **	
			6	0.59 **	
			8	0.66 **	
Hereford (low plane)	4	17	40	0.84 **	Furr and Nelson (1964)
			74	0.38 NS	
			110	0.80 **	
			146	0.59 **	
			160	0.45 *	
			173	0.30 NS	
			Overall to 173 days	0.81 **	
			Overall to 173 days	0.81 **	
Hereford (high plane)	4	16	40	0.41 NS	Furr and Nelson (1964)
			74	0.65 **	
			110	0.73 **	
			146	0.13 NS	
			160	0.17 NS	
			173	0.36 NS	
			Overall to 173 days	0.85 **	
Angus	4 to 7	24	14	0.37 NS	Schwulst <u>et al.</u> (1966)
			21	0.50 **	
			35	0.29 NS	
			Overall to 35 days	0.58 **	

NS = P > 0.05

** = P < 0.01

* = P < 0.05

Perhaps the most serious criticism of this method is related to the comparison of intermittent versus continuous suckling. Lampkin and Lampkin (1960), conducted a small trial with four calves to estimate the degree of error that might be involved. The calves were allowed to suckle their dams three times every day for 12 weeks at 7.00am, 12.00noon, 5.00pm. thus representing a nightly separation interval of 14 hours. 54, 21 and 25% of the total milk consumed over the 12 weeks was taken at the morning, noon and evening tests respectively. Errors in estimation increased as the intervals between tests became greater. Thus it appears from this work that estimates of milk production obtained by W.N.W. using a calf separation interval of 12 to 16 hours, should be regarded as only being between 50 and 60% of the total daily milk yield. Close observations of calf suckling behaviour by Walker (1962) using 9 Angus, 10 Hereford x Angus, and 3 Angus x Jersey two-year heifers revealed that the most regular suckling time was about daybreak, the majority suckling between 4.00am. and 6.00am. Most calves fed again between 9.00am. and 12.00noon, mainly between 11.00am. and 12.00noon. There was no clearly defined late afternoon suckling time. Most feeding occurred between 3.00pm. and 6.00pm. Intervals between sucklings tended to increase as the season progressed.

An alternative technique of estimating milk production is by administering oxytocin, a hormone which causes the cow's udder

muscles to contract expelling the milk. Schwulst et al. (1966) investigated the effects of oxytocin injection using two groups of 12 Angus cows ranging from four to seven-years-of-age. Comparisons were made between milk yields obtained by using or not using oxytocin, calculations being carried out by W.N.W. Observations were made when calves were approximately 2, 3 and 5 weeks of age, over one 24 hour period of each week. All cows were milked by machine immediately calves had completed nursing.

The data indicate that milk consumption results obtained by W.N.W. lead to a significant error in estimating total cow production in early lactation. At the two and three week observations the average residual milk was 15 and 11% respectively of the total milk production measured. At five weeks residual milk was only 6% of total milk production. However as the authors point out, this decrease may have been because the calf consumed a greater percentage of total milk, or the cow may have become refractory to oxytocin. The authors conclude that the evidence from this experiment does not indicate that oxytocin is useful for estimating either milk consumption of calves, or total milk production of beef cows (accurately?). However from the results of this trial it appears that oxytocin, used in conjunction with W.N.W., would be more accurate than W.N.W. alone, especially in early lactation.

Lamond et al. (1969) treated mixed age Hereford cows with oxytocin at six hour intervals. This time interval was chosen to ensure continuous milk secretion into the udder. Estimates of between 6.0 to 8.0 kg per day were obtained. A similar estimate was obtained by Gleddie and Berg (1968) of 6.4 kg after milking by machine following oxytocin injection. Their estimate by W.N.W. after 24 hour separation was 6.5 kg. Totusek and Arnett (1965) using 24 cows kept in a drylot found the average daily milk production to be 5.86 kg by W.N.W., and 4.55 kg by hand milking. Dawson et al. (1960) calculated an average daily milk yield of 7.7 kg/day over 245 days by W.N.W. for 30 Beef Shorthorns between 1931 and 1935. Twenty-nine heifer calves from these cows consumed, on average, 2.24 kg T.D.N./day (from milk, grain, and hay) for an average daily gain of 0.81 kg per day. Their estimated requirement based on nutrient requirements for normal growth (0.76 kg/day) for dairy heifers of large breeds (N.R.C. 1956) was 2.3 kg T.D.N./day. Thus they ate a little less than the recommended requirement, and gained a little more. This would seem to indicate that the cows gave as much milk as was estimated.

A very interesting approach to this problem of measuring the milk yield of the beef cow has been undertaken by Nicol and Irvine (1973). Upon calf separation 1 mg. of Iodine 131 was injected

into the mammary gland. After six hours of separation, and just before suckling the cow's milk was sampled for Iodine 131. Then a milk sample taken previously and incubated with Iodine 125, at $1 \mu\text{c}/5 \text{ kg}$ of calf liveweight to simulate conditions applying to the Iodine 131 in the mammary gland, was forced up the teat canal. Suckling was then permitted. Finally blood samples were taken from the jugular vein of the calf at one and four hours after suckling for measurements of the Iodine 125/Iodine 131 ratio. Six hour milk consumption was then calculated by the formula:

$$\text{Six hour total milk yield} = \frac{\text{Total Iodine 125}}{\text{Iodine 131 in milk}} \times \frac{\text{Iodine 131 in calf blood}}{\text{Iodine 125 in calf blood}}$$

The author's report that the technique accurately measured the known milk intakes of bucket-fed Friesian calves.

As a control the same cows had their milk yields measured by W.N.W., after oxytocin treatment. In comparison with the radioactive iodine method some large differences for milk yield were obtained. As the authors point out it is impossible to decide which is the more realistic figure from this work. However the authors felt that the differences may be due in large part to incomplete emptying of the udder by the calf in the oxytocin induced W.N.W. studies.

The greatest inaccuracy from this method would appear to come from sampling, and measures of radioactivity. The radioactivity involved two separate measures, each with an accompanying error.

The Iodine 131 is absorbed onto the fat globules of the milk, and it is known that the yield of fat varies with the stage of milking. There is thought to be a particularly high concentration of fat in the residual milk. The present technique involves obtaining a sample at the beginning of suckling only, and this could lead to over-estimation of the amount of milk consumed by the calf. No doubt, the technique could be improved by sampling again at the conclusion of suckling. The authors report recovery rates of Iodine 125 varying from 84-96%. However the extrapolation of this to infer that Iodine 131 also has a high recovery rate is invalid since Iodine 131 has had far more time to bind onto fat globules, and thus leaving less opportunity for the Iodine 125 to bind. The recovery of Iodine 125 is probably unrelated to the recovery of Iodine 131. Nevertheless this method appears to have promise, and further investigations of it should be profitable.

The correlation computed between dam's milk yield, and calf liveweight gain depends largely upon the age of the calf at the time of measurement. Neville (1962) noted that the value of milk, and its relationship to calf gain was greatest during the first 60-day period. Similarly, Drewry and Hazel (1966), found that maternal effects through the first 100 days post partum weremost important when calves werenot creep-fed. Christian et al. (1965) calculated the correlation between the dam's butterfat production and the liveweight gain of Hereford calves to be $r = 0.44$ for the

first 60 days. This dropped to $r = 0.32$ for the period 60-240 days, (both $P < 0.01$), for calves having access to creep feed. Gleddie and Berg (1968), found correlations of milk yield with average calf daily gain of $r = 0.62$ (first month); $r = 0.75$ (second month); $r = 0.76$ (third month); $r = 0.51$ (fourth month). Gifford (1949) using 57 Hereford cows to estimate the gross (presumably uncorrected) correlations between dam's daily milk production, and the A.D.G. of their calves gave $r = 0.60$ (first month); $r = 0.71$ (second month); $r = 0.52$ (third month); $r = 0.35$ (fourth month). Both these latter trials lend support to Neville's (1962), statement concerning the diminishing value of milk after 60 days. Furr and Nelson, (1964) worked with fall-calving Hereford calves fed different levels of winter supplement. The group getting the low level was fed 1.23 to 1.27 kg cottonseed meal/day. The high level group was fed 0.82 to 1.18 kg of cottonseed meal/day, plus 1.72 to 2.18 kg of ground milo. Table 1.8 shows the average daily gains of the calf, average dam milk yields, and the correlation coefficient for each month. Both groups exhibit a diminishing strength of correlation as the season progressed. The degree of correlation, and the significance of it show some tendency to be affected by the level of winter supplement.

Montsma (1960), working with Zebu type cattle in Ghana found a very high correlation of $r = 0.96$ between milk yield and calf A.D.G. at eight weeks of age. The author considered that this was due to

Table 1.8 The average daily gain (A.D.G.) of calves and the milk yield of their dams and the correlations between them.

Furr and Nelson (1962)

Date	<u>Low Winter Supplement</u>			<u>High Winter Supplement</u>		
	A.D.G. (kg)	Milk Yield (kg)	r	A.D.G. (kg)	Milk Yield (kg)	r
30 Jan. - 11 Mar.	0.19	2.03	0.84**	0.29	2.69	0.41
11 Mar. - 14 April	0.14	1.89	0.38	0.25	2.97	0.65**
14 April - 20 May	0.72	2.93	0.80**	0.72	3.31	0.73**
20 May - 25 June	0.88	3.36	0.59**	0.95	3.28	0.13
25 June - 9 July	0.80	3.10	0.45*	0.95	2.79	0.17
9 July - 22 July	0.73	2.66	0.81**	0.57	2.88	0.85**

* P < 0.05

** P < 0.01

a relatively low milk yield of the dam resulting in a sub-maximal growth rate for the calves. However it would seem more likely that an environmental component was acting as well to reduce the values of both variables. It is known that high ambient temperatures reduce animal intake, and this could well be a factor operating in this case. This comment applies to all milk determinations by W.N.W. in a tropical environment.

Neville (1962), reported that as nutrition and milk production of the dam improved there was a lower correlation between milk production of the dam and 240-day weight of the calf. Using 135 Hereford cow-calf pairs he calculated for $N_1 < N_2 < N_3$ $r = 0.90, 0.83, 0.69$ respectively. This is supported by Lampkin and Lampkin (1960), working with Zebu cattle in Kenya, who found whereas on average over the three years of the trial 8.7 and 9.7 kg of milk consumed by male and female calves respectively in the first 12 week period were accompanied by 1 kg of growth, the regressions showed that 18.0 and 19.9 kg respectively would have been required to produce an extra kilogram of growth within the limitations of the grass available at any given time.

Drewry and Hazel (1966), calculated the correlation between dam's milk yield and 205-day calf weaning weight to be less when the calves were creep fed. The fact that the calves were creep

fed almost certainly means that the dams were restricted in their feeding, thereby lowering milk yields, thus forcing calves to become more independent.

Breed Considerations

Willham (1972) cites the average milk yield for the British beef breeds (Angus, Hereford and Shorthorn) to be 2.8 kg/day. However this would seem to be much lower than that generally given. Schwulst (1969) gives figures of 6.9 kg Angus, 6.4 kg Hereford, 6.9 kg Shorthorn. Klett et al. (1965) found averages to be 3.90 kg and 2.92 kg for Angus and Hereford respectively. These estimates would probably be further in error due to only one W.N.W. determination following separation. Gifford (1949), found the Angus and Shorthorn breeds to be better milkers than the Hereford, and this appears to be true generally.

Abadia and Brinks (1972) working with 68 Hereford heifers which had their calves weaned soon after birth, and were then milked twice daily by machine until the 150th day of lactation found these animals gave an average total milk yield of 379.2 kg over 93 days: butterfat % was 3.8; solids-not-fat % 8.7. Average milk production increased from 39.9 kg during the first 14-day period to 49.9 kg in the second and third, gradually declining to 11.8 kg in the eighth 14-day period.

Dawson et al. (1960) determined the milk yield of 30 Beef Shorthorns aged between 2.5 and 7 years by W.N.W. The average for 245 days was 1875 kg. Cows reached the peak of lactation at the end of the second month at an average of 10.2 kg/day.

Deutscher et al. (1970) compared 31 Angus-Friesian crossbred heifers with 41 Angus heifers for milk production by W.N.W. Crossbred cows produced 8.2 kg/day compared to 4.1 kg/day for the Angus cows ($P < 0.05$). Work by Plum and Harris (1971) using 42 Holstein cows under beef management showed that these animals had a potential to produce 14 kg of milk daily for four months.

Walker and Pos (1963) measured the average 180-day milk production of Angus, Hereford x Angus and Angus x Jersey two year-old heifers to be 972 kg, 1040 kg, 1404 kg, respectively, with respective ranges of 810-1134 kg, 744-1353 kg, 1112-1674 kg. These figures were determined by W.N.W., but with two sucklings each day at 5am. and 3.30pm. Calves were permanently separated from their dams between these times. It should be noted that these animals were grazed under much better conditions than would be considered normal in New Zealand for beef breeding cows.

The Lactation Curve

Gifford (1949) working with Angus, Hereford, and Shorthorns, and Dawson et al. (1960) using Beef Shorthorns, found the peak of the lactation curve to occur at the end of the second month of lactation. Gifford (1953), using Herefords and Montsma (1960) studying Zebu type cows in the tropics found the peak of lactation to occur in the first month after calving. Gifford (1953) quoted evidence to show that the peak of production for milk yield in dairy cows generally comes within the first month after calving. Johansson and Rendel (1968), and McDonald et al. (1966) place the peak of production for lactation within the first 45 days of calving in the dairy breeds. Thus the evidence supports the hypothesis first formulated by Gifford (1953), and later supported by Klett et al. (1965) using 15 Angus and 15 Hereford cows milked by a machine, that the lactation curves of beef cows differ from those of dairy cows. The latter authors consider beef cows to be more flexible in their milk production in response to changing feed conditions. However Lampkin and Lampkin (1960) studying Zebu cows in the harsh conditions of Kenya disagree on this point. Their evidence showed that milk yield in Zebus was relatively insensitive to changes in the environment. Cows tended to put on weight, rather than increase milk production.

It would be interesting in this connection to know what part winter nutrition plays in influencing the shape of the lactation

curve. Current thinking in the dairy field places importance upon the wintering policy in the determination of milk yield of the cows. A similar relationship may exist for beef cows.

Gifford (1949) pointed out that the maximum milk production normally measured during the first six weeks of lactation is considerably influenced by the capacity of the young calf to consume milk. Thus determination of the lactation peak by W.N.W., may be considerably biased, with the lactation peak actually occurring earlier than shown.

In most studies of the lactation curve of beef cows milk yields are reported as averages (commonly monthly averages). Yet whenever individual values are reported there appears to be a large amount of variation for this trait. Klett et al. (1965), found a range from 0.34 kg to 7.14 kg per milking (with a machine) for 30 cows. Jeffery and Berg (1970) using 277 cows of Hereford, Angus, Galloway and their crosses, obtained a variation in the mean 24-hour milk yield of 3.8 kg to 6.1 kg/day. Mason (1963) using 15 Angus, and 15 Hereford cows found production to lie between 1.01 kg to 7.08 kg per milking for Angus, and 0.33 to 5.17 kg per milking for Herefords, Dawson et al. (1960) found that the range at the end of the second month of lactation for 30 Beef Shorthorn cows aged from two-and-a-half to seven years was 5.58 kg to 15.98 kg, and for the same animals in the last month of lactation (245 days) the range was 2.7 kg to 10.8 kg/milking. Gleddie and Berg (1968)

working with 42 cows of mixed breeding found that the estimated calf consumption (uncorrected) for June ranged from 2.7 kg to 13.2 kg/24 hours. Caldwell et al. (1962), quoted a coefficient of variation of 25-35% for the milk yields of Angus, Herefords, and Shorthorns.

This large variation within cows occurring for milk yield data makes simple monthly averages of milk production of rather questionable value, particularly when small numbers of animals are used, and especially so when no correction of data for variables known to effect milk yield (see later) has been carried out.

The curves in Fig. 1.1 have been drawn from data published by the various authors cited, situated at different locations. They emphasise the apparent flexibility, and seasonal dependence of the lactation curve of beef cows. This flexibility, and the ability to recover milk production upon an improvement in feed conditions is a very important trait in beef cattle and will be discussed below.

Nutrition and Milk Yield

Wilson et al. (1969) found energy level to significantly ($P < 0.01$) influence the 12-hour milk yield for 24 Angus - Friesian cross cows. Sink et al. (1973) ran 24 Angus-Friesian cross cows at two ration levels, one at 85%, and the other at 115% of N.R.C.

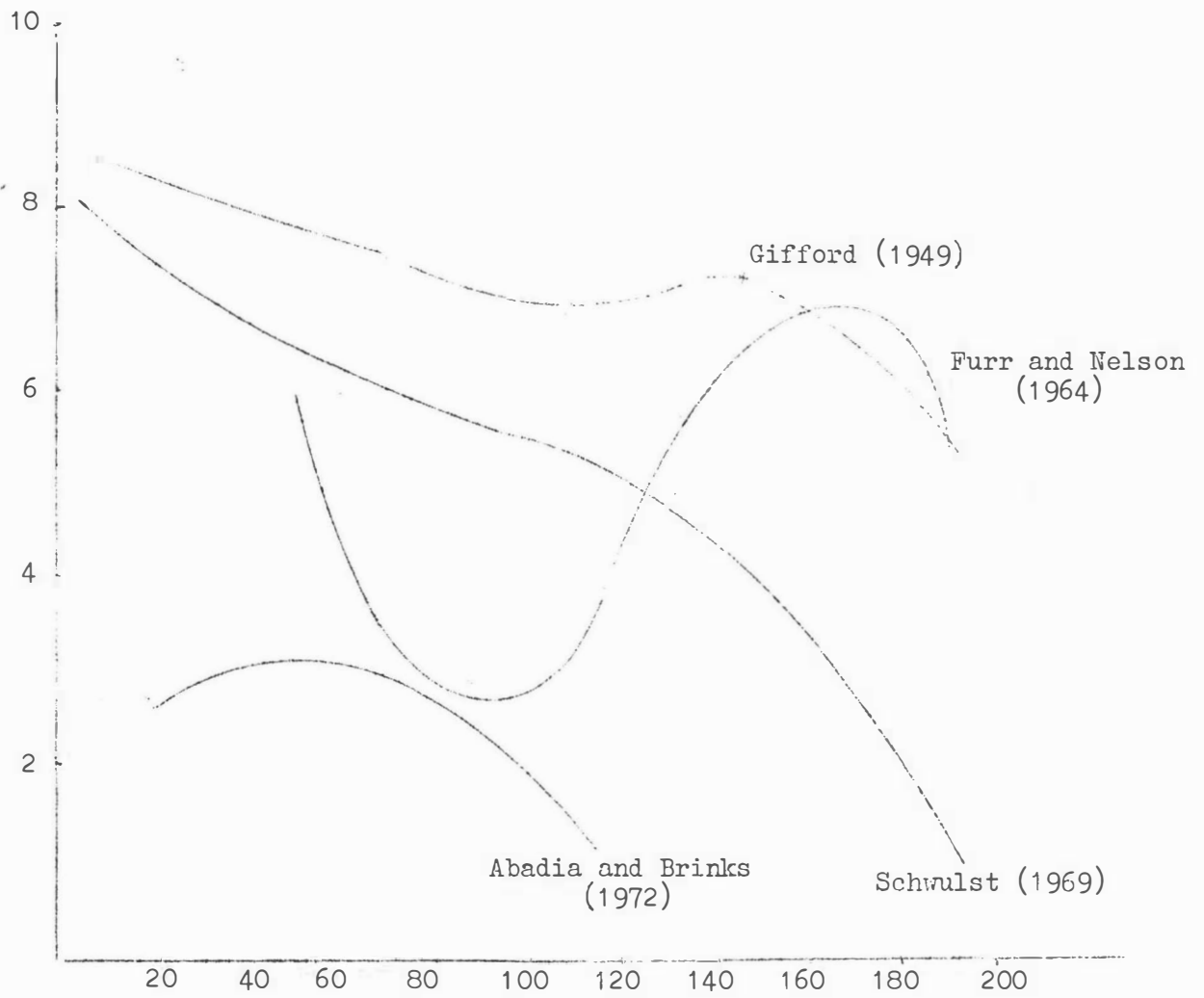


Figure 3.2 Beef cow lactation curves as reported by various workers.

requirements. The 24-hour milk yield was 4.0 kg for 85%, and 5.4 kg, for 115%. Harris et al. (1965) put 20 Hereford cows and 10 bred Hereford heifers, calving in the fall onto two planes of winter nutrition. The high level group had pasture plus hay, plus 0.9 kg cottonseed meal. The low level group was confined to drylot, with poor quality (undefined) hay, block salt, and water. The trial was conducted over a period of six years. The average daily hay consumption of the high plane group was 8.2 kg, compared with 10.9 kg for the low plane group. Average weight losses in the winter were 30.2 kg for the high plane cows and 58.1 kg for the low plane group. The low plane cows were found to secrete less milk when on the drylot, but when both groups moved onto lush spring pasture, they produced more milk than did the high plane cows. However the average adjusted calf weaning weight was still 14 kg less for the low plane cows.

Furr and Nelson (1964) fed fall-calving Hereford cows different levels of supplemental winter feed on native grass pasture. A second group was held in a drylot and fed prairie hay as roughage. The two groups were further divided into high and low ration levels. The milk yield of each group is presented in Table 1.8. The higher initial milk yield of those cows receiving the high plane of winter nutrition is obvious. But comparisons are less definite at the latter part of the cycle.

Schake et al. (1966) experimenting with mature Hereford cows confined them between three and four months pre-partum, and fed a silage-grain ration at 100%, 130% and 70% of their non-pregnant body maintenance requirement. At calving, the 70% and 130% levels were interchanged. Two consecutive 12-hour milkings were added to give a 24-hour milk yield using W.N.W. The milk yields each month are presented in Table 1.9. The drop in milk yields in May and the marked recovery in April can be clearly seen. This was due to changing pasture conditions. It would seem that milk yield is more dependent upon immediate energy rations, than upon energy stores. The effect of a more favoured wintering treatment on milk yield does not appear to have any significant influence beyond the first six weeks.

Hughes (1972) working with 60 Hereford heifers placed on low, moderate, high, and very high (all undefined) levels of winter nutrition, found the least squares means for high and moderate levels were largest for milk production. Milk production for the low cows were lowest with the very high cows intermediate in the first year of the trial. However, the production of the low plane cows increased faster than that of the very high plane cows in succeeding years, implying that some mechanism for adaptation was operating. Further evidence of this nature was provided by Pinney et al. (1962) who studied the lifetime production of 120 beef cows divided into three groups for wintering. Group I was fed 0.45 kg

Table 1.9 The milk yield (kg), of beef cows on different levels of feeding.

Schake et al. (1966)

Feed Level %	<u>Milk Yield (kg)</u>				
	April	May	June	July	August
100-100	4.58	3.14	4.00	3.18	3.68
70-130	4.26	3.76	4.60	2.95	3.73
130-70	4.90	3.81	3.86	2.63	3.05

cottenseed meal; Group II got 1.13 kg cottenseed meal; Group III was given 1.13 kg cottenseed meal, plus 1.35 kg of oats. The weaning weights of the calves during the 'lifetime', trial were unaffected by the winter treatment.

Neville (1971) fed 30 Hereford cows three levels of energy to give liveweight gains of -0.59 kg/day, +0.19 kg/day, and +0.77 kg/day. The trial began five weeks after parturition, which was likely to be about the time of peak milk production for the animals. He found daily 4% fat corrected milk (F.C.M.) to be unaffected by the energy level.

Besides research into energy levels, the level of protein required in the diet and its effects on milk yield of the beef cow have attracted some interest. Work in this field is difficult because protein may be catabolised, for energy. Thus it is difficult to know whether or not the results simply reflect the increased energy available rather than the protein per se.

Bond et al. (1964) divided 54 Angus heifers on a drylot into nine equal groups. The heifers averaged 176 kg. Three levels of energy were fed -high, medium and low. At each energy level, protein was fed at three levels, high, medium and low. The animals were kept on these rations until 180 days after their first calving then fed a high roughage ration ad. lib. until they were with their third calf. Milk yield was estimated by W.N.W. for a

a 12-hour separation weekly for 150 days. Results are presented in Table 1.10,

These results appear to favour restricting the energy levels of beef heifers in the winter they are carrying their first calf. High energy levels show a tendency to reduce milk yield, which may be due to the deposition of fat amongst mammary gland tissue. High protein gives much the same effect, and may have been catabolised for energy purposes. Of interest is the depressing effect of the low protein diet carried through into the second year. However, this trial was carried out with heifers which would still be growing when carrying and suckling their first calf. Thus a protein restriction could interfere with the structure or function of the mammary gland.

Harris et al. (1962) working with two groups of Hereford females of 30 and 25 animals each, assigned them to either of two winter feeding levels. One group was given its ration while on good pasture, and the other group was fed on a drylot and had no protein supplement. The daily F.C.M. was 4.1 kg for the pasture group, and 2.7 kg for the drylot group. Again protein effects were confounded with energy effects.

Gorden and Forbes (1970) gave eight lactating dairy cows rations to supply 80% or 120% of estimated energy requirements, and 80% or 120% of estimated protein requirements. The energy

Table 1.10 The milk yield (kg), for beef cows fed at different levels of energy and protein.

Bond et al. (1964)

Parity	<u>Milk Yield</u> (kg)					
	<u>Energy Level</u>			<u>Protein Level</u>		
	Low	Medium	High	Low	Medium	High
First calf	3.4	6.7	6.6	4.6	6.3	5.8
Second calf	8.6	8.0	7.5	7.3	8.6	8.2

intake significantly affected milk yield energy output, fat %, SNF %, and non-protein nitrogen (N.P.N.). Intake of protein significantly affected milk energy output, and N.P.N. content. This higher level of energy in the milk was probably due to an increased protein fraction. This could have significance for the growth rate of the calf. Gordon and Forbes (1970), noted that it was evident that the effect of each of these factors on milk yield or composition was dependent on the other. There was a greater partitioning of additional energy toward milk energy with the larger allowance of protein.

Protein and its interrelationships with energy in affecting the milk yield of beef cows appear to be poorly understood. Much of the difficulty lies in the confounding of protein and energy in their effects. A useful avenue of research in applied beef production would be to determine the effects of increasing protein levels in the dam's milk upon the performance of the calf. This would be of particular interest in the drylot production of beef calves.

Milk Constituents and Calf Performance

Relatively little examination has been made of the effect of milk constituents upon calf weight gain. Firestone (1969), working in the field of Dairy Science with eight Friesian cows showed that the fat % in the milk could be significantly lowered

by feeding less fibrous feed, while the milk yield did not differ. Walker and Elliot (1969), also using Friesian cows, gave the animals a diet (unspecified) to reduce the fat content of the milk starting five to seven weeks before calving. Treatment continued after calving. The intake of dry matter was significantly lower, and milk fat content steadily declined for the first six to eight weeks of lactation.

Sink et al. (1973) using 24 Angus-Friesian cross cows, and their calves fed at two ration levels 85% and 115% of N.R.C. (1956) requirements, found that although the 85% ration produced 1.4 kg less milk the butterfat % and S.N.F. % were not affected by the drop in energy intake. Schake et al. (1966) worked with mature Hereford cows in the trial described earlier where the animals were fed at 100 %, 130%, 70% of non-pregnant body maintenance. The 130% and 70% levels were interchanged at calving. Again the fat % was unaffected, 70-130% giving 1.43 % and 130-70% giving 1.41%. Similarly for the S.N.F. 70-130% 8.53 and 130-70% 8.28. Results appeared to be better when the nutrition levels were kept constant: butterfat % 1.78; solids-not-fat % 8.84.

Christian et al. (1965) reported a correlation between calf A.D.G. and butterfat % of $r = 0.44$ for the period 0 to 60 days, and $r = 0.32$ for the period 60 to 240 days. Melton et al. (1967) found a correlation of $r = 0.31$ between calf gain and butterfat yield. However, butterfat yield is closely related to milk yield.

When Melton et al. (1967) related calf gains to butterfat % and S.N.F. %, they found the correlations to be near zero. Gleddie and Berg (1968), found the percentage variation in calf A.D.G. was accounted for by percentage protein.

An interesting result was reported by Mason (1963) for 15 Angus and 15 Hereford cows which showed that the variation in S.N.F. was approximately 50% more important in the weight gain of the calves than were variations in butterfat. However the results may have been spurious since 20 Angus calves which were bucket fed showed butterfat and S.N.F. to be of equal importance. It is likely that one constituent would be of overriding importance only if the level of that constituent was directly limiting to growth.

Vitamin A concentration in the milk of cows may be of some importance in contributing to the disease resistance, and general health of the calf. Ferrando et al. (1969) reported that vitamin A content of cow's colostrum fell from between 412 and 860 I.U. in the first lactation to between 191 and 481 I.U. in the third or fourth. The authors considered that the first calves resisted infection and survived better than latter calves of the same cow. Cvetkovic' (1966), found a negative correlation between vitamin A concentration in the cow's serum and calf death rate.

Sunclaresan et al. (1967) found cold treated rats to require at least 20 times more retinoic acid than their controls to maintain growth and survival.

Baker et al. (1954) noted that the mobilisation of stored vitamin A and carotene by lactating beef cows which occurs on a low plane of carotene intake was inadequate to provide sufficient vitamin A in the milk for their calves. The vitamin A, and to a lesser extent the carotene content of the milk seemed much more closely related to the dietary carotene intake during lactation than to differential liver stores resulting from various levels of carotene intake pre-partum. The authors found that supplementation with 300 mg of carotene per cow daily resulted in normal milk. McGillivray (1957), considered that the bulk of vitamin A was derived from the diet, but also stated that irrespective of immediate carotene or vitamin A intake of the animals, or of their liver reserves, some of the milk-fat vitamin A ester is derived from vitamin A of other than immediate dietary origin.

Work by Thompson and McGillivray (1957), with four cows, and six heifers of Jersey origin established that there is a large decrease in plasma vitamin A concentration at or near parturition. This is despite a high intake prior to calving. They suggested that this was due to the extra drain of colostrum synthesis.

Harris et al. (1965) found vitamin A levels to be less in cows restricted in their winter ration.

The evidence indicates that vitamin A deserves more consideration than it has been given in beef cattle research, particularly where the level, and type of winter feeding in a drylot is concerned. If the vitamin A level of the diet is low, then there appears to be a need to increase it during the period of colostrum synthesis to safeguard the health of the calf.

The Efficiency of Milk Conversion to Liveweight Gain

Melton et al. (1967) compared the Angus, Charolais, and Hereford breeds using 15 animals in each breed, and found that the amount of milk required to produce 1 kg of calf gain was 12.5 kg, 11.4 kg, 10.3 kg for Angus, Charolais and Hereford cattle. Montsma (1960) in Ghana with Zebu-type cattle found conversion rates to vary with the stage of lactation. At eight weeks it took 11 to 13 kg of milk/kg A.D.G.; at 13 weeks 10 kg to 14 kg/kg A.D.G.; at 26 weeks 15 kg 18 kg/kg A.D.G.

Neville (1962), using 135 calves born to 61 dams during the period 1957-1959 placed three groups of these onto three nutritional treatments until they were four months old ($N_1 < N_2 < N_3$). Under N_2 and N_3 it took 5.6 kg of milk to produce 1 kg of calf gain, but under N_1 it took 10.6 kg of milk fat for 1 kg of calf gain. It is known that as intake increases digestibility drops, but this

would mean a very large drop in digestibility indeed. Preston and Willis (1971), consider this result unacceptably large, and suspect faulty methodology.

Barton (1971) reviewing the subject noted that large differences have occurred between the results of various workers for this trait. He argues that this may be due to the different methods employed to determine milk yield, or be affected by such factors as the stage of lactation, whether the milk was the sole diet, the nature of the dam's diet, the composition of the milk, the breed of the cow and calf, and possibly the sex of the calf.

Although the conversion of food to milk by the cow and its utilisation by the growing calf cannot be considered an efficient process of producing weight gain, Willham (1972) reviewing beef cow milk production and efficiency, made the point that it may be much more efficient than generally believed if the possible use by the cow of low quality forage which is not utilisable by the calf is considered.

Age of Dam Effects

Rutledge et al. (1971) using 279 cow-calf pairs, with the cows aged 2 to 15 years, measured milk yield once each month by the W.N.W. method and found that the age of dam had a quadratic effect on milk yield with a maximum occurring at 8.4 years. Neville

(1971), working with 30 Hereford cows of ages, two, three, four, six, and twelve years with six in each age class, reported a steady increase in 4% F.C.M. five weeks after parturition when the experiment was conducted, due to the age of dam effect. This was significant at all ages, except between years three and four. The highest production occurred at 11 years, and was thought to be largely due to culling of poorer producers at younger ages.

Reynolds et al. (1967) found three-year-old Angus cows gave 3.1 kg, compared to 3.8 kg for four-year-old cows using W.N.W. after the calves had been separated from the cows for 16 hours. Dickey (1972) also obtained a significant ($P < 0.01$) effect of cow age on milk yield.

Melton et al. (1967) working with 15 Angus, 15 Charolais and 15 Herefords aged between two and ten years determined milk yield by W.N.W. using the average of two, 12-hour separation intervals. Two-year-old dams gave a milk yield of 553 kg; three- and four-year-old dams gave 667 kg. Five-year-old dams and over, gave 809 kg.

An interesting observation was made by Christian et al. (1965) working with identical and fraternal Hereford heifers held in a drylot. Milk production was measured by hand-milking two udder sections, while the calfnursed the other two, after a $15\frac{1}{2}$ -hour separation interval. In this study, although the three and four-year-old dams produced more milk than did the two-year-old dams,

the latter were more persistent in their production yielding 4.7% more of their total milk during the period 60 to 240 days post partum.

Neville (1962) calculated that age of dam effects on weaning weight were not important, or significant, when weaning weights were adjusted for variation in dam weight and milk production. Similarly Rutledge et al. (1971) reported that the age of dam did not contribute to the variation in weaning weight beyond its influence, through corrected variables - dam weight, calf birth weight, and dam's milk yield.

The Sex of the Calf

The literature remains confusing on the subject of the influence of the sex of the calf on its dam's milk production. Melton et al. (1967) using 45 cows (15 of each of the Angus, Charolais, and Hereford breeds) found that those cows nursing bull calves gave 0.58 kg/day more milk than those nursing heifer calves. However, the position was reversed in the work of Rutledge et al. (1971), who reported from the results of 279 cow-calf pairs that dams nursing females produced significantly more milk. Carpenter (1972), Jeffery et al. (1971), Dickey et al. (1971), Gleddie and Berg (1968) all found the sex of the calf to be inconsistent, and not significant in its effect on the milk yield of the dam.

Hughes (1972) used 60 Hereford cows in an investigation into winter nutrition levels over a period of several years. Cows nursing males produced more milk between 1961 to 1963, but from 1965-1967 the position was reversed (all cows were of the same age). Cow milk yield increased up to 1963, so the results strongly suggest the presence of a sex x cow age interaction operating with the male sex being the more dominant at the lower milk yields.

A point worthy of consideration in this context concerns the earlier discussion regarding the large amount of variation between individual cows for milk yield. With the small numbers of animals common in milk-yield studies, any sex effect could easily be masked.

Cartwright and Carpenter, (1961) working with 145 Hereford cows nursing Hereford or crossbred calves, obtained results which led them to believe that milk production may be affected not only by the genotype of the dam, but also by the genotype of the calf. This means the sire may have an influence, and sire x sex interactions may also be important in milk production.

is not nearly maximal. To increase weaning weight through excess fat deposition by more milk than can be used for lean tissue growth destroys efficiency in the feedlot when cattle are fed to a target slaughter weight.

However, Willham (1972) also states that it may be harder to alter a weak start through lack of adequate milk than is generally thought. This may be especially true when animals are grown (post-weaning) and finished on pasture. Bailey and Bishop (1972) weaned autumn-born Hereford calves at four, six and eight months. The liveweights of the calves the following autumn were respectively, 225 kg, 253 kg, 271 kg. The evidence of Harris et al. (1965) described under 'nutrition' lends further support to the importance of good milk production early in the life of the calf.

Of great practical significance in beef production systems operating under a variable feeding regime such as pasture grazing, is the degree of flexibility of the lactation curve, or the ability to recover milk production after a period of low energy consumption. Beyond the fact that this occurs, and seems to operate before the peak of lactation, little is known about it. Much more information is needed, particularly how the drop in production affects the performance of the calf, not only at weaning but also in post-weaning traits, in the light of Willham's (1972) comments.

MATERIALS AND METHODS

Husbandry

This experiment has been carried out over three complete years (1970/71, 1971/72, 1972/73), and is continuing into a fourth year (1973/74).

Two herds of Angus cows are involved. One herd of cows designated the Stud herd was originally the Massey University stud Angus herd. It is comprised of cows aged from three to ten-years-of-age. Cows are mated to calve first at three-years-of-age. Replacements were added to the trial in 1971 and 1972. Cows older than ten-years-of-age, or those showing signs of age, were removed from the trial. The cows in the other herd designated as the Commercial herd were purchased as 14-month heifers. Twenty-five of these were mated to calves as two-year-olds. The remainder calved as three-year-olds. All cows in this herd are of the same age. No replacements were entered during the experiment.

For experimental purposes both herds were run together as a unit. A distinction was only made for the mathematical analysis.

Approximately three weeks before they were due to begin calving the cows were assigned (see experimental design) to either the hill pasture or to the sawdust confinement pad. About 80 days later the

cows were removed from the pad and all animals were grazed together on the hill until the next winter. The time cows spent on the pad varied between years according to the onset of the spring pasture growth (Table 2.1). In 1970 the cows were removed prematurely from the pad owing to bad weather which caused the pad to break down and become a quagmire.

The pad consisted of two separate yards packed with sawdust. Feed could be placed in racks which ran along one side of the pens. A concrete feeding apron was situated between the sawdust and the feeding racks. This apron was scraped off weekly with a tractor and blade. Protective railings were installed to provide an area in each pad where the calves could rest free of movement by the cows. The whole pad was protected from the prevailing wind by a stand of Toetoe planted along the southerly side.

The bottom rail of the yards was removed so that the calves were able to get out and creep-feed on the adjoining pasture. In this respect access was often easier for the calves on pad I than for the calves on pad II due to the deposition of a mound of pad 'scrappings' at the exit to pad II. This inhibited the passage of the calves between their dams and the pasture. In September 1973 a load of metal was dumped on this site and this removed the impediment to the movement of the calves.

Each calf was weighed within 24 hours of birth, and a numbered ear-tag clipped into its ear. Weights were taken using a sling and

a clock-face scales both of which were supported from an iron bar. The bar could be lifted by one or two men.

In 1970 cows remained on the pad throughout the winter. In 1971, the cows on pad II were taken off the pad one day a week and grazed on nitrogen top-dressed pasture. Pad I cows remained on the pad throughout the winter. In 1972 cows were removed from the pad for up to three days after calving. They were then returned to the pad. Some of these cows went out onto pasture while others remained within a holding yard. In an effort to stop thieving of colostrum from young calves due to a tendency to multiple suckling by the older calves, and also in an attempt to ensure that there were adequate vitamin A levels in the milk, the cows were turned out onto pasture for four days after calving.

During the first winter of the trial (1970) some experimentation was needed to determine suitable feeding levels. Bales of hay weighing 27.5 kg and bales of barley straw weighing 28.8 kg were fed. From 16 July 1970 to 1 August 1970 three bales of hay and three bales of barley straw were placed in the racks of each pad. This was insufficient supplement so from 1 August 1970 to 8 August 1970 four bales of hay and four bales of barley straw were offered to the cows. Further supplementation was obviously needed so from 8 August 1970 to 12 August 1970 five bales of hay and four bales of barley straw were provided. From 12 August to the end of the winter the

ration was increased to six bales of hay and four bales of barley straw.

Over the winters 1971, 1972, 1973, barley meal was added to the ration. For these years the animals received a constant ration of 4.3 kg of hay, 2.3 kg of barley straw and 0.6 kg of barley meal per animal per day.

The cows which were wintered on the hill received no supplement. They had only what they were able to obtain from the pasture.

The Experimental Design 1970 to 1972/73

In the winter of 1970 cows were assigned to either the pad or to the hill pasture by using a set of random numbers which were matched with the numbered ear tags of the cows. The numbers of cows entering the pad, or being turned out on the hill each winter are shown in Table 1.1.

In 1971 a switchover design was adopted by randomly allocating cows which had wintered on the pad during 1970 between the pad and the hill, and similarly dividing those cows which had wintered on the hill. Previous winter treatment was taken into account in the statistical analysis, thus four distinct treatments were recognised for 1971/72 (Table 2.1).

Further switching of the cows between treatments was carried out in 1972 to produce the treatment combinations outlined in Fig. 2.1.

Table 2.1 The number of cows on each treatment in each year of the trial.

STUD HERD

<u>1970</u>		<u>1971</u>		<u>1972</u>		<u>1973</u>	
Treatment	Number of Animals	Treatment	Number of Animals	Treatment	Number of Animals	Treatment	Number of Animals
Pad	20	Pad-Pad	9	Pad-Pad-Pad I	5	Pad-Pad-Pad I	5
Hill	26	Pad-Hill	13	Pad-Pad-Pad II	5	Pad-Pad-Pad II	5
		Hill-Pad	12	Pad-Hill-Pad I	4	Pad-Hill-Pad I	9
		Hill-Hill	16	Pad-Hill-Pad II	5	Hill-Pad-Hill	11
				Hill-Pad-Hill	11	Hill-Hill-Hill	18
				Pad-Hill-Hill	3	Hill-Hill-Hill	15
				Hill-Hill-Hill	15		

COMMERCIAL HERD

<u>1970</u>		<u>1971</u>		<u>1972</u>		<u>1973</u>	
Treatment	Number of Animals	Treatment	Number of Animals	Treatment	Number of Animals	Treatment	Number of Animals
Pad	12	Pad-Pad	9	Pad-Pad-Pad I	5	Pad-Pad-Pad I	5
Pad	19	Pad-Hill	22	Pad-Pad-Pad II	3	Pad-Pad-Pad II	3
Hill	14	Hill-Pad	17	Pad-Hill-Pad I	6	Pad-Hill-Pad I	16
Hill	20	Hill-Hill	17	Pad-Hill-Pad II	10	Pad-Hill-Pad II	6
				Pad-Hill-Hill	6	Hill-Pad-Hill	16
				Hill-Pad-Hill	17	Hill-Hill-Hill	6
				Hill-Hill-Hill	17	Hill-Pad-Hill-Pad I	16
						Hill-Pad-Hill-Pad II	16
						Hill-Hill-Hill	17

NOTE: I refers to those animals on pad I which were fed every day.

II refers to those animals on pad II which were fed every second day.

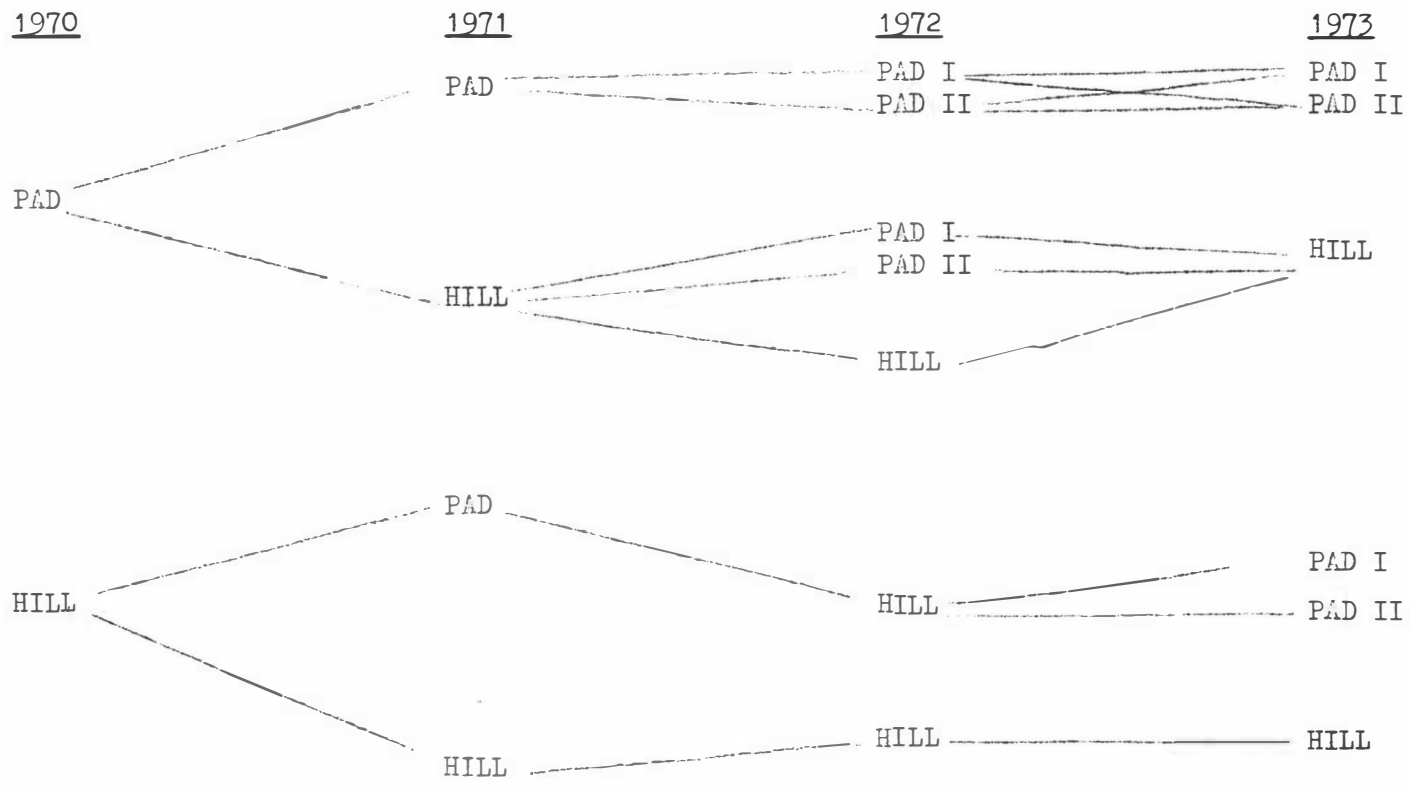


Figure 2.1 Treatments Imposed Each Year.

Extra investigation was carried out over 1972/73 to determine whether there was any affect on the cows or the calves which were confined to the pad which was due to feeding out a double ration every second day. If feasible such a technique would reduce labour costs in a commercial operation. In order to study this the cows on pad I were fed normally every morning, while the cows on pad II were fed only every second morning, but fed a double ration.

Occasionally cows were removed from the pad due to sickness. In these instances they were not included in the analysis for that year.

Two sets of twins were born during the trial. Their weights were added, and the data analysed as if their dams had produced a single calf weighing the sum of the twin pairs.

The Experimental Design 1973/74

Analysis of the data from the previous three years showed no significant differences for calf traits due to the previous wintering treatments of the dam. Thus no further analysis of previous wintering treatments on calf traits was undertaken. Since the data on the performance of the cow remain to be analysed, but because further complex switching would have been impractical with the numbers of cows available, the procedure outlined in Table 2.1 was adopted. Basically those cows which had been switched in 1972 were switched again, while the others were wintered as they were in 1972.

Preliminary analysis of the data from the earlier three years indicated that valuable information could be obtained by closely monitoring the liveweight gains of the calves and their dams. Accordingly the calves and cows were weighed at three-weekly intervals.

Biometrical Analyses

All models were linear fixed effects models.

1. Birth Weight, Weaning Weight, Milk Consumption, Calving Interval

(a) Stud herd

$$Y_{ijkl} = \bar{Y} + t_i + S_j + a_k + b_{ijk} (x_m - \bar{x}) + e_{ijkl}$$

where

Y_{ijkl} the l^{th} observation of the k^{th} age of the j^{th} sex of the i^{th} treatment

\bar{Y} . Is a general mean

$b(x - \bar{x})$ is the covariate. b is the regression coefficient of time of birth of the calf (x) on the weight, of the calf, milk consumption of calf or calving interval of the dam.

(b) Commercial herd

$$Y_{ijpl} = \bar{Y} + t_i + S_j + C_p + b_{ijp} (x_m - \bar{x}) + e_{ijpl}$$

where

Y_{ijpl} is the l^{th} observation of the p^{th} parity order of the j^{th} sex of the i^{th} treatment.

\bar{Y} is a general mean.

2. Winter Liveweight Change of the Cow

Data were available for the Commercial herd only but no data were available for 1972. The liveweight of the cows on their removal from the pad was analysed.

$$Y_{ijkl} = \bar{Y} + t_i + S_j + C_p + b_{ijp}(x_m - \bar{x}) + d_{ijp}(z_m - \bar{z}) + e_{ijpl}$$

where

Y_{ijkl} refers to the l^{th} observation of the p^{th} calving of the j^{th} sex of the i^{th} treatment.

\bar{Y} is a general mean.

b refers to the regression coefficient of time of birth of the (x) calf and cow weight d refers to the regression coefficient of autumn cow liveweight (z) and cow liveweight at the end of the pad treatment.

3. Liveweights of 1973 Calves from 12 September 1973

For Commercial herd only

$$Y_{ijk} = \bar{Y} + t_i + S_j + b_{1ij}(x_m - \bar{x}) + b_{2ij}(x_m^2 - \bar{x}^2) + e_{ijk}$$

where

Y_{ijk} refers to the k^{th} observation of the j^{th} sex of the i^{th} treatment

b_1 is the linear regression coefficient of time of birth of calf (x) on the calf's liveweight.

b_2 is the quadratic regression coefficient of time of birth of the calf on the calf's liveweight.

These models may be stated in matrix terms as

$$y = X B + e$$

where

y is an $N \times 1$ vector of observations

X is a known fixed $N \times p$ matrix

B is an unknown fixed $p \times 1$ vector

e is an $N \times 1$ vector having a multivariate distribution with mean zero, a variance-covariance matrix assumed equal to the identity matrix.

The method of least squares was chosen to estimate the B 's.

B is chosen so that the sum of squares of the deviations of the y 's from their expected values is a minimum.

Since $y = X B + e$

$$e = y - X B$$

and

$$\begin{aligned} e^1 e &= (y - X B)^1 (y - X B) \\ &= \\ &= Y^1 Y - B^1 X^1 y - y^1 X B + B^1 X^1 X B \end{aligned}$$

The order of $Y^1 X B$ is $(1 \times N) (N \times p)(p \times 1) = 1$. Thus $y^1 X B$ is a scalar, and thus will be equal to its transpose

$$\text{i.e., } y^1 X B = B^1 X^1 y$$

Thus

$$e^1 e = y^1 y - 2B^1 X^1 y + B^1 X^1 X B$$

To minimise the square of the errors with respect to B set the first partial derivative equal to zero

$$\frac{d e^1 e}{d B^1} = -2 X^1 y + 2 X^1 X B$$

And the minimum

$$2X^1 X B - 2X^1 y = 0$$

$$X^1 X B = X^1 y$$

∴

$$B = (X^1 X)^{-1} X^1 y$$

Because the equations making up the $X^1 X$ matrix were not independent the matrix was not of full rank in all the models used. Hence $(X^1 X)^{-1}$ does not exist, so the equations cannot be solved by obtaining the ordinary inverse.

However the equations can be solved by the use of a generalised inverse (Searle, 1966). Given G is a generalised inverse,

$$B^0 \text{ is given as } G X^1 y$$

This is only a solution and not an estimator of B, since a generalised inverse is not unique. Thus the B's are not estimable. However, any linear function of the $E(B^0)$ is estimable, such as differences between treatments.

In the analysis the matrix was made full rank by deleting appropriate rows and columns. Inversion of the reduced matrix gave the generalised inverse.

The reduction in the sum of squares due to fitting the model and the analysis of variance were carried out according to Harvey (1960). Differences between means were tested by Duncan's Multiple Range test.

RESULTS AND DISCUSSION

The Effect of the Sex of the Calf(a) Birth Weight

The least square differences associated with the effect of the calf sex on its birth weight are shown in Table 3.1, for each herd-year. The values are similar to those reported in the literature for Angus calves, particularly where the animals have been wintered outside on pasture (Table 1.2).

Males were consistently heavier than females, although results were only significant ($P < 0.05$), in the years 1972 and 1973 for the Stud herd. The general lack of significance was probably due to low numbers of animals which were used within each herd-year. The year 1971 shows a reduced difference for both herds. Since the male superiority is attributed to both a longer gestation period, and a greater capacity to grow, this infers that either one or both of these parameters were affected. Table 3.25 shows the calving intervals to be similar to other years, which provides some evidence that the gestation periods were unaffected. However the New Zealand Gazette (August - October, 1971) reported the winter of 1971 to be mild in comparison, and thus feed supplies for the

Table 3.1 The least square differences between sexes in each herd-year for the birth weight of the calf.

<u>Herd</u>	<u>Year</u>	<u>Difference (kg)(Male-Female)</u>	<u>Number of Animals</u>
Commercial	1970	+ 1.4	22
Stud	1970	+ 3.1	45
Commercial	1971	+ 0.5	48
Stud	1971	+ 0.1	48
Commercial	1972	+ 1.4	50
Stud	1972	+ 2.8*	47
Commercial	1973	+ 1.0	54
Stud	1973	+ 3.3*	37

* Significant at the 5% level ($P < 0.05$)

cows on the hill should have been above normal. Thus there does not appear to be any simple explanation for these unusual results.

It is interesting to note an apparent trend towards lower sex differences for birth weight which occur in the Commercial herd compared with those that occur in the Stud herd. This indicates that:

1. Male calves in the Stud herd had a longer gestation period than did those in the Commercial herd.
2. There was a less favourable maternal environment in the Commercial herd which reduced the expression of male superiority.
3. There was a sire effect operating.

The lower sex difference was to be expected in 1970 and 1971, when the cows in the Commercial herd were only aged two- and three-years-of-age, respectively. However, the trend does continue into the mature age classes.

Both herds were run together with the same bulls at mating. Nevertheless lack of specific information on the sires, and lack of significance in the results inhibit further speculation on this point.

(b) Weaning Weight

The least square differences between sexes for the linearly adjusted 200-day weaning weight are shown in Table 3.2. Males were heavier than females for all herd-years. Differences are significant at the levels shown in the Table. These differences appear to give more advantage to the male sex than do values reported by other authors (Table 1.5), especially in 1972.

Any disadvantage suffered by the Commercial herd at birth for sex differences compared to the Stud herd appear to have been regained and generally the Commercial herd sex differences for weaning weight are larger than those for the Stud herd in the same year. Again interpretation is not possible without information on the respective sires, but there is a strong possibility that the Commercial cows provided a better maternal environment, probably in the form of better milk production than did the Stud cows. Certainly this should be the case in 1971 when all the Commercial cows were aged four years, whereas the Stud herd included a number of first calving three-year-olds, and older cows.

The unexplained reduction in the sex effect noted for birth weight in 1971, also appeared for weaning weight, in 1971.

Table 3.2 The least square differences between sexes in each herd-year for the weaning weight of the calf (200-day adjusted).

<u>Herd</u>	<u>Year</u>	<u>Difference (kg)(Male-Female)</u>	<u>Number of Animals</u>
Commercial	1970	+ 16.7*	19
Stud	1970	+ 12.3**	44
Commercial	1971	+ 15.1*	42
Stud	1971	+ 9.0 ^a	44
Commercial	1972	+ 23.6**	44
Stud	1972	+ 18.6**	43

^a 0.05 > P > 0.1

* Significant at the 5% level (P < 0.05)

** Significant at the 1% level (P < 0.01)

(c) Milk Production

The least square differences for the effect of sex of calf upon the milk production of the dam are shown in Table 3.3. Estimates were made at two separate times in each of the years 1970 and 1971 for both herds. However, the two values obtained for each herd within each year are not directly comparable since different numbers of animals contributed towards each figure. Thus for the Commercial herd the first estimate taken on 19 September, 1970, showed the male sex to be significantly ($P < 0.05$) dominant in milk consumption. But on 20 October, 1970, the position had altered, and females were consuming significantly ($P < 0.01$) more milk. However, between estimates the population structure of the model had altered, with some animals added and others removed. The net result was more females and less males. Thus the estimates given are of questionable validity. A similar situation occurs for the Stud herd in 1971.

Broadly speaking the male sex appeared to consume more milk in 1970, while the female sex consumed more in 1971. In view of the contrary results published on this subject, the present analysis hints at the possibility of an environmental effect operating, which produced differential milk consumption. Examination of meteorological reports published in the New Zealand Gazette (August to October 1970, 1971) for the late winter and spring of 1970 and 1971 reveal them to be two very different years for climate. From

Table 3.3 The least square differences between sexes for the milk consumption of the calf.

Year	Date	Herd	Difference (kg) (Male - Female)	No. of Animals
1970	17 September	Commercial	+ 1.35*	20
	18 September	Stud	+ 0.72**	42
	20 October	Commercial	- 0.45**	17
	20 October	Stud	+ 0.27**	49
1971	9 September	Commercial	- 0.27	18
	9 September	Stud	- 0.41	32
	28 October	Commercial	- 0.36**	28
	28 October	Stud	- 0.09**	29

* $P < 0.05$

** $P < 0.01$

August to October in 1970 unusually high frequencies of winds were reported, while September was reported to be the windiest and wettest since 1943. Pasture growth was also reported to have suffered. On the other hand, the period from August to October 1971 was characterised by being unusually mild with September being reported as a warm month.

Cold stress is known to cause changes in the metabolism of the ruminant (Hess and Bailey, 1961). Stimulation of the thyroid, pituitary, and adrenal glands occur, and blood electrolytes, notably the potassium and sodium concentrations, shift. It is possible that climatic stress may cause a differential effect on the sexes, the altered metabolism causing a change in appetite, and milk consumption.

The Effect of the Age of the Dam

(a) Birth Weight

The least square means for the effect of the age of the dam on calf birth weight are shown in Table 3.4. Estimates are only possible within each year for the Stud herd, as the Commercial herd comprised cows which were all of the same age, thus confounding age and year effects in this herd.

All estimates are non-significant and they are also erratic. This is probably due to the small numbers of observations, and to

Table 3.4 The least square means for the effect of the age of the dam (years) on the birth weight of the calf (kg).
(Values for the Stud Herd only)

Year	<u>Birth Weight (kg) according to Dam Age (yrs)</u>				Number of Animals
	Three	Four	Five to Seven	Eight to Ten	
1970	23.91	28.67	28.25	28.93	45
1971	26.37	24.35	28.02	27.84	48
1972	21.73	27.33	25.66	25.83	47
1973	not available	27.62	26.48	27.34	37

disproportionate age-class grouping between years, i.e., a grouped age class such as the age five to seven, may contain different proportions of animals of ages five, six, and seven in different years.

Generally the three-year-old dams produced the lightest calves at birth, and this has been the experience of most other workers. Four-year-old cows, that is, those calving for the second time, performed surprisingly well, being the best age class for 1972 and 1973, but results lack significance.

(b) Weaning Weight

The least square means for the effect of the age of the dam on the calf weaning weight are shown in Table 3.5. Results are not significant, although the difference between the four-year-old cows and the three-year-old cows approached the 5 per cent significance level in 1971/72 and 1972/73. Estimates suffer the same disadvantages mentioned above.

The best age class is consistently that of the four-year-old cows. This is peculiar to this series of experiments. At Whatawhata Hight (1966; 1968) reported six-year-old cows to be better producers of calf liveweight at weaning. This provides suspicion in the present study that an age x treatment interaction is acting to inflate values for the four-year-old cows. This requires further investigation.

Table 3.5 The least square differences for the effect of the age of the dam (years) on the weaning weight of the calf (kg).

(Values for the Stud Herd only)

Year	Differences in Weaning Weight (kg) according to Dam Age (years)				Number of Animals
	Three	Four	Five to Seven	Eight to Ten	
1970	+ 1.1	+ 2.4	0	- 0.2	45
1971	- 5.6	+ 14.0	0	- 3.2	48
1972	- 9.5	+ 12.5	0	+ 5.0	47

(c) Milk Consumption of Calves

The least square differences are shown in Table 3.6. Results were not significant for the earlier estimate in both years, but showed significance in the latter estimates. Three-year-old cows show estimates which are consistently below the other age classes, this difference tending to increase in the latter estimates. The older cows in the eight- to ten-year-old age group give the highest estimate in all years except for the latter estimate in 1971. Some of this would be due to culling, but some may also be due to the more docile nature of the older cows during measurement, showing less anxiety and better milk let-down. The particularly good performance of the four-year-old cows is noticeable, and this is to be expected in view of the weaning weight differences discussed above. This difference between the ages becomes more evident when the cows come off the pad, as is apparent from the second estimate of the year.

Milk consumption estimates at 28 October 1971, show the same ranking order for age of cow as do the estimates for weaning weight in 1971/72 for the age of the cow. This is to be expected considering the high correlation established between the milk production of the dam (of which calf consumption is assumed to be a measure), and the growth of the calf. In 1970 however, no such relation appears. This may have been due in large part to lack of randomness in selection of calves which participated in

Table 3.6 The least square differences for the effect of the age of the dam on the amount of milk consumed by the calf.

Month Year	Differences in Calf Milk Consumption (kg) According to Dam Age (yrs)				Numbers of Animals	Significance
	Three Year	Four Year	Five- Seven Year	Eight- Ten Year		
18 Sept., 1970	-0.48	-0.45	-0.09	0	42	N.S.
20 Oct., 1970	-1.02 ^a	-0.03 ^b	-0.09 ^b	0 ^b	49	P < 0.05
9 Sept., 1971	-1.40	-0.40	-0.41	0	27	N.S.
28 Oct., 1971	-1.48 ^a	+1.41 ^b	+0.36 ^{ab}	0 ^{ab}	29	P < 0.01

NOTE: Superscripted values are significantly different from unsuperscripted or differently superscripted values at the levels indicated.

the trial, and to the errors in the measurements. But explanation along these lines does not seem to be fully adequate, and interest attaches to the drought which was experienced from December to February in 1970-71. It is possible however that the different age classes differed in the persistency of their lactation during the dry period. Although it cannot be regarded as anything except the scantiest of evidence, the values shown in Table 3.6 support the suggestion that the youngest dams, noticeably the three-year-olds, may provide a better maternal environment over the drought. Further elucidation of this should be possible when data presently being collected at Massey University are analysed. By comparison 1971-72, although dry over the summer, does not seem to have offered the degree of animal stress as did 1970-71.

The Effect of Previous Calvings

The interest in this case lay within the Commercial herd, and was primarily concerned with comparing those cows which calved as two-year-olds in 1970, with those which calved as three-year-olds in 1971.

(a) Birth Weight

The least square means for the effect of calving history on birth weight are shown in Table 3.7 for the Commercial herd. In 1971, which was the first year the complete herd was calved, the

Table 3.7 The least square differences for the effect of the parity of the dam on the birth weight of the calf.

(Values for Commercial Herd only.)
All same age.

<u>Year</u>	<u>Parity</u>	<u>Difference (kg)</u>	<u>Number of Animals</u>
1971	Calved as two-year-olds in 1970	3.13**	22
	Dry as two-year-olds in 1970	0	
1972	Third calving	0.37	50
	Calved 1970 Dry 1971	3.39	
	First Calving; Dry 1970 and 1971	3.62	
1973	Calved as two-year-olds in 1970	0	54
	Dry as two-year-olds in 1970	0.42	

** P < 0.01

difference between those which had previously calved as two-year-olds in 1970, and those which calved for the first time as three-year-olds in 1971 was 2.8 kg in favour of the former cows. This difference was very highly significant ($P < 0.01$). Lack of records on gestation periods however precludes speculation on the material environment.

In 1972 no significant differences were obtained between cows with different calving histories, although there was some slight tendency for those cows which had been dry the previous season (1971) to produce calves with heavier birth weights.

In 1973 comparison was made only between cows which had calved first at two- and first at three-years-of-age, since further discussion of calving histories would have been impracticable. There was no discernible difference between the two classes in 1973, when the cows would have been five-years-old.

(b) Weaning Weight

The effects (Table 3.8) in all years were non-significant, although in 1971/72 the animals which were calved at two-years-of-age in 1970/71 showed some superiority. However, this was probably due, in large part, to the better start provided by their higher birth weight. In 1972 results show some advantage to the calves of the cows which had remained empty the previous season, although

Table 3.8 The least square differences for the effect the parity of the dam on the weaning weight of the calf.

<u>Year</u>	<u>Parity</u>	<u>Difference (kg)</u>	<u>Number of Animals</u>
1971	Calved as two-year-olds in 1970	+ 7.1	42
	Dry as two-year-olds in 1970	0	
1972	Third Calving	0	44
	Calved 1970, Dry 1971	3.68	
	First Calving, Dry 1970 and 1971	13.44	
	Dry 1970, Calved 1971	3.12	

again this was probably due to the advantage in birth weight just discussed, rather than any improvement in the post-natal maternal environment.

These results show little advantage in keeping cows dry over their second year under hill country conditions, from the point of view of weight of calf weaned. Provided the cows are reasonably well fed, both when they are carrying, and when they are suckling their first calf, this trial indicates that calving Angus heifers at two-years-of-age has no detrimental effect on the cow's ability to produce and feed subsequent calves.

(c) Milk Consumption

The least square differences for the effect of the parity of the cow on her subsequent milk production, as measured by the milk consumption of her calf, are shown in Table 3.9. There is a clear difference in favour of the cows which had calved at two-years-of-age for the latter estimate of 1971. This difference was highly significant.

The Effect of the Wintering Treatment

(a) Birth Weight

All the effects of the treatments on birth weight were non-significant except for the Commercial herd in 1971 where a

Table 3.9 The least square differences for the effect of the parity of the dam on the milk consumption of her calf.

<u>Date</u>	<u>Parity</u>	<u>Difference (kg)</u>	<u>Number of Animals</u>
9 September, 1971	Calved as two-year-old in 1970	+ 0.68	18
	Dry as two-year-old in 1970	0	
28 October, 1971	Calved as two-year-old in 1970	+ 4.18**	28
	Dry as two-year-old in 1970	0	

** P 0.01

significant ($P < 0.05$) difference of 2 kg was recorded (Table 3.10). Superior birth weights occurred on the hill in both herds in 1970 and 1973, but failed to reach significance. There did not appear to be any effect due to switching the treatments between years, nor to feeding out every other day as opposed to feeding daily. However, the numbers in the sub-classes are too low, particularly in 1972 to demonstrate anything other than a major effect.

The Stud herd in 1971, and both herds in 1972, present a confusing picture. The lack of pattern in the results was probably caused largely by low, sub-class numbers and a long calving season (over 70 days) which extended through marked changes in the physical environment as the spring pasture flush occurred.

Lower birth weights on the pad may have been due to a restriction of energy intake by the dam before calving or by a shortening of the gestation period due to the treatment. This might be caused by high levels of corticosteroids triggered by stressful social conditions on the pad. The experiment provides no indication of which of these alternatives might be the case, without information on the stage of the gestation period of each animal.

Table 3.10 The least square differences for the effect of the treatments on the birth weight of the calf.

<u>Year</u>	<u>Herd</u>	<u>Treatment Differences (kg)</u>							<u>Number of Animals</u>	<u>Significance</u>
		<u>P</u>	<u>H</u>							
1970	Stud	0	2.05						45	N.S.
1970	Commercial	0	2.18						22	N.S.
		<u>PP</u>	<u>PH</u>	<u>HP</u>	<u>HH</u>					
1971	Stud	0	0.29	0.49	-1.03				48	N.S.
1971	Commercial	0	0.02	2.0 ^a	2.62 ^a				48	P < 0.05
		<u>PPPI</u>	<u>PPPII</u>	<u>BHPI</u>	<u>BHPII</u>	<u>HPH</u>	<u>PHH</u>	<u>HHH</u>		
1972	Stud	0	2.21	0.43	-6.46	4.68	4.54	0.97	47	N.S.
1972	Commercial	0	-0.34	-3.36	-3.06	-4.49	-1.68	-1.89	50	N.S.
		<u>PI</u>	<u>PII</u>		<u>H</u>					
1973	Stud	0	1.10		1.70				37	N.S.
1973	Commercial	0	0.28		1.63				54	N.S.

NOTE: Superscripted values are significantly different from unsuperscripted values at the levels indicated.

P = pad; H = hill treatment; I = pad I; II = pad II.

(b) Weaning Weight

The problem of the interpretation of weaning weights arises because of the extended calving period even though the weaning weights were linearly adjusted for age before their statistical analysis. However, the long calving period would have meant that calves were exposed to different environments at different ages and this may have biased the results. Evidence that differential response does in fact occur is presented when the growth of the calves born in 1973 is discussed. If most of the calves in one sub-class were born in a different time period to calves in another sub-class, then the resulting weaning weights would not be strictly comparable if the response was not linear and accounted for by the covariate. Where sub-class numbers are low (between two and five animals in many cases), the danger that this might have occurred becomes greater.

The least square differences for the 200-day linearly adjusted weaning weight are shown in Table 3.11. In 1970 there were significant differences in favour of the hill for both herds. There is a difference in favour of the hill for the Stud herd in 1971 although it is not significant. On the other hand, the Commercial herd in 1971 showed the pad treatment to be slightly better.

Both herds in 1972 present a confusing picture. Although differences are significant ($P < 0.01$) for the Commercial herd

Table 3.11 The least square differences between the treatments for the adjusted weaning weight of the calf.

<u>Year</u>	<u>Herd</u>	<u>Treatment Differences</u>							<u>Number of Animals</u>	<u>Significance</u>
		<u>P</u>					<u>H</u>			
1970	Stud	0					4.98 ^a	44	P < 0.01	
1970	Commercial	0					14.90 ^a	19	P < 0.05	
		<u>PP</u>	<u>PH</u>	<u>HP</u>	<u>HH</u>					
1971	Stud	0	3.96	10.40	9.39			44	N.S.	
1971	Commercial	0	-4.42	-4.17	-5.22			42	N.S.	
		<u>PPPI</u>	<u>PPPII</u>	<u>PHPI</u>	<u>PHPII</u>	<u>HPH</u>	<u>PHH</u>	<u>HHH</u>		
1972	Stud	0	2.74	-10.69	-8.93	1.31	11.43	-1.90	43 N.S.	
1972	Commercial	0	-17.67 ^{ab}	-23.98 ^a	-2.92	-4.82	-18.09 ^a	-8.66 ^b	44 P < 0.01	

NOTE: Superscripted values are significantly different from unsuperscribed or different superscripted values at the levels indicated.

there does not appear to be any discernible pattern, and differences may have been due to the bias mentioned above. It was known that certain calves scoured badly during 1970, 1971, and 1972, particularly those on the pad. A further source of bias could have been caused by the presence of some of these calves in one treatment class, but not in another. This may have been the case in 1972 when class numbers were very low.

The data showed evidence of a sex \times treatment interaction which may have been caused by multiple suckling amongst the pad calves. That this did occur was observed often during the experiment. This possible effect was apparent in the class means as the better performance among the male calves on the pad against male calves on the hill, was probably due to pirated milk. Unfortunately numbers did not allow the calculation of this interaction. No doubt this pirating contributed to lower weaning weights of other more timid calves, and when colostrum was stolen this may have caused disease and subsequent lowering of the calf's growth rate.

This multiple suckling effect is a real disadvantage of the pad system of wintering and nursing, and any technique to eliminate or reduce it should result in an improvement of the performance of calves whose dam's milk has been taken by other calves. In 1973 each cow and calf pair was removed from the pad soon after calving, and run in an adjacent paddock for four

days to allow the calf to obtain colostrum unhindered. There was only one mild case of scours in 1973. However other factors such as a very mild winter and an early spring were also operative.

When the pad apron was scraped off, it was normal practice to blade the dung just outside the gate of the first pad, and leave it. The result of this was the formation of a quadrangle around the gate which made passage for the calves (which were creep fed) from the first pad very difficult. This may have been a discouragement to the calves on pad I to return to their mothers for a feed.

(c) Milk Consumption

Estimates of calf milk consumption were made twice when the calves were aged approximately 20 and 50 days respectively, in the years 1970 and 1971. The first observation was made while the animals were still confined, while the second observation was made after they had been removed from the pad and were grazing on the hill. The least square differences are shown in Table 3.12. For the confined estimate taken when the pad cows were still on the pad, showed that those on the hill were significantly ($P < 0.01$) superior in the milk consumption of their calves for both herds. However the second unconfined estimate taken on 20 October, 1970, when the cows had been removed from the pad showed there was no

Table 3.12 The least square differences for the effect of the treatment on the milk consumption of calves.

<u>Date</u>	<u>Herd</u>	<u>Differences (kg)</u>		<u>Number. of</u>	<u>Signifi-</u>
		<u>Pad</u>	<u>Hill</u>	<u>Animals</u>	<u>cance</u>
17 September 1970	Commercial	0	3.43	20	P < 0.01
18 September 1970	Stud	0	0.96	42	P < 0.01
20 October 1970	Commercial	0	0.18	17	P < 0.05
20 October 1970	Stud	0	-0.27	49	N.S.
19 September 1971	Commercial	0	-0.11	18	N.S.
19 September 1971	Stud	0	0.54	27	N.S.
28 October 1971	Commercial	0	-1.05	28	P < 0.05
28 October 1971	Stud	0	-0.30	29	N.S.

significant difference between the treatments for the Commercial herd in 1970, and a much reduced though still significant ($P < 0.05$) difference in favour of the hill for the Stud herd in 1970.

A different situation occurred in 1971, with there being no significant difference between treatments for the estimate of the confined cows taken on 9 September, for both herds. However, the latter estimate taken on 28 October shows a significant ($P < 0.05$) difference of 1.15 kg of milk consumed in favour of the PP treatment compared to the PH treatment in the Commercial herd. The pad treatment is also favoured at this point for the Stud herd although the differences are not significant.

These results are interpreted as evidence that the cows confined to the feeding pad over the winter, possibly under stressful conditions, increase their milk production when they are removed from the pad and placed onto hill pastures under what are possibly less stressful conditions. The type, cause, and degree of stress will be discussed later when other variables that also have a bearing on the matter have been introduced.

The extended calving period means that the estimates include records from cows at very different stages of lactation. The only New Zealand observation on the time of peak lactation was made by Walker and Pos (1963) who found that Angus cows reached their peak of lactation between 8 and 9 weeks following calving under a grassland

grazing system. Most of the cows would have been within this time when the earlier estimates of the confined cows were but the latter estimates would have included a number of cows which could have been past their peak of lactation. This may have caused biased results since the linear adjustment for the age of the calf might have been insufficient to cope with different stages of lactation.

Time of Calving

(a) Birth Weight

The effect of the date of birth was calculated as a covariate in the mathematical model, for increments of one day. The regression coefficients for birth weight are shown in Table 3.13.

In 1971 when the cows in the Commercial herd were three-years-old, and about half were calving for the first time, the regression coefficient shows a significant ($P < 0.01$) decrease of 0.17 kg in birth weight for every day calving was delayed after 21 July. On the other hand, in 1972 when the cows in the Commercial herd were four-years-old the regression coefficient shows a significant ($P < 0.01$) increase of 0.17 kg in birth weight for every day calving is delayed after 21 July. Both the late winter and early spring were reported by the New Zealand Gazette (August 1971, September 1971, August 1972, September 1971) as mild for both years. Interpretation is hampered by the absence of data

Table 3.13 The regression coefficients for the time of calving (days) on the birth weight (kg).

<u>Herd</u>	<u>Year</u>	<u>Regression Coefficient (kg/day)</u>	<u>Number of Animals</u>
Stud	1970	0.0149	45
Commercial	1970	- 0.0247	22
Stud	1971	0.1239	48
Commercial	1971	- 0.1653**	48
Stud	1972	- 0.0440**	47
Commercial	1972	0.1697**	50
Stud	1973	0.0144	37
Commercial	1973	- 0.0178	54

** P < 0.01

on the gestation length of each cow, and of climatological data within the environment in which the cattle existed. Nevertheless there remains a remote possibility of an age of dam x season interaction operating in lieu of a more likely explanation. The Stud herd in 1972 showed a low but significant ($P < 0.01$) negative regression coefficient. The existence of this regression coefficient which is opposite in sign to that of the coefficient for the Commercial herd improves the attractiveness of the hypothesis of an age of dam x season interaction.

With the exception of 1972 the regression coefficients for each herd within each year were of similar magnitude but of opposite sign. The Stud herd showed a positive regression coefficient indicating an increase in the birth weight of the latter-born calves, while the Commercial herd showed a negative coefficient indicating that the earlier calves tended to have the heaviest birth weight. However, there is a general lack of statistical significance of these data.

(b) Weaning Weight

The least square regression coefficients from fitting the covariate are shown in Table 3.14. The covariate was fitted after calf weaning weight had been linearly adjusted to 200 days of age.

All values were not significant for 1970 and 1971, indicating that the linear adjustment compensated for time of birth adequately.

Table 3.14 The least square regression coefficients for the effect of the time of calving on the 200-day adjusted weaning weights.

<u>Herd</u>	<u>Year</u>	<u>Regression Coefficient (kg/day)</u>	<u>Number of Animals</u>
Stud	1970	- 0.1641	44
Commercial	1970	0.0984	19
Stud	1971	- 0.1403	44
Commercial	1971	0.0152	42
Stud	1972	0.4772 **	43
Commercial	1972	0.6111 *	44

** P < 0.01

* P < 0.05

However, 1972 showed positive significance ($P < 0.01$ for the Stud v. $P < 0.05$ for the Commercial herd) regression coefficients. This would indicate that the amount of the adjustment to weaning weight was too low for the younger calves. The spring of 1972 was sunny, but dry, which could be interpreted as providing good growing conditions for the calves born earlier. Drought became general in December and conditions were dry in November. (New Zealand Gazette, August 1972 to December 1972). However drought would have occurred at the time the older calves were becoming less dependent on their dam's milk. Lack of feed may have handicapped their growth.

(c) Milk Consumption

The least square regression coefficients are shown in Table 3.15. Except for the earlier confined estimates in 1970, values are low and negative implying an increase of between 0.02 and 0.03 kg of milk consumed for every day of age of the calf. This was as expected.

The early estimates of 1970, taken while the cows were still confined are contrary to all expectations. However, when these data were collected there was considerable confusion, due to problems associated with the operation of the weigh-nurse-weigh technique for the first time. It seems that the older calves might have finished earlier then urinated or defecated before being weighed. If this were the case it would result in the positive regression coefficients.

Table 3.15 The least square regression coefficients for the effect of the time of calving on the milk consumption of the calf.

<u>Date</u>	<u>Herd</u>	<u>Regression Coefficient (kg/day)</u>	<u>Number of Animals</u>
17 September 1970	Commercial	0.3083 **	23
18 September 1970	Stud	0.0029 **	42
20 October 1970	Commercial	- 0.0796 *	17
20 October 1970	Stud	- 0.0397 *	49
9 September 1971	Commercial	- 0.0223	18
9 September 1971	Stud	- 0.0248	32
28 October 1971	Commercial	- 0.0354 **	28
28 October 1971	Stud	- 0.0317 **	29

** P < 0.01

* P < 0.05

The Liveweight Change of the Cows over Winter(a) Treatment

The least square differences between treatments for the cow liveweights following the removal of the Commercial Herd cows from the pad are shown in Table 3.16. The differences were significant in 1971 and 1973 ($P < 0.01$) in favour of the hill. The year 1971 was favourable climatically, particularly for the hill environment as warm temperatures would favour pasture growth (Table 3.26). The climatic data for 1973 at the time of writing are unavailable, however a subjective assessment of the climate prevailing at that time would indicate a mild spring with good pasture growth.

In 1970 when the Commercial cows were two-years-old there was no significant difference between the cows kept on the pad, and those kept on the hill over the winter. The climatic conditions (Table 3.26) reveal the period from July to October to be unfavourable to animals living on exposed hill pastures. Unusually high winds prevailed and September was reported to be the windiest and wettest since 1943, necessitating the early removal of cows from the pad due to its breaking down. Conditions were too wet for pasture growth, and a very cold southerly change occurred on 26 September. The pad would be better sheltered against wind, and not subject to fluctuating feed levels, but would be more prone to become excessively wet. Thus no one environment could be said to

Table 3.16 The least square difference between the liveweights of the cows according to winter treatment when they were removed from the pad.

(Commercial Herd only)

<u>Year</u>	<u>Difference (kg)</u>			<u>Number of Animals</u>
1970	<u>P</u> 0		<u>H</u> 4.21	22
1971	<u>PP</u> 0	<u>HP</u> 9.05 ^b	<u>PH</u> 34.16 ^a	<u>HH</u> 47.28 ^{a**} 26
1973	<u>PI</u> 0 ^a	<u>PII</u> 5.72 ^b	<u>H</u> 35.01 ^c	** 42

Superscripted values are significantly different.

** P < 0.01

be any more favourable than another in 1970, and lack of any demonstrable liveweight difference between the cows involved in each is a reflection of this statement.

(b) Sex of the Calf

The least square differences are shown in Table 3.17. A significant ($P < 0.01$) difference of 7.6 kg in favour of those cows suckling female calves occurred in 1971 for the Commercial herd. Since the female calves showed a greater tendency to consume milk in 1971 this result is explicable in these terms.

(c) Parity of the Cow

The least square differences are shown in Table 3.18. Those cows which had calved at two years of age in 1970 were significantly ($P < 0.01$) 12 kg lighter than those calved at three-years-of-age in 1971 when they come off the pad. However, the two-year calvers were shown to have had calves which consumed significantly ($P < 0.01$) more milk on 28 October, 1971.

There is no significant difference between degrees of parity for 1973.

Table 3.17 The least square differences for the effect of the sex of the calf on the liveweight of the dam at the end of winter.

(Commercial Herd only)

<u>Year</u>	<u>Difference (kg) (Male - Female)</u>	<u>Number of Animals</u>
1970	+ 1.5	22
1971	- 7.6 *	26
1973	+ 2.31	42

* $P < 0.05$

Table 3.18 The least square differences for the effect of the parity of the cow on her liveweight at the end of the winter.

(Commercial Herd only)

<u>Year</u>	<u>Parity</u>	<u>Difference (kg)</u>	<u>Number of Animals</u>
1971	Calving at two years of age in 1970	0	26
	Dry at two years of age in 1970	12.1**	
1973	Calved 1970, 1971, 1972	0	42
	Calved 1970, Dry 1971, Calved 1972	5.43	
	Dry 1970, Calved 1971, Calved 1972	-4.56	
	Dry 1970, Dry 1971, Calved 1972	-10.78	
	Dry 1970, Calved 1971, Dry 1972	-24.23	

** P < 0.01

(d) The Autumn Liveweight of the Cow

This was expressed in the mathematical model as a covariate. The regression coefficients are shown in Table 3.19. As expected the autumn liveweight taken at the point when the cows were placed on the pad was highly significant ($P < 0.01$).

(c) The Time of Calving

This was expressed in the mathematical model as a second covariate. The regression coefficients are shown in Table 3.20. Results are only available for the Commercial herd. The decreasing importance of the regression coefficient as the cows increase in age can be seen. There appears to be considerable advantage in terms of liveweight recovery, probably by compensatory growth, (since they will be still growing at two and three-years-of-age) for the younger dams having their calves early. This lends support to the current recommendations to mate yearling heifers two weeks before the mature cows.

The Growth of the 1973/74 Calves

(a) Winter Treatment

Although there was no significant difference between treatments for the calf birth weight a significant ($P < 0.01$) difference of about 8.0 kg in favour of the hill had developed between the live-

Table 3.19 The least square regression coefficients for the effect of the autumn liveweight of the cow on her liveweight at the end of the winter.

(Commercial Herd only)

<u>Year</u>	<u>Regression Coefficient (kg/kg)</u>	<u>Number of Animals</u>
1970	0.9339**	22
1971	0.8503**	26
1972	0.8602**	42

** P < 0.01

Table 3.20 The least square regression coefficients for the effect of the time of calving of the cow on her liveweight at the end of the winter.

(Commercial Herd only)

<u>Year</u>	<u>Regression Coefficient (kg/day)</u>	<u>Number of Animals</u>
1970	1.4082**	22
1971	0.8761**	26
1973	0.4563	42

** P < 0.01

weight of calves on the pads and the calves on the hill when the animals were removed from the pad to the hill pastures on 12 September, 1973 (Table 3.21). There was no significant difference between the two halves of the pad implying that feeding every day (pad I), as against feeding only every second day (pad II) produced no effect on the liveweight gains of their respective calves. A similar situation was apparent on 5 October, 1973.

On 25 October the difference between the two pads had increased to become significant ($P < 0.01$) in favour of pad I. This difference remained up to the last weighing on 20 December, although it was reduced to the five per cent level of significance on this date. This implies that the calves from the cows fed only every second day while on pad I grew slower than the calves from the cows that were fed every day while on pad II. This is difficult to understand, but if this disadvantage in growth is due to lower milk production on the part of the dams in the earlier period from 12 September, 1973 to 25 October, 1973 then perhaps these cows having become accustomed to having food easily available to them become lazy foragers on the hill, and the month was required for them to reacquire the habit of foraging. Further data on the 1973 winter treatments are available from the Stud herd, and the analysis should provide additional information on this point.

The calves from the two pads steadily gained in liveweight at a faster rate than did those calves from the hill once they were

Table 3.21 The least square means for the effect of the treatment on calf weight at birth and three weekly intervals, post pad.

<u>Date</u>	<u>Pad I (kg)</u>	<u>Pad II (kg)</u>	<u>Hill (kg)</u>	<u>Number of Animals</u>	<u>Signifi- cance</u>
Birth weight	27.60	27.88	29.23	54	N.S.
12 September 1973	49.21	46.07	56.83 ^a	45	P < 0.01
5 October 1973	62.02	66.80	73.88 ^a	49	P < 0.05
25 October 1973	78.89 ^a	72.04	85.50 ^a	49	P < 0.01
15 November 1973	96.66 ^a	89.63	101.65 ^a	49	P < 0.01
6 December 1973	114.37 ^a	107.38	118.38 ^a	49	P < 0.01
20 December 1973	137.89 ^a	132.00 ^b	135.70 ^{ab}	49	P < 0.01

NOTE: Superscripted values are significantly different from unsuperscripted or differently superscripted values at the levels indicated.

removed from the pad. By 6 December, 1973 there was no significant difference between pad I and the hill for calf liveweight. On 20 December, 1973 there was no significant difference between the hill calves and either pad treatment calves for liveweight. The better weight gains achieved by those calves previously on the pad occurred while the majority of calves were less than 100 days of age. Considering the high correlation between milk production of the dam, and the liveweight gain of the calf demonstrated for calves aged less than 100 days (Chapter Two) these results provide grounds for strong suspicion that the milk yield of those cows which had been removed from the pad increased to a level which was above the milk yield of the cows wintered on the hill.

(b) The Sex of the Calf

The least square differences for the liveweight differences between the sexes are shown in Table 3.22. There is an increasing advantage due to the males up to 6 December, 1973, all differences being significant ($P < 0.01$). The environment was subjectively assessed to be good for calf growth, and the increasing male advantage was probably due to the environment allowing the full expression of the inherent capacity of the male to grow faster than the female.

Castration took place on 6 December, 1973, and this was probably the main reason for the reduced sex difference shown on 20 December, 1973.

Table 3.22 The least square differences for the effect of sex on calf weight at birth and at three weekly intervals post partu.

<u>Date</u>	<u>Male Advantage (kg)</u>	<u>Number of Animals</u>	<u>Significance</u>
Birth weight	1.0	54	N.S.
12 September 1973	5.28	45	P < 0.01
5 October 1973	9.30	49	P < 0.05
25 October 1973	11.39	49	P < 0.01
15 November 1973	12.14	49	P < 0.01
6 December 1973	18.58	49	P < 0.01
20 December 1973	6.24	49	P < 0.05

The Effect of the Time of Birth

In order to obtain more information on the interaction of the age of the calf with the season, the time of birth of the calf was included in the mathematical model both as a linear and as a quadratic covariate. The regression coefficients are shown in Table 3.23, and the curves are plotted in Fig. 3.1. The youngest calf was born 44 days into the calving season. There were two calves born after 40 days, and six born after 30 days, but before day 35 of the calving season. This makes interpretation of the covariate unrealistic beyond 35 days. Differentiating and setting the derivative equal to zero enables the curve minimum to be found (Table 3.24). As expected this lies between 30 and 40 days implying that the latter-born calves needed the most adjustment. However, the degree of adjustment diminishes as the calf age decreases, which is probably due to better growing conditions for the younger calves as the season progressed.

The strength of the quadratic covariate increased up to 15 December, 1973 then decreased on 6 December, 1973. Examination of climatic data in connection with this phenomenon may prove interesting when such data become available.

The complete reversal of the quadratic on 20 December, 1973 is more difficult to understand. It shows an advantage to the younger calf. The onset of dry conditions which may have affected the milk yields of cows more advanced in lactation as

Table 3.23 The linear and quadratic regression coefficients of calf age on weight at birth and three weekly intervals post part.

<u>Date</u>	<u>Linear Regression Coefficient</u>	<u>Signifi- cance</u>	<u>Quadratic Regression Coefficient</u>	<u>Signifi- cance</u>	<u>Number of Animals</u>
Birth weight	- 0.0178	N.S.	-		54
12 September 1973	0.0531	N.S.	-		45
5 October 1973	- 1.5000	N.S.	0.0132	N.S.	49
25 October 1973	- 1.6166	P < 0.01	0.0188	0.1 > P > 0.05	49
15 November 1973	- 2.4951	P < 0.01	0.0371	P < 0.01	49
6 December 1973	- 2.1268	P < 0.01	0.0287	P < 0.01	49
20 December 1973	1.9059	N.S.	- 0.0311	P < 0.01	49

Table 3.24 The minimums of the quadratic regressions of calf age on calf weight at three weekly intervals post pad.

<u>Date</u>	<u>Minimum Value (days)</u>
5 October 1973	56.80
25 October 1973	42.99
15 November 1973	33.62
6 December 1973	37.05
20 December 1973	30.66

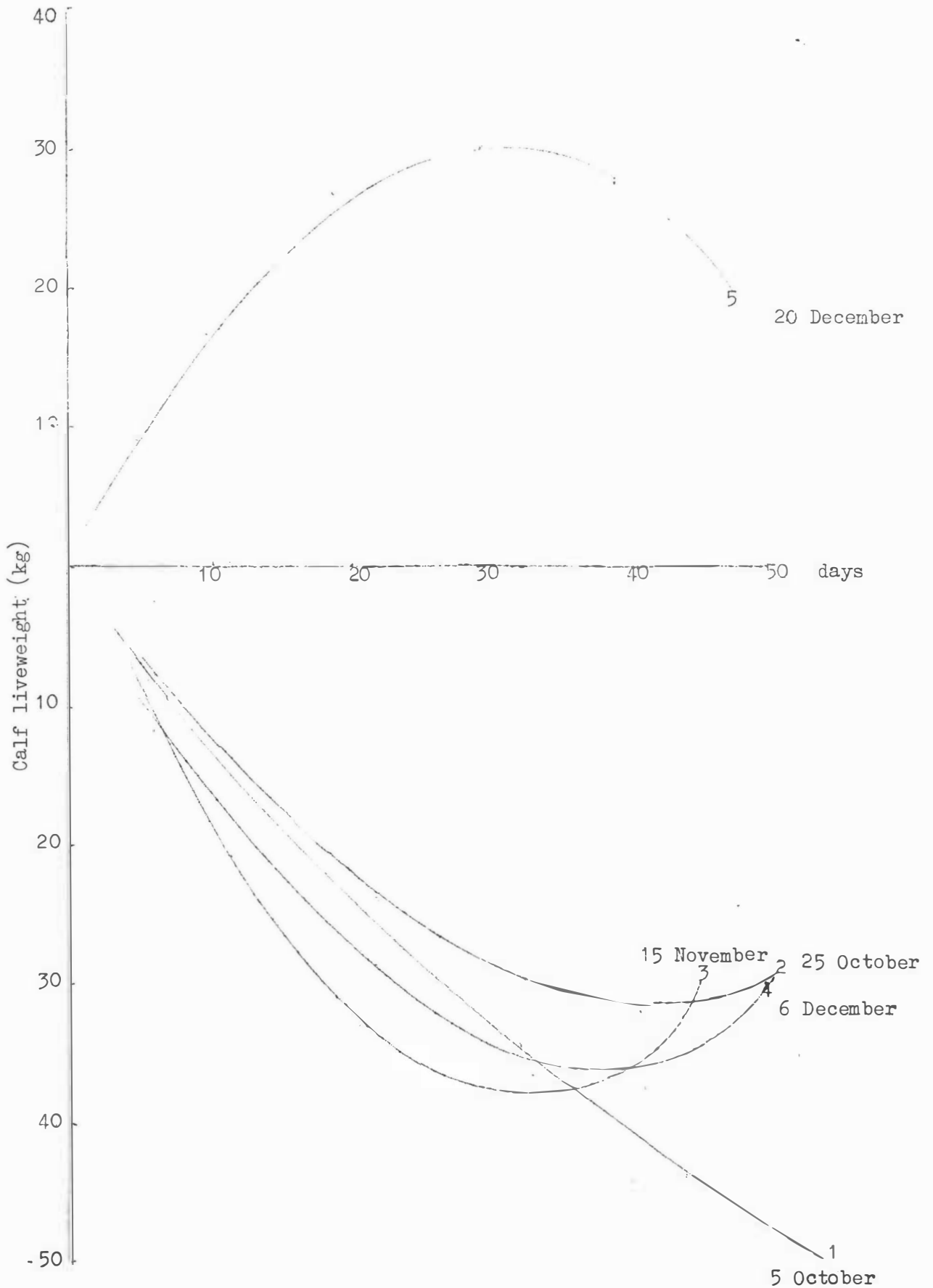


Figure 3.1 The graph of calf liveweight y calf age at each three weekly weight for the 1973/74 calves.

well as the greater shock due to castration suffered by the older calves, which would have been converting from milk to grass, and this may also have been a factor, in their loss of superiority. However, further and fuller interpretation must wait until the data from the Stud herd have been analysed. Meanwhile the present analysis gives another warning on the undesirability of castration being carried out at a time when climatic stresses are also likely to operate.

The Calving Interval

The least square means and differences for the calving interval between treatments are shown in Table 3.25. A full analysis was not carried out as only the treatments were tested for significance to see whether any treatment produced an increase in calving interval. Full analysis will be the basis for later work. All treatments were not significant except for the Commercial herd in 1971/72 where PP and HP had a significantly longer calving interval than did t_{PH} ($P < 0.01$). Generally however, there appeared to be no other tendency for longer calving intervals to be associated with the pad treatment.

Although there was no significant difference in calving interval, the two-year-old in-calf heifers which were wintered on the pad in 1970 had only a 64.3% positive pregnancy diagnosis

Table 3.25 The least square differences for the effect of treatment on the calving interval of the cows.

<u>Year</u>	<u>Herd</u>	<u>Least Square Differences/ Means (days)</u>				<u>Number of Animals</u>	<u>Significance</u>
		<u>P</u>		<u>H</u>			
1970/71	Commercial	0		6.97	15	N.S.	
1970/71	Stud	0		-3.56	34	N.S.	
		<u>PP</u>	<u>PH</u>	<u>HP</u>	<u>HH</u>		
1971/72	Commercial	380.6	346.5	366.9	354.8	43	P < 0.01
1971/72	Stud	368.9	367.8	387.7	372.7	29	N.S.
		<u>PI</u>	<u>PII</u>	<u>H</u>			
1972/73	Commercial	350.1	360.7	356.3		43	N.S.
1972/73	Stud	366.8	369.9	368.5		37	N.S.

following their second mating. The comparable figure for the heifers wintered on the hill was 93.3%. This was despite any significant differences in the liveweight of these heifers on removal from the pad. Full analysis of the heifer liveweight changes through the year may clarify this observation.

GENERAL DISCUSSION AND CONCLUSION

The original trial was designed to investigate the feasibility of a system of weaner calf production from beef-breeding cows which involved removing the cows from the hill pasture in the winter and maintaining them on a sawdust pad until one or two months after calving in the spring. The preceding work, consists of the analysis of the cow and calf liveweight data collected over the three-and-a-half years the system was operated. Because it was an investigation of a system of production, and not a trial set up to test a specifically formulated hypothesis, this work does not prove anything in the scientific sense. It does however, provide evidence of the occurrence of some phenomena of practical importance in the management of beef-breeding cows and their calves, and establishes a model from which future experiments can be planned to further investigate these phenomena.

The results show the importance of climate on the growth of the calf. Climate may affect the calf directly through the variables temperature, wind, and rain, as well as indirectly through the effect of these variables on the cow (especially her lactational physiology), and upon pasture growth. It appears that the climatic effect depends on the age of the calf. This means

that it is affected by such things as the stage of lactation of the dam, the degree of dependence by the calf on its dam's milk, as well as the effect of increasing size of the calf.

Climatic stress was most likely to occur at two periods within each year of the experiment. The first was between August and September when cold stress was likely owing to stormy weather accompanied by temperatures below the critical temperature for the calf. The second between January and February when drought conditions usually prevailed (Table 3.26). The curvilinear regression for the effect of calf age on liveweight (Table 3.23) favours the younger calves, i.e., those born later in the spring when conditions were warmer. The data collected over the summer drought have not yet been analysed. Crack (1964) reported younger calves to gain significantly ($P < 0.01$) more than older calves during a drought in Jamaica. The older calves would be more dependent on pasture than the younger calves, and would probably find less milk available to them from their dams.

Consideration of the above two points invites suspicion on the method of comparing calves by linear adjustment of the liveweight data to a constant age, usually 200 days. When the ages of calves are far enough apart for them to have been exposed by different climatic conditions at each stage of their life then linear adjustment may not be valid. Evidence of the error introduced by linear

Table 3.26 Climatological Data

New Zealand Gazette
Monthly July 1970 - March 1972.

Year 1970/71

<u>Month</u>		<u>Mean Air Temp. °C</u>	<u>Total Rainfall(mm)</u>	<u>Total Sun- shine (hrs)</u>	<u>Comments</u>
July	1970	9.1	115	92	An unusually mild month marked by a high frequency of westerly winds.
August	1970	9.6	70	109	An unusually high frequency of northerly to easterly winds.
September	1970	11.6	165	122	Windiest and wettest September since 1943. Reported as too wet for pasture growth by the end of the month. Cold southerly change on 26 September.
October	1970	13.3	91	118	Varied effects
November	1970	14.8	51	204	Dry, warm, and sunny.
December	1970	16.6	72	210	Drought starting to show an effect.
January	1971	18.6	135	194	Cyclone Rosie relieved drought a little.
February	1971	19.4	90	178	Exceptionally warm. Frequent nor-east winds. Nearly all rain fell in period 23-25 February.
March	1971	16.7	34	209	High wind frequency. Weather dry in the early period.

Year 1971/72

July	1971	8.5	10	134	
August	1971	10.5	119	122	Unusually mild.
September	1971	11.0	81	112	Windy. A warm month.
October	1971				
November	1971	14.7	60	227	Sunny month
December	1971	16.9	53	193	Warm month. Good growth.
January	1972	17.4	64	190	Dry in North Island.
February	1972	16.7	50	199	Dry and sunny.
March	1972	17.5	139	128	Wettest March for 50 years in the North Island. Also generally warm.

Table 3.26 Climatological data (Cont'd.)

Year 1972/73

<u>Month</u>		<u>Mean Air Temp. °C</u>	<u>Total Rainfall (mm)</u>	<u>Total Sun- shine (hrs)</u>	<u>Comments</u>
July	1972	9.1	100	123	Mild month.
August	1972	8.1	80	156	Cold but sunny.
September	1972	11.5	55	106	Warm month. Strong westerly winds. Conditions dry.
October	1972	13.2	65	128	Windy month.
November	1972	16.1	29	111	Warm, cloudy and rather dry.
December	1972	15.1	40	143	Cool and windy. Dry conditions.
January	1973	18.0	50	227	Dry and warm.
February	1973	18.4	16	217	One of the driest months on record. Drought conditions became general.
March	1973	14.4	59	100	

adjustment without regard to the climatic conditions operating is provided by the highly significant regression coefficients for the age of the calf on the 200-day linearly adjusted weaning weights for both herds in 1971/72 (Table 3.14), and the significant curvilinear regressions of the age of the calf on uncorrected calf liveweights in 1973/74. Further analysis of the 1973/74 calf liveweight data should provide more information on this aspect.

Present methods of selection do not permit the comparison of animals raised on different farms under different management conditions. This work casts some doubt upon the comparison of animals on the same farm whose differences in age has caused them to experience different climatic conditions when of the same age. The question is how far apart ages must be to produce a significant effect? Johnson and Dinkel (1951) counselled caution in applying a linear correction factor for age to calves where the weaning weight has been taken more than 30 days preceding or following the standard weaning age, while Creek (1964) recommended that the time between the youngest and oldest calf should not be more than 60 days if their standardised weights are to be compared. Minyard and Dinkel (1965) and Swiger et al. (1962) found that linear correction appeared to over-adjust calf weight for extreme age groups being too high for the younger calves and too low for the older calves. This would also seem to be the case in this study. Harwin et al. (1966) showed a significant year x age of calf effect

with Hereford calves, and this led them to recommend the use of within-year regressions on each calf's own preweaning daily gain to adjust for age of calf effects. The magnitude of this effect under a climate such as that of New Zealand where seasonal fluctuations occur, and animals are largely dependent on pasture, remains to be determined. However, the graph (Fig. 3,1) indicates a departure from linearity of calves born after 30 days of the calving period have passed.

An important point which has arisen from this work concerns the performance of the younger (three- and four-year-old) dams under climatic stress, particularly drought conditions. Christian et al. (1965) found younger dams to be more persistent in their lactation than older dams and this may be a consideration over the drought period which tends to occur towards the end of lactation. Harwin et al. (1966) reported a significant interaction between calf weaning weight and dam age, leading to the conclusion that in poor years there was a marked trend for the weaning weights of calves from younger cows to be more adversely affected than the weaning weights of calves from mature cows. However a poor year was undefined, and may not have referred to drought. The effect of drought on the milk production of beef cows deserves further investigation.

The climatic influence on beef weaner production is more important than it is on other phases of the production cycle,

since the economics of land-use dictate that breeding-cow herds should be kept in areas of climatic and feed extremes. There are probably advances to be made in this field from a study of the interactions of climatic variables and calf growth.

The most interesting aspect of this trial concerns the growth of the calves and the changes in the milk yield of the dam when the animals are removed from the pad and grazed on the hill in the spring. The results reported are not conclusive, but they offer evidence that upon removal from the pad in the spring the milk yield of the cows wintered on the pad increases from a point where they were giving less milk than those cows wintered on the hill, to a point where they were giving more milk than those cows wintered on the hill, as determined by the weigh-nurse-weigh method. Further support to the hypothesis that the pad wintering causes a surge in milk production on a return to full feeding is given by the growth figures of the 1973/74 calves from the Commercial herd. The growth rate of the calves raised on the pad was much faster on leaving the pad than was the growth rate of their contemporaries on the hill, indicating an increase in the milk yield of their dams and/or availability of pasture to the calves.

Kropp et al. (1973) compared the systems of keeping cows on a drylot, or on open range. They reported that the lactation curves

of cows in the drylot were more typical of dairy cows with a much more marked peak, than the lactation curves from the range cows. The better the cows over the winter were fed the more marked was the lactation peak.

Gifford (1953) proposed that the physiological processes of milk secretion in beef cows are limited to the capacity of the calves to consume milk and the rate of consumption during the first month of lactation automatically sets the pattern for the remainder of the lactation curve. Milk secretion is probably adjusted by hormonal feed-back to the pituitary. If, however, something such as a change in the diet, or an increase in the energy supplied, occurs, then this might upset the hormonal balance of the animal sufficiently for a new equilibrium of milk secretion to be established. If this new equilibrium point is also determined by the appetite of the calf it will be higher than the earlier figures. However, there are no data to indicate whether this might be the case. The absence of milk yield data in 1973/74 and lack of significance in many of the observations on treatment differences in the milk yield data for 1970/71 and 1971/72 means that further work is needed to establish this hypothesis.

Assuming that the milk yield of the cows wintered on the pad does surge as has been indicated, then this opens up a new field of investigation of practical importance in beef husbandry. A number of questions become apparent: the first concerns the

optimum wintering conditions in terms of the degree of weight loss before and after calving as well as the type of feed available. Experience in dairy science shows that wintering treatment is important in determining subsequent milk production, and Kropp et al. (1973) showed that the milk yield of two-year-old beef cows was influenced by the level of supplementary feed, both on the range and in the drylot. However, the present question concerns the degree of nutritional stress to be allowed after calving.

The second question concerns the suspected age x treatment interaction. Normally the older cows would be expected to settle easier than the younger cows under the less comfortable and more socially stressful conditions of the pad, and, therefore, perform a little better. The better production of the four-year-old cows calls for closer examination, although this production was measured over all treatments. There was no difference in the milk yield of the four-year-old cows from the other age classes upon removal from the pad in 1970/71. But in 1970/71 the advantage in calf weaning weight to the four-year-old cows was not very great. However, in 1971/72 the milk yield of the four-year-old cows increased sharply over the other age classes on removal from the pad. Correspondingly the weaning weights of the calves from these four-year-old cows were much higher than those calves from the other age classes. Perhaps the younger dams are more

sensitive to the stimulus causing the surge in milk production. Unfortunately this effect is confounded for weaning weights of the calves with a possible effect of drought on the effect of the age of the dam as mentioned earlier. Nevertheless, further enquiry might be directed towards a system in which the younger cows winter and calve on the pad, while the older cows winter and calve on the hill.

The third question concerns the optimum stage of lactation at which the cows should be returned to full feed in order to cause the surge in milk production. One would expect that this would be before the peak of lactation, ordinarily six to eight weeks in a beef cow. At the moment this is only conjecture with no evidence to support it.

These questions, among others, will constitute the next stage of enquiry for the phenomena. The answers to them will no doubt invite modifications to the present system, and provide suggestions for new approaches.

Providing that the type of feed the cows have does not affect this surge in lactation then a pad need not be built in order to stress the animals. They may be kept short on pasture after calving. This has wide application in the field of pasture management, a very important consideration on hill country farms, and likely to become even more important in the future as

conservation pressures increase. Keeping breeding cows on short rations for some time after calving as a husbandry technique will also provide a manager with much more flexibility for pasture maintenance. Suckling (pers. comm. 1974) recommends that for the health of the pasture the management in the spring should aim to spell the pasture until it is two to three-inches high. It should then be grazed off, and this process repeated periodically. If beef cows do not need to be fully fed straight after calving, this allows more freedom to operate this policy.

Large areas of New Zealand hill country are unsuitable for grazing cattle over the winter due to climatic, topographical and soil limitations. On these areas, topography often limits the extent to which supplementary feed can be carried over a wet winter and soil erosion is a major problem. On the other hand, conditions at other times of the year may mean that abundant feed is available. Indeed farmers are often embarrassed by being unable to utilise all the pasture grown. A stock policy which is uninhibited by these fixed factors of soil, climate, and topography would enable more capital stock to be carried. This would have a direct effect on profitability through increased production, and an indirect effect due to better pasture control. Confinement of beef-breeding cows on a cattle pad during the winter represents one such possible policy.

Evaluation of the wintering of beef cows on a pad as a system of production compared to the normal policy of wintering them on

the hill is difficult because of the climatic fluctuations which have occurred every year the experiment has operated. In fact there has been no season one would call typical of Manawatu hill country.

A further implication arises when attempting to extrapolate these results to hill country generally. Tuapaka carries a Drysdale flock, and raises stud Perendale rams. A herd of Galloway cows is carried as well as the two herds of Angus cows under discussion. The running of other experiments also competes for the available resources. This means that the resources available to the cows and calves on Tuapaka may be less than those which would be allocated to such an enterprise on a commercial farm. Certainly calf weaning weights at Tuapaka which averaged 160 kg in 1970/71 and 1971/72 for the mixed-age Stud herd would be considered less than average in the Manawatu. However, the cows wintered fairly well; those on the hill only losing 2% of their autumn liveweight at the end of the wintering period. The check came during the summer droughts when management of the property favoured the stud sheep.

Brown et al. (1968) confined 45 cows on a drylot where they remained throughout the year. They did not find any problem in this system and the 250-day weaning weights averaged 240 kg. Marion et al. (1971) reported the lifetime performance of beef cows confined to a drylot. These cows performed as well as those on

pasture for the first seven years, weaning 216 kg in the drylot compared to 212 kg on pasture. But during the next three years the average birthweight on the drylot fell to 26 kg compared to 34.2 kg on pasture. The survival rate of calves on the drylot was also reduced. This was attributed to a cumulative nutritional deficiency since the cows were not fed minerals or vitamin A regularly. The calf crops improved when the amount of digestible protein in the diet fed to the confined cows was increased. These results refer to cows which were confined in the pad continuously, and were not grazed on pasture at all.

Kropp et al. (1973) compared the drylot against the range for the productivity of two-year-olds. Cows on the drylot were confined continuously, and fed to approximate the weight changes of the range cows. The 240-day adjusted weaning weight for Hereford cows was 229 kg on the range, and 188 kg on the drylot, despite the same daily milk yield of 5.2 kg observed under both conditions. High roughage creep-feed was provided for these calves which was calculated to contain sufficient digestible energy and protein for adequate gains, but intakes of creep-feed calves were much lower than anticipated, probably owing to the individual stallfeeding of the calves.

Two major problems with the pad policy have become apparent during the four years of operation, namely, multiple suckling among the calves, and pad hygiene.

Multiple suckling presents a threat to the younger and weaker calves. The apparent robbing of colostrum from the new-born calf was assumed to cause the most trouble, and presumably would have been one of the main reasons for the high incidence of calf scours noted on the pad, over the first three years. This was prevented in 1973/74 by removing the cow and calf from the pad to an adjacent pasture for the four days immediately after parturition. Calf bullying and the robbing of milk from the less aggressive calves were probably the main reasons for the greater variability among the weaning weights of the calves from the pad.

Further improvements during 1973/74 designed to reduce the incidence of calf scours included the spraying of the pad with formalin prior to moving the cows onto the pad and more attention was paid to the regular scraping off of the pad feeding-apron. On the sawdust foundation the dung does not break down as readily as it does on pasture, thus it gives a favourable environment for micro-organisms to grow and disease among the calves is the result. Access is too free from the feeding racks to the sawdust bedding area. An improvement might be to construct a railing behind the feeding apron which forced the cows to walk through a gate to one side of the pad in order to get a feed. This would encourage them to defaecate on the concrete apron. Closing of the feeding area might also help to reduce the incidence of multiple suckling, since this was observed to occur most frequently when the cows

were feeding. Hygiene might also be improved by regular working up of the sawdust with harrows or a rake in order to break up the dung for rapid oxidation, and to expose new sawdust.

The removal of the new-born calf and its dam from the pad for at least four days is strongly recommended. Not only does this ensure that the young calf gets adequate colostrum, but vitamin A levels in the milk may also be increased. The young calf begins life in a much healthier environment, and this early familiarity with the pasture encourages creep-feeding. Perhaps the opportunity thereby provided for the calf to become acquainted with its mother may help to prevent later milk robbing.

As a system of beef production (on Tuapaka), which increases the number of capital stock carried, the policy of wintering and calving on a sawdust pad was successful. Provided hygiene is carefully considered this work shows that there is no reason why this system should not be operated as part of a profitable commercial weaner-beef production enterprise.

Further, more detailed investigation of the other phenomena observed should provide valuable information on how management of the breeding-cow herd might be improved for greater productivity and hence more profit to both the individual farmer, and to the country as a whole.

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APPENDIX I

Example to show the arithmetic involved in estimating the fixed effect model.

The calf weaning weights of the 1971 Stud herd.

Model

$$Y_{ijkl} = \mu + a_i + s_j + t_k + b(x - \bar{x}) + e_{ijkl}$$

where a_i includes a_3 = The three-year-old dams

a_4 = The four-year-old dams

$a_{5/7}$ = The five to seven-year-old dams inclusive

$a_{8/10}$ = The eight to ten-year-old dams inclusive

s_j includes S_m = The male calves

S_f = The female calves

t_k includes PP = Pad in 1970, Pad in 1971

PH. = Pad in 1970, Hill in 1971

HP = Hill in 1970, Pad in 1971

HH. = Hill in 1970, Hill in 1971

$b(x - \bar{x})$ = the regression of calf age on corrected 200-day calf weight.

The normal equations, or the X^1X matrix was set up as in Fig A.1

	μ	a_3	a_4	$a_{5/7}$	$a_{8/10}$	S_m	S_f	PP	PH	PP	HH	b
μ	44	8	10	16	10	22	22	8	12	3	16	
a_3	8	8	0	0	0	4	4	2	22	1	3	9.2728
a_4	10	0	10	0	0	7	3	2	2	1	5	51.5910
$a_{5/7}$	16	0	0	16	0	6	10	2	5	3	6	-59.4544
$a_{8/10}$	10	0	0	0	10	5	5	2	3	3	2	-1.4090
S_m	22	4	7	6	5	22	0	3	6	5	8	61.5002
S_f	22	4	3	10	5	0	22	5	6	3	8	-61.5002
PP	8	2	2	1	3	3	5	8	0	0	0	-5.7272
PH	12	2	2	5	3	6	6	0	12	0	0	4.9092
HP	8	1	1	3	3	5	3	0	0	3	0	-75.7272
HH	16	3	5	6	2	8	8	0	0	0	16	76.5456
b		9.2728	51.5910	-59.4544	-1.4090	61.5002	-61.5002	-5.7272	4.9092	-75.7272	76.5456	13325.8864

And the right hand vector is

μ	:	7534.4
a_3	:	1309.6
a_4	:	1850.5
$a_{5/7}$:	2715.8
$a_{8/10}$:	1658.5
S_m	:	3839.9
S_f	:	3644.5
PP	:	1304.8
PH	:	2085.3
HP	:	1352.8
HH	:	2791.5
b	:	-171.0455

Figure A.1 The normal equations

In order to reduce the size of the $X'X$ matrix before inversion the mean effect, and the age effects were absorbed into the sex, treatment and covariance equations.

Dividing a_i th equation by a_i

	S_m	S_f	PP	PH	HP	HH	b	R.H.V.
a_3	0.5	0.5	0.25	0.25	0.125	0.375	1.159100	163.7
a_4	0.7	0.3	0.2	0.2	0.1	0.5	5.15910	185.05
$1_{5/1}$	0.375	0.625	0.125	0.3125	0.1875	0.375	-3.7159	169.7375
$a_{8/10}$	0.5	0.5	0.2	0.3	0.3	0.2	-0.14090	165.85

Calculate absorbed matrix.

$$S_{AB} = s_{JJ} - \left(\frac{Sa_{3j}}{a_3}\right) \cdot Sa_{3j} + \left(\frac{Sa_{4j}}{a_4}\right) \cdot Sa_{4j} + \left(\frac{Sa_{5/7j}}{a_{5/7}}\right) \cdot Sa_{5/7j} \\ + \left(\frac{Sa_{8/10j}}{a_{8/10}}\right) \cdot Sa_{8/10j}$$

e.g.

$$S_m = 22 - 0.5(4) + 0.7(7) + 0.375(6) + 0.5(5) \\ = 10.3500$$

etc.

Thus the matrix is:

	S_m	S_f	PP	PH	HP	HH	b	R.H.V.
S_m	10.3500	-10.3500	-1.1500	0.2250	1.1750	-0.2500	43.7500	92.0750
S_f	-10.3500	10.3500	1.1500	-0.2250	-1.1750	0.2500	-43.7500	-92.0750
PP	-1.1500	1.1500	6.4500	-2.1250	-1.4250	-2.9000	-10.6500	-63.8750
PH	0.2250	-0.2250	-2.1250	8.6375	-2.2875	-4.2250	11.2750	41.5625
HP	1.1750	-1.1750	-1.4250	-2.2875	6.3125	-2.6000	-70.4750	-2.7125
HH	-0.2500	0.2500	-2.9000	-4.2250	-2.6000	9.7250	69.8500	25.0250
b	43.7500	-43.7500	-10.6500	11.2750	-70.4750	69.8500	12827.8500	-910.5935

To make this matrix of full rank, in order to obtain a generalised inverse a row and column are set to zero. The matrix is of rank five, but there are seven rows and columns. Therefore, one row and column from each of the two classes is set to zero.

$$\text{Thus } S_f = PP = 0$$

This gives the reduced matrix.

S_m	PH	HP	HH	b	R.H.V.
10.3500	0.2250	1.1750	-0.2500	43.7500	92.0750
0.2250	8.6375	-2.2875	-4.2250	11.2750	41.5625
1.1750	-2.2875	6.3125	-2.6000	-70.4750	-2.7125
-0.2500	-4.2750	-2.6000	9.7250	69.8500	25.0250
43.7500	11.2750	-70.4750	69.8500	12827.8500	-910.5935

This matrix was inverted and the equations solved using the method of Gaussian elimination with a package programme on the I.B.M. 1130 computer. Latter, more ill-conditioned matrices were solved on the Burroughs B 6700 computer using a FORTRAN programme for iteration.

Solutions to the above equations are: The fixed effect least square estimates = B $S_m = 9.0406$ PH = 10.4008 HP = 3.9577
 HH = 9.3901 b = -0.1403

Calculate the absorbed age effects:

$$\text{Effect of the } i^{\text{th}} \text{ age} = \frac{1}{a_i} (Y_i - S_{ij} B_j)$$

where

i goes from a_3 to $a_{8/10}$

a_i refers to the number of animals in the i^{th} age group.

j refers to the columns of the $X'X$ matrix, Thus $j = S_m$ to b for each a_i

Thus

$$a_3 = \frac{1}{8} \quad 1309.6 - 4(9.0406) - 2(10.4008) - 3.9577 - 3(9.3901) \\ - 9.2728 (-0.1403) = 152.7261$$

$$a_4 = \frac{1}{10} \quad 1850.5 - 7(9.0406) - 2(10.4008) - 3.9577 - 5(9.3901) \\ - 51.5910(-0.1403) = 172.2744$$

$$a_{5/7} = \frac{1}{16} \quad 2715.8 - 6(9.0406) - 5(10.4008) - 3(3.9577) - 6(9.3901) \\ + 59.4544 (-0.1403) = 158.3123$$

$$a_{8/10} = \frac{1}{10} \quad 1658.5 - 5(9.0406) - 3(10.4008) - 3(3.9577) - 2(9.3901) \\ + 1.4090 (-0.1403) = 155.1244$$

To calculate the variance due to fitting the full model:

In matrix terms this equals $B'X'y$

Where B' is the vector of least square constants

$X'y$ is the right hand vector for the $X'X$ matrix

Thus

$$B'X'y = R \left(\begin{matrix} a & t & s & b \end{matrix} \right) = (152.7261 \times 1309.6) + (172.2744 \times 1850.5) \\ + (158.3123 \times 2715.8) + (155.1244 \times 1658.5) + (9.0406 \times 3889.9) \\ + (10.4008 \times 2085.3) + (3.9577 \times 1352.8) + (9.3901 \times 2791.5) \\ + (-0.1403 \times -171.0455) \\ = 1294468.4957$$

Therefore, the unaccounted or error variance is $Y'Y - B'X'y$

where $Y'Y$ is the raw sum of squares of the observations

$B'X'y$ is the reduction in the sum of squares due to fitting the model

Thus

$$\begin{aligned}\text{Error variance} &= 1304090.5 - R(\mu, a, s, t, b) \\ &= 9622.0043\end{aligned}$$

To estimate the effect of the treatments, the treatment rows and columns of the $X'X$ matrix are set equal to zero. Then the reduced matrix becomes

	S_m	b	R.H.V.
S_m	10.3500	43.7500	92.0750
b	43.7500	12827.8500	-910.5935
$S_m =$	9.3307	$b =$	-0.1028

Solve for age equations again

$$\begin{aligned}a_3 &= \frac{1}{10} \quad 1850.5 - 7(9.3307) - 51.5910 (-0.1028) \\ &= 179.0489\end{aligned}$$

$$\begin{aligned}a_{5/7} &= \frac{1}{16} \quad 2715.8 - 6(9.3307) + 59.4544 (-0.1028) \\ &= 165.8565\end{aligned}$$

$$\begin{aligned}a_{8/10} &= \frac{1}{10} \quad 1658.5 - 5(9.3307) + 1.4090 (-0.1028) \\ &= 161.1702\end{aligned}$$

The reduction in the sum of squares due to fitting all the model except for the treatments is

$$\begin{aligned}R(\mu, a, s, b) &= (1309.6 \times 159.1538) + (1850.5 \times 179.0489) \\ &\quad + (2715.8 \times 165.8586) + (161.1702 \times 1658.5) \\ &\quad + (9.3307 \times 3839.9) + (-0.1028 \times -171.0455) \\ &= 1293810.4416\end{aligned}$$

The sum of squares associated with the treatments is

$$R(\mu, a, s, t, b) - R(\mu, a, s, b) = 658.0541$$

Variation	S.S.	D.F.	M.S.
Treatment	658.0541	3	219.3513
Error	9622.0063	35	274.9144

$$F = 0.7978$$

$$= \text{N.S.}$$