INFLUENCE OF PLANE OF NUTRITION ON THE

PRODUCTIVITY OF ANGUS HEIFERS

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

Warren James Anderson
1977

ABSTRACT

This experiment was designed to study the influence of autumn live weight and nutritionally-enforced live weight change on calf birth weight and the subsequent productivity of three-year-old, primiparous Angus heifers, calving in the spring of 1975. All heifers were pasture fed on "Tuapaka", No. 3 sheep farm, Massey University, and the treatments imposed followed those normally experienced by cattle on hill country. This was achieved by altering pasture intake by the manipulation of stocking rate during first pregnancy.

The research herd of 54 heifers was comprised of animals reared to two-and-a-half-years-of-age at three different origins, namely Massey (Tuapaka), Hawke's Bay and Wairarapa, which consequently gave the three autumn live weight groups.

On 1 May, 1975, a switchover design for pre-calving nutritional plane was initiated by allocating heifers within origin to one of three treatment groups. The first group of 19 heifers was fed at a high plane continuously to calving. A second group of 18 heifers was fed at a high plane of nutrition for 70 days (to 10 July, 1975) until three weeks before the start of calving (30 July, 1975). The third group of 17 heifers was fed on a low plane of nutrition from 1 May to 10 July, 1975, when it was switched to a high plane. The three groups were identified as HP-HP, HP-LP and LP-HP, respectively.

The least squares means for the live weight of the groups at the start of the experiment, at switchover 70 days later, and at the last weighing date before calving were:

1 May, 1975: HP-HP, 382.4kg; HP-LP, 382.0kg; LP-HP, 380.1kg (NS).
10 July, 1975: HP-HP, 381.3kg; HP-LP, 382.1kg; LP-HP, 362.2kg ($p < 0.01$).
25 July, 1975: HP-HP, 395.7kg; HP-LP, 376.0kg; LP-HP, 375.0kg ($p < 0.01$).

The live weight of the heifers, as classified by origin at the last weighing date before calving (25 July, 1975), did not differ from that at the start of the experiment (1 May, 1975) by more than 1.7kg. The least squares means for the weight of the heifers of the origin

groups at 25 July was: Massey, 367.8kg; Hawke's Bay, 407.4kg; Wairarapa, 371.7kg. The Hawke's Bay heifers were significantly (p<0.01) heavier than those from the other two origins.

The first order interaction between winter nutritional regime and autumn live weight was not significant.

The birth weight of the calf was not significantly influenced by the plane of nutrition of the dam or her autumn starting weight. Within treatments, the least squares means for birth weight were: HP-HP, 27.9kg; HP-LP, 25.7kg; LP-HP, 25.9kg. The maximum difference was 2.1kg (0.05<p<0.10). Within origins of dam, the least squares means for birth weight were: Massey, 26.6kg; Hawke's Bay, 27.9kg; Wairarapa, 25.0kg. The difference between extremes was 2.9kg (0.05 <p<0.10).

After calving the heifers and their calves were grouped into three herds according to age of calf. The live weight of both were taken on eight occasions after parturition, including a weight at weaning. Calves were weaned on 11 March, 1976 at 210 days of age. Estimation of the milk consumption of the calf was made by the weigh-nurse-weigh method after a 17-hour separation at each of three 20-day intervals.

The influence of the pre-calving plane of nutrition on the milk consumption and weaning weight of the calf was not significant, although the heaviest calves were weaned by the heifers of the HP-HP group. Compared to the LP-HP group the HP-HP heifers gave preference to lactation ahead of body weight gain to wean heavier calves and have a lighter body weight at weaning. The HP-LP heifers showed relatively poor live weight recovery and weaned the lightest calves.

The influence of the autumn live weight of the dam on the weaning weight of the calf was significant (p<0.05), where the calves of the Hawke's Bay heifers were 18.0kg heavier than those of the other two groups. The amount of milk consumed by their calves at each of the three days of determination was also greater than that of the other two origin groups (NS).

The effect of sex of calf on its weight before and at weaning, and the live weight of the dam showed that male calves were heavier on all occasions, and their dams consequently showed less live weight gain than the heifers rearing female calves. Female calves consumed more milk at each determination (NS).

The time of calving did not significantly affect the birth weight of the calf, but those calves born earliest had an advantage at weaning ($b = -0.89 \pm 0.53$kg/day; $0.05 < p < 0.10$). The effect of climatic variation was discussed as it related to the three post-calving herds.

Evidence was found of residual effects of the previous year's post-calving plane of nutrition, but not autumn live weight, on the live weight change of the heifers in their second gestation and on the birth weight of the second calf.

It was concluded that the advantage of a high live weight in the autumn during the heifer's first pregnancy was positively and significantly exhibited in the weaning weight of its calf. The LP-HP regime, of a mild loss (5%) of autumn live weight to four weeks before calving, with elevated feeding to calving, was believed to be the most advantageous to pasture growth, winter stocking rate and efficiency of pasture utilization by the heifer.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

<u>LIST OF TABLES</u>

LIST OF FIGURES

INTRODUCTION

This study was undertaken primarily to investigate the influence of two major factors on the birth weight of the calf. These factors were the live weight of the dam in the autumn, and the plane of nutrition of the dam before the calf was born.

There is abundant information concerning the relationship between the age of the dam and the birth weight of the calf with respect to the incidence of dystocia. The evidence is conclusive that within breed, dystocia occurs more frequently among first-calving heifers than among females of any other age group. Because the birth weight of the calf has been found to be the most important factor causing dystocia - among factors attributed to both the cow and its calf - there has been much research conducted to reduce the birth weight of calves by the manipulation of the intake of the pregnant bovine. Most of this work has been conducted in climates, and with feeding methods, dissimilar to the conditions existing on New Zealand hill country, and hence the conclusions obtained in those studies have involved considerable extrapolation in the application of the principles locally.

The popular belief among some cattlemen who have been confronted with a high incidence of dystocia in their herds, especially among first-calving heifers, has been that restriction of intake within the last trimester of pregnancy has the effect of reducing the birth weight of the calf, thereby minimizing the risk of dystocia from this factor in particular. There has been little objective measurement in New Zealand of the response of primiparous animals to restricted nutrition upon which to base this action.

The planes of nutrition which were imposed on the first-calving, three-year-old Angus heifers of the present experiment were intended to emulate normal New Zealand hill-country winter feeding and to provide an estimate of the response of the birth weight of the calf to differing

levels of nutrition offered the dam. In this work there were three nutritional levels with restricted intake being imposed on one of the groups for a predetermined period, either early in the winter, or beginning later and continuing through to calving.

The period of most pronounced pasture shortage on New Zealand hill country is usually in the winter, and the levels of nutrition imposed in this study were designed with the intention of examining the effect of the time of the restriction on the performance of the heifer, not only with respect to the birth weight of its calf, but also her subsequent lactation, the post-calving live-weight growth of the heifer and the performance of the calf. The results have provided an indication of the most effective use of a limited pasture resource.

Most of the studies which have evaluated the influence of managerial manipulation of the pregnant heifer have been directed towards the weight change of the heifer up to calving. There have been few investigations of the influence of the weight of the pregnant heifer in the autumn.

The manner in which the heifer accomplishes its growth to the time of first-calving, whether by rapid growth after her own weaning to a large size at mating, or a more protracted growth period continuing up to, and beyond calving, at a more constant rate has not previously been thoroughly considered. The design of the present experiment included heifers which varied in live weight in the autumn of their first pregnancy. This presented the opportunity to evaluate the effect of this characteristic on the productivity of the heifer, involving the birth weight of the calf, the lactational performance of the dam and the live weight growth of the heifer and her calf in the pre-weaning period.

There have been investigations reported elsewhere which found a varying amount of residual influence from the previous experimental constraints (Hight, 1968c; Pinney et al., 1962). By continuing to obtain data from the heifers in the current study in their second calving season it was possible to determine if the effects of the nutritional treatments and autumn live weight persisted for more than one pregnancy and lactation.

The outcome of this project should be of value to the beef cattle industry. It attempts to quantify and examine beliefs strongly held by cattlemen with respect to the management and feeding of young pregnant cattle. The results are contradictory to opinions held by some producers, especially those relating to the possible manipulation of the birth weight of the calf. It is also hoped that there is a significant contribution in this thesis to the information on the importance of feeding heifers in preparation for their first pregnancy.

C H A P T E R   T W O

REVIEW OF LITERATURE

1.   Calf Birth Weight and Dystocia

   1.1   Introduction
        Discussion of the response of birth weights of calves to managerial
manipulation occupies a major part of this review. However, an apprec-
iation of the importance of birth weight per se is necessary to under-
stand the significance of changes in it which can result from genetic
effects, and more especially, environmental effects.

        A light birth weight may be associated with poor vitality, low
resistance to exposure, a diminished stimulus to suckle, and hence
higher mortality (Ried, 1960; Alexander, 1964; Corah et al., 1975).
Conversely, heavier calves have a greater capacity for milk, tend to
maintain the lactation persistency of the dam, and thus at weaning have
heavier weights than their contemporaries of lighter birth weights.

        Working with Angus cattle, Drewry et al. (1959) reported a
correlation between the birth weight of the calf and average daily milk
consumption of 0.43 in the first month of life. The values obtained
indicated a positive relationship between higher milk records and larger
calves at birth. The relationship declined as lactation progressed and
the dependence of the calf upon its dam diminished. The authors
obtained data which indicated that heavier calves at birth were able to
maintain their weight advantage to six-months-of-age. Gifford (1953)
also found that the milk-consuming ability of the calf influenced the
subsequent milk production of its dam. By supplementing the diets of
three-year-old Beef Shorthorn heifers, Bernard et al. (1973) were able
to report 30kg more weight of calf at weaning than the unsupplemented
group, mainly because of the higher viability of their calves. Koger
et al. (1967) found that 50.8 percent of losses occurred within 24 hours
of birth - these deaths occurred in calves of low or high birth weights
with the greatest survival rate being in the intermediate ranges.

        The significance of birth weight and its role in peri-natal

survival of calves has attracted much attention when studied in relation
to the effects of high weights at birth.

Most of the recent studies of crossbreeding have strengthened the
evidence that dystocia is the major cause of peri-natal calf loss, i.e.
calf death at or within 48 hours of birth (Anderson and Bellows, 1967;
Carter et al., 1975; Laster et al., 1973). Although Woodward and Clark
(1959) cautioned that birth weight should not be accepted as the sole
criterion of dystocia, the published findings are that it is the most
important causative factor identified of those attributed to either the
dam or the calf (Bellows et al., 1969. 1970: Fagg et al., 1975; Hodge
et al., 1976; Philipsson, 1976a; Rice and Wiltbank, 1970). Within
parity, among the most important factors attributed to the dam was size
of pelvic opening.

The practical significance of the relationship of birth weight
to dystocia has been discussed. Smith et al., (1976) observed a 1.6
percent increase in dystocia per kg increase in birth weight. This was
less than the figure of 2.3 percent reported by Laster et al. (1973)
although the data of the latter authors included a larger proportion of
younger cows. They found in their study of calving difficulty that
calf mortality at or near birth was four times greater (p<0.01) in
calves experiencing dystocia than those that did not.

In addition to the economic loss caused by dystocia through a
reduction of the number of calves weaned as a proportion of those born,
the association of dystocia with impaired rebreeding performance has
also been found to be very highly significant (Laster et al., 1973;
Philipsson, 1976e).

1.2   The Significance of the Birth Weight of the Calf
       in Relation to its Pre-weaning Gain and Weaning Weight
The importance of birth weight as it relates to weaning weight is
notable because of the mutual association of the two traits with genetic
ability for growth, and of viability as already discussed. Lasley et al.
(1961) reported a high genetic correlation of 0.93 ($\pm$0.07) between intra-
and post-uterine growth, which illustrates that many of the same genes
affect the growth rates of calves before and after birth.

Drewry et al. (1959) provided phenotypic correlations between birth weight and calf weight at sampling at the first, third and sixth month of age, which ranged between 0.30 and 0.37. Correlations between calf age and calf weight at sampling, and, calf age and total gain from birth, indicated that during the first month, older calves were heavier, but as lactation progressed calves born earlier tended to lose their advantage in weight. This suggests an effect due to season was operating.

Drennan and Bath (1976b), working with Hereford-cross cattle, reported a significant effect of birth weight on calf gain, where a 1kg increase in calf birth weight gave a 1.6kg increase in total gain from birth to 180 days of age. In support, Jeffrey et al. (1971b) and Powell (1972), reported significant ($p < 0.01$) regressions of weaning weight on calf birth weight of 1.7 and 2.0, respectively. Singh et al. (1970) found that birth weight significantly ($p < 0.01$) influenced pre-weaning average daily gain and weaning weight, and reported regressions of birth weight on the two growth traits of 0.004 and 2.01, respectively. The partial regression coefficient of birth weight on weaning weight reported by Christian et al. (1965) of 0.31 was also highly significant ($p < 0.01$).

From their early study with Beef and Milking Shorthorn cattle, Knapp et al. (1940) concluded that birth weights of calves were of limited value as an index of their growth potential. They held that birth weight was primarily an expression of size, weight, age and constitution of the dam, and that a minor part of this variation was due to the different potentials for growth of the calves.

Preston and Willis (1974) observed that the genetic correlations between birth weight and pre-weaning growth are mostly higher than the observed phenotypic correlations, indicating that selection for birth weight should increase subsequent gain.

A contrary view was expressed by Cartwright and Warwick (1955) who considered that the predictive value of birth weight (or weaning weight) taken singly, or together, is small. For practical purposes, their conclusion that selecting for any one stage is not antagonistic to selection at another stage, has greater importance.

Table 2.1

Genetic, environmental and phenotypic correlations of

birth weight with pre-weaning gain and weaning weight

(adapted from Preston and Willis, 1974)

Correlated Trait	Correlation			Reference
	Genetic	Environmental	Phenotypic	
Pre-weaning gain	0.11	0.14	0.12	Brinks et al. (1962)
	0.30	0.18	0.20	Pahnish et al. (1964)
	0.46	0.08	0.23	Brinks et al. (1964)
			0.31	Cartwright and Warwick, (1955)
	0.55		0.36	Loganathan et al. (1965)
	0.82		0.32	Berruecos and Robison, (1968)
			0.44	Gregory et al. (1950)
			0.44	Haycock, (1973)
			0.52	Christian et al. (1965)
	1.98	0.01	0.09	Pahnish et al. (1964)
			0.31	Koger et al. (1957)
Weaning weight	0.21	0.42	0.30	Brinks et al. (1962)
	0.42	0.42	0.42	Pahnish et al. (1964)
	0.60	0.28	0.41	Brinks et al. (1967)
	0.68		0.37	Shelby et al. (1963)
	0.84		0.42	Berruecos and Robison, (1968)
	0.99	-0.13		Lasley et al. (1961)
	1.12	0.22	0.31	Pahnish et al. (1964)
			0.12	Singh et al. (1970)
			0.27	Gregory et al. (1950)
			0.60	
			0.37	Meade et al. (1959)
			0.47	Koger et al. (1957)
			0.62	Christian et al. (1965)

1.3   Factors Affecting the Birth Weight of the Calf

       (i)   Breed

It is well established in the literature that breed differences
exist between the birth weights of calves.   (Table 2.2).

The two breeds of beef cattle of greatest numbers in New Zealand
are the Angus and Hereford.   The tabulation of the reported findings
indicated that birth weights among Hereford calves exceed Angus birth
weights by approximately 5kg (Hereford, 33kg: Angus 28kg).   There were
no reported cases reviewed where purebred Hereford calves were lighter
at birth than Angus calves.

The importance of the dam in expressing breed differences has
been well documented.

Holloway et al. (1975) compared Holstein, Hereford-Holstein cross,
and Hereford breeds in drylot and on range.   The breed differences for
birth weight corresponded to differences in body size of the dams of
the calves, the Holstein cows being the heaviest (p < 0.01).

Comparing two-year-old Friesian heifers with three-year-old Angus
heifers under North Island, New Zealand, hill-country conditions, Hight
(1969) found a difference between breeds of 2.7kg (28.1kg vs 25.4kg) in
favour of the Friesian.

Franke et al. (1965) studied the effect of breed of dam and breed
of sire on the birth weights of beef calves and concluded that the breed
of dam was more important than sire breed, or sex, in its influence.
Breed of dam accounted for 7.4 percent of the total variance in birth
weight. Gregory et al. (1965) and Pahnish et al. (1969) also found a
significant influence of breed of dam on calf birth weight.

Preston and Willis (1974) summarized the general ranking of
common beef breeds. Charolais and Holstein breeds were considerably
larger at birth than the overall average; the Hereford breed was about
average, and Brahman and Angus calves occupied the lowest place on the
list of breeds studied.

From the discussion of the significance of birth weight when

related to dystocia and stillbirths, an association between the three
was found. Since breed-of-calf has been seen to influence its birth
weight, a brief discussion of breed effect on dystocia is justified.

Laster and Gregory (1973) have reported on 5,064 parturitions,
from grade Hereford and Angus cows, the calves sired by eleven breeds,
including the major breeds: Hereford, Angus, Jersey, South Devon,
Limousin, Simmental and Charolais.

There were more (p <0.01) difficult parturitions in Hereford
than in Angus cows bred to the same sires, and the average birth weight
of calves from the Hereford cows was higher (p <0.01) than from Angus
dams.

That a higher incidence of dystocia, associated with higher
birth weights, occurs in Hereford than Angus cows has been supported by
the preliminary findings of Carter et al. (1975) and confirmed by Laster
et al. (1973) and Smith et al. (1976).

The amount of heterosis exhibited in birth weights has been
studied. Batra and Touchberry (1974) found that from crosses between
breeds of dissimilar birth weights, namely Jerseys or Guernseys mated to
Holsteins or Brown Swiss, there was little or no heterosis. The main
feature of the results was the effect of the dam's breed on the weight
of the crossbred offspring at birth. On the other hand, when breeds of
more similar size were crossed, namely Brown Swiss, Holstein, Red Dane
and Red Poll, deviations from the mid-parent average were consistently
positive. In these cases the deviations amounted to between 2 and 10
percent of the parental mean.

The studies of Sagebiel et al. (1972) and Laster and Gregory (1973)
showed insignificant effects of heterosis on calf birth weight.

The general belief that increased birth weight results from
increased heterosis levels generated by the crossing of B.taurus breeds
with B.indicus breeds has been confirmed by the findings of Koger et al.
(1973, 1975). A difference occurred between apparent heterosis levels in
Angus-Hereford and Brahman-British crosses. For birth weight the Angus-
Hereford back-crosses showed a negative heterosis of -5 percent while
Brahman-British crosses showed a positive value of 17 percent. The

explanation given for part of the increased birth weight from the cross
was the imparting of genetic ability for longer gestation length to the
crossbred calves from the Brahman sires. B.indicus cattle have
characteristically longer gestation lengths than B.taurus breeds.

With respect to the influence of crossbreeding on dystocia, the
findings of Carter et al. (1975), Laster and Gregory (1973) and Wiltbank
et al. (1967) have been that the mean birth weights of straightbred and
crossbred calves experiencing difficulty at calving are similar. However,
an important conclusion was drawn that at comparable birth weights, cross-
bred calves are better able to tolerate the high levels of stress
encountered in difficult birth.

Changing from a situation of genetic dissimilarity, as in cross-
breeding, to one of genetic likeness, notably inbreeding, the findings of
Foote et al. (1959); Jafar et al. (1950), Sutherland and Lush (1962) and
Gianola and Tyler (1974) attract interest. They all concurred that
inbreeding of the dam is unimportant in its influence on birth weight,
but that the inbreeding of the calf is associated with depressed birth
weight, although the gestation length is normal.

(ii)   Gestation length

A strong association between gestation length and birth weight of
calves has been demonstrated by most workers who have studied the relat-
ionship. Reported correlations of gestation length with birth weight,
regressions of birth weight on gestation length, and the amount of
variance of birth weight affected by gestation length have all been
included to show the significance of gestation length to the pre-partum
growth of the calf.

Bellows et al. (1971) reported that the positive effect of gest-
ation length on birth weight was highly significant ($r = 0.34$; $p < 0.01$)
in primiparous, two-year-old Hereford heifers, and significant ($r = 0.19$;
$p < 0.05$) in Angus heifers of similar age and parity. The authors
considered the positive effect was expected since the calf grows through-
out gestation and the greater the gestation period, the greater this
growth would be.

The MMB Charolais Report (1966), cited by Haycock (1973), showed

Table 2.2

Birth weight and gestation length

Breed	Breed Average (kg)	Birth weight range	Breed Average (days)	Gestation length range	Reference
Angus	28.1	20.4-35.2	281	277-286	1,2,11-25
Hereford	33.0	29.1-39.0	286	282-289	1,2,3,11-25
Charolais	42.5	36.7-50.2	285	282-288	1, 11-13
Holstein/Friesian	38.9	28.1-45.0	279	274-284	1,2,9,25
Shorthorn	31.3	27.6-33.7	282	281-284	1,2
Brahman	27.4	25.6-29.7	292	290-293	1,27

Breed	Birth weight (kg)	Gestation length (days)	
Simmental	46.3; 43.3; 39.0	287; 286; 287	1,2,6
South Devon	46.2; 45.0	287; 288	1,2
Santa Gertrudis	30.0; 34.4	286; 292	1,27
Brangus	28.6; 29.0	286	1
Galloway	33.3; 27.0	283	1,2

References

[1] Preston and Willis (1974)*

[2] Anderson and Plum (1965)

[3] Singh et al. (1970b)

[4] Molinuevo (1971)

[5] Bodisco and Cevallos (1971)

[6] Meyer (1972)

[7] Hight (1966)

[8] Hight (1968a)

[9] Hight (1968b)

[10] Hight (1968c)

[11] Sagebiel (1968)

[12] Sagebiel et al. (1972)

[13] Sagebiel et al. (1973)

[14] Burris and Blunn (1952)

[15] Laster et al. (1973)

[16] Bellows et al. (1969)

[17] Absher and Hobbs (1968)

[18] Swiger et al. (1962)

[19] Smith et al. (1976)

[20] Rice et al. (1954)

[21] Singh et al. (1970a)

[22] Alexander et al. (1960)

[23] Dawson et al. (1947)

[24] Hironaka and Peters (1969)

[25] Holloway et al. (1975)

[26] Knapp et al. (1940)

[27] Harricharan et al. (1976)

* The figures of Preston and Willis (1974) are their breed averages based on a variable number of published research reports. The figures attributed to them are taken from their Tables 6.10; 6.12.

that Charolais-cross calves were carried for three days longer than
Hereford crosses and over four days longer than the Friesians in the
survey. Haycock (1973) reported correlations between gestation period
and calf birth weight, within breeds (0.51, 0.48 and 0.50 respectively)
that were not only very highly significant, but higher than reported by
other workers.

The small and non-significant effects of heterosis on birth
weight have already been discussed under breed effects. The results of
Sagebiel et al. (1973) indicate there was no significant heterosis effect
on gestation length either. The percentage of heterosis for gestation
length was negligible regardless of cross (Angus, Hereford and Charolais
breeds crossed reciprocally, two-way only), and was in agreement with
Brandt (1958) and Touchberry and Bereskin (1966) who worked with the
Guernsey and Holstein breeds.

Gerlaugh et al. (1951) reported that male and female reciprocal
crossbred calves were carried 1.85 and 0.55 days longer, respectively,
than the average of their purebred Angus and Hereford counterparts. The
generally high estimates of heritability for gestation length (Sagebiel,
1968) seem to indicate that much of the variation, like birth weight, is
additively genetic and heterosis would therefore probably be small. A
later study (Sagebiel et al. 1973) supported this contention, with an
overall estimated heterosis level of 2 percent in male calves and 1 percent
in females. The significant effect of sire breed ($p < 0.01$) on gestation
length and on the regression of birth weight on gestation length, reported
by Smith et al. (1976), further indicates the importance of the additive
genetic variability in the sire's progeny.

The effect of sex on calf birth weight is to be discussed in
Section 1.3 (iii). However, with regard to reported correlations of birth
weight with gestation period, many workers have removed the effect of sex
by reporting separate values for each. In this connection, Lampo and
Willems (1965) found correlation coefficients of 0.42 and 0.27 between
calf birth weight and gestation length for male and female calves,
respectively in the East Flemish Red Pied breed. Working with Red Danes,
Andersen (1962) reported correlations between these traits of 0.42 and
0.41 for the two sexes and Skinner and Joubert (1966) obtained values of
0.35 and 0.24 for various breeds of cattle in South Africa.

Knapp et al. (1940) were concerned as to whether the difference in birth weight between the sexes is due to the relatively longer gestation lengths for bull calves. The analysis of results indicated that 25 to 35 percent of the difference in birth weight could be attributed to differences in gestation length. The authors reported correlations between gestation length and birth weight of 0.60 (Beef Shorthorns), 0.50 (Milking Shorthorns) and for the whole population, 0.50, when the difference between breeds was accounted for. Further analysis revealed that gestation length had the greatest single influence on the birth weight of the calf, and that calving sequence and weight of dam had small influence with calving sequence being slightly more important than weight of dam. Knapp et al. (1940) also found that for gestation length there was a significant amount of variation between cows, and that there was an apparent tendency for a cow to have a characteristic and repeatable gestation length.

That birth weight is significantly correlated with gestation length has been well established. To give an indication of the relationship between the growth of the calf and its age in utero (days), regressions of birth weight on gestation length have been reported. Since the calf is growing throughout gestation a positive sign of these regression coefficients is to be expected. None the less, Smith et al. (1976) have cautioned that the regression of birth weight on gestation length should not be interpreted as an accurate estimate of growth rate during late gestation, because of the other factors which influence birth weight. Burris and Blunn (1952) reported that 7.9 percent of the variance in calf birth weights was accounted for by differences in gestation length, and 7.3 percent when the effect of age of dam was removed.

A positive influence of nutrition on calf gestation by the dam was recorded by Bewg et al. (1969) who found a significant increase in gestation length in the year when the greatest weight gains were recorded. To differentiate between the effect of nutrition on calf birth weight, and the positive correlation between length of gestation and calf birth weight, Tudor (1972) calculated the average daily increase in foetal weight. An increase of one day in the gestation period resulted in an approximate increase of 0.2kg in the birth weight of the calf. The mean 5.4 days difference in gestation periods accounted for only 1.3kg of the 6.8kg difference in birth weight. Therefore, although the length of gestation is correlated with the birth weight of the calf, Tudor (1972) considered

the nutrition of the dam contributed a greater amount to the growth of the foetus.

Reported values for the regression of birth weight on gestation length have been consistent, positive, and in the range 0.20 to 0.38 (Bellows et al., 1971; Burris and Blunn, 1952; Carter et al., 1975; Reynolds et al., 1965; Smith et al., 1976).

There is a divergence in the literature regarding the relationship between the length of the gestation period and dystocia. For instance, Bellows et al. (1971) reported a regression of birth weight on gestation length of 0.20 to 0.30 (p<0.05) and found that gestation length did not significantly effect calving difficulty in either the Angus or Hereford breeds of dam. Philipsson (1976c) who studied Swedish Friesian cattle (a breed prone to experiencing calving difficulty) found that the relationships of calving performance and stillbirth rate to gestation length were all positive, but of relatively low magnitude. The relationships to calving performance and more particularly, to stillbirth rate, were not linear; the lowest stillbirth rates were obtained close to the average gestation length for the breed.

Laster et al. (1973) obtained data from Angus and Hereford dams which indicated that gestation length was associated with a higher incidence of dystocia. The importance of the genotype of the calf in influencing gestation length and birth weight was supported by the findings of these authors that the gestation period was associated with that of the sire breed.

(iii) Sex

Almost all studies reviewed have indicated that the birth weight of male calves is greater than that of females, and many of the differences were statistically significant (Table 1.3). Part of this superiority of the male sex is associated with the prevailing phenomenon of male calves having the longer gestation period. Knapp et al. (1940) considered that differences in gestation length accounted for 25 to 35 percent of the variation in birth weight between sexes.

A highly significant (p<0.01) effect of sex was reported by Singh and Tyagi (1970) who studied the magnitude of factors affecting the

Table 2.3

The influence of sex on the birth weight and
gestation length of the calf

(presented as differences between male and female)

Breed	Gestation length (days) (male minus female)	Birth weight (kg) (male minus female)	Reference
Hereford		2.1 (p <0.01)	Alexander et al. (1960)
Hereford		1.0	Bellows et al. (1969)
Angus		2.6	
Hereford and Angus	0.2	1.0	Bellows et al. (1971)
Angus		2 yr.dam 5.9	Bond and Wiltbank (1970)
		3 yr.dam 2.4	
Hereford		2.4	Brinks et al. (1961)
Angus	2.2	2.4	Burris and Blunn (1952)
Hereford	1.4	2.2	
Hereford and Angus	1.5	2.0	Carter et al. (1975)
Hereford	2.5	1.8	Corah et al. (1975)
Holstein	0.9	1.6	Everett and Magee (1965)
Four breeds		1.9	Franke et al. (1965)
Santa Gertrudis		0.9	
Sahiwal		2.3	Harricharan et al. (1976)
Brahman		2.3	
Shorthorn		2.1	Knapp et al. (1940)
Hereford		2.5	Koch and Clark (1955a)
Three breeds		2.4	Koch et al. (1959)
Hereford		0.7	Lasley et al. (1961)
Hereford	0.8	2.3	Rice et al. (1954)
Angus		2.4	
Hereford		2.7	Sagebiel et al. (1972)
Charolais		1.8	
Hereford		2.35	Singh et al. (1970a)
Hereford and Angus	1.7	2.7	Smith et al. (1976)
Hereford	-1.5	1.0	Tudor (1972)

birth weight of Hariana calves. The analysis of birth weight records of
130 calves in 10 sire groups revealed 9.38 percent of the total variance
in birth weight was attributable to sex of calf. (Sire effects 10.6
percent; season of birth, 4.6; dam weight, 3.3; and parity of dam,
2.4 percent).

Working at Massey University, Pleasants (1974) considered that a
sex by age of dam interaction was operating where sex differences were
lowest when cows were two- to three-years-of-age.

The sex of the calf has been seen to influence the level of dystocia,
largely because of differences in birth weight (Brinks et al., 1961;
Carter et al., 1975; Laster et al., 1973; Sagebiel et al., 1969; Smith
et al., 1976). In the majority of situations where sex differences were
measured the levels of dystocia among males have been found to be highly
significantly ($p < 0.01$) greater than among females. Furthermore, the
results of Carter et al. (1975) and Laster and Gregory (1973) have shown
that the rate of calf mortality at difficult parturition is also greatest
for bull calves.

Studies have shown a significant effect of the age of dam by sex
of calf interaction on dystocia, where the difference between sexes was
most pronounced among cows of two- and three-years-of-age (Smith et al.,
1976; Laster et al., 1973).

Philipsson (1976b) considered that the effect of sex on calving
performance may have been dependent to a large extent on sex differences
in birth weight, and the relationship between calving performance and
birth weight. Even within birth weight classes, however, differences in
calving performance existed between the sexes ($p < 0.01$). Consequently
the author suggested there are other factors beside gestation length and
calf birth weight, such as calf conformation and hormonal activity, that
may influence the difference between the sexes with respect to calving
performance and stillbirth rate. This was also suggested by Bellows et al.
(1971).

It is important to appreciate that much of the Northern Hemisphere
work, especially that of Philipsson (1976) has been with cattle wintered
indoors where the exercise of the cows is minimal compared to the New
Zealand situation. Furthermore, under New Zealand conditions, stillbirths

and peri-natal deaths due to a low birth weight are likely to be more
significant because of the factors generally referred to as "exposure",
including hypothermia and starvation as a result of weakness.   The
influence of sex of calf relative to such phenomena has not been invest-
igated adequately.

   (iv)   Weight of dam
        The weight of the dam has been shown to be positively associated
with the birth weight of the calf (Table 2.4).   Although the correlations
among cow weights and calf weights are not high, they indicate that
heavier cows tend to produce heavier calves at birth (and also at weaning).
Approximately only 6 percent of the variation exhibited in birth weight
was associated with weight of dam (Alexander et al., 1960).   These authors
reported a regression of birth weight on cow weight for Herefords of
0.019, indicating that for every 100kg increase in cow weight, calf weight
was expected to be 1.9kg heavier.

        Working with four dam breeds of mixed B.indicus and B.taurus breed-
ing, Moin et al. (1975) reported that cow breed significantly (p <0.01)
affected calf birth weight.   Significant partial regression coefficients
obtained for linear and quadratic effects of cow weight on birth weight
indicated that cow breed effect on progeny birth weight was mainly mani-
fested in cow weight differences.   Holloway et al. (1975) working with
Hereford and Holstein breeds also observed that breed differences in calf
birth weight corresponded to differences in body sizes of the dam breeds.

        Bellows et al. (1971) observed that the pre-calving body weight of
the dam exerted a highly significant positive effect on birth weight for
the Hereford and Angus dams.   This effect ranked first in importance of
factors attributed to either the dam or calf and was the most important
of the variables accounted for.   This would seem to indicate that larger
heifers had larger calves through some component of maternal environment.
This component, however, did not appear to be associated with total
gestation weight gain.   It was tentatively suggested by the authors that
the partition of nutrients between dam and foetus is not the same in large
and small dams and this results in different foetal growth rates.

        With respect to the relationship between calf birth weight and the
weight of the dam after parturition Joubert (1954) attempted to correlate
the post-calving weights of the heifers with the birth weights of their

offspring and failed to reveal a significant relationship (p>0.05).
No noticeable difference was found to exist between the respective
gestation periods despite differing dam weights, a characteristic also
shown by the findings of Reynolds et al. (1965). Hight (1968c) reported
the influence of plane of nutrition on calf birth weight of Angus cattle
and despite significant changes in birth weight as a result of treatments,
he found no significant relationship between post-calving cow live weight
and weight of the calf at birth.

The importance of the weight of dam and its relationship with
birth weight to dystocia has been stressed by Fagg et al. (1975) and
Singleton et al. (1973). In both studies dam's weight was highly correl-
ated with dystocia score at calving, and was the most significant factor
(p<0.01) affecting it with sire breed ranking second in importance. As
the weight of the cows in both trials increased, the incidence of calving
difficulty decreased. Similarly from the study of Bellows et al. (1971)
involving Angus and Hereford dams, the pre-calving body weight of the
Angus dams exerted a highly significant negative effect on calving
difficulty. The effect of this variable was the most important of factors
attributed to the dam for the Angus cows (non-significant for Hereford)
although with respect to factors attributed to both calf and dam, calf
birth weight was the most important.

(v)   Age and parity of the dam
Under normal management of the beef breeding herd, cows are mated
to calve first at two-, or more usually, three-years-of-age. However, on
the basis of measurable traits such as calf birth weight, milk production
and weaning performance of the progeny, most beef cows are not regarded
as being fully mature until six- to eight-years-of-age (Braude and Walker,
1949; Burris and Blunn, 1952; Knapp et al. 1940, 1942). For pregnancies
in cows of less than maturity, the growing foetus has to compete for
resources with physiological growth and development of the dam. The
competition may be accentuated when the resources are restricted.

The weight and size of the dam have been seen to control much of
the variation occurring in birth weights and the age of dam effect, within
breed, is likely to be a reflection of dam size, especially at younger
ages. If birth weight is seen to decline at older ages it is more likely
to be due to the aging process than to cow body size per se. Pleasants

Table 2.4

The correlation between weight of dam and birth
weight of calf

Breed	No. animals	Correlation	Reference
Hereford	502	0.26	Alexander et al. (1960)
Angus	103	0.36	Bellows et al. (1971)
Hereford	9797	0.29	Brinks et al. (1962)
Beef Shorthorn	71	0.49*	Dawson et al. (1947)
Hereford	60	0.32	Gregory et al. (1950)
Hereford	253	0.21*	
Shorthorn	297	0.22	Knapp et al. (1940)
Hereford	619	0.26	Singh et al. (1970)
Hereford	40	0.40	Tudor (1972)

Note: * Cow weight recorded immediately after parturition, as opposed
to pre-calving.

(1974) observed that older dams appear to be much more variable than younger ones with regard to calf birth weight, and considered that environmental influences play a greater role at older ages.

Obviously parity number may differ within age of dam depending on the age at first calving and the interval between calves. The significance of differing parities within an age group was discussed by Harricharan et al. (1976), working with three B.indicus breeds. It was seen that the length of the preceding calving interval of the dam had no significant influence on the birth weight of the calves in all three breeds.

Koch and Clark (1955a) discussed the effect of bias due to culling which may exist with increasing age of dam, and for weaning weight this is a strong possibility. Selection seldom occurs for birth weight, however, and it will be shown that the repeatability of birth weight is too low to be greatly affected by any inadvertent or intended selection which might take place (repeatability range reported: -0.03 to 0.35; see Section 1.3 ix).

Several studies have been made of the lifetime production of beef cow herds and the findings have strongly indicated that the greatest increase in birth weight can be expected between first and second calves, usually being between the ages of three and four years. From the same long-term studies it has been observed that dam maturity for calf birth weight has been attained at six- to nine-years-of-age. The findings have consistently been that increases between first calving and maturity of the order of 2.5 to 5.0kg may be expected for the birth weights of calves from most beef breeds, including both the B.taurus and B.indicus species (Brinks et al., 1962; Burris and Blunn, 1952; Everett and Magee, 1965; Harricharan et al., 1976; Hight, 1966, 1968b; Knapp et al., 1942; Koch and Clark, 1955; Kress and Webb, 1972; Smith et al., 1976; Swiger et al., 1962).

Drewry et al. (1959) reported a correlation between calf birth weight and lactation number of the dam of 0.32 which also indicated that older cows tended to give birth to heavier calves.

Some workers who failed to find a significant age-of-dam effect

or influence of parity on birth weight, were Singh et al. (1970) and
Tudor (1972). The latter was reporting upon levels of nutrition that,
in his view, were either sufficiently high as to reduce the competition
between the growing foetus and growing dam at young ages of dam, or too
low to allow parity to influence birth weight. Rollins and Guilbert
(1954) found the effect of age of dam smaller for female calves than
for males.

Besides the general influence of age of dam on birth weight of
calves born to all ages of dam, there is the influence of dam's age at
first calving. Philipsson (1976b) reported that the effect of age at
first calving on birth weight was highly significant. In the group of
Swedish Friesian heifers studied by him, birth weight increased linearly
with age at 0.1kg per month for ages of dam between 25.3 and 30.8 months.
Amongst a group of Swedish Red and White cattle of similar age to the
Swedish Friesians, the relationship was curvilinear with an increase of
approximately 0.3kg per month up to 28 months of age. A second group
exhibited a linear increase of approximately 0.3kg per month.

Bernard et al. (1973) found that calves born to Beef Shorthorn
cows calving for the first time at three-years-of-age were 0.8kg ($p < 0.01$)
heavier at birth than those born of cows calving for the first time at
two-years-of-age. Pleasants (1974) compared the calves of Angus three-
year-old heifers which had calved first as two-year-olds and the calves
of a group calving first as three-year-olds. He found a significant
difference (2.8kg; $p < 0.01$) in favour of the former cows.

The regression of birth weight on gestation length has been seen
to be significant in most cases and hence the possible effect of age-of-
dam on birth weight through its direct influence on gestation length has
been considered in the literature. Burris and Blunn (1952) reported an
intra-breed correlation between age of dam and gestation length of 0.078
(non-significant) for cows ranging in age from two to eleven years.
Others who have recorded non-significant age-of-dam effects on gestation
length have been Burris et al. (1964); Knapp et al. (1940); Lasley et al.
(1961); Reynolds et al. (1965); and Tudor (1972).

Despite the lighter birth weights exhibited by calves of dams at
younger ages, especially two- and three-year-olds, there is evidence
that the incidence of stillbirth and calving difficulty is greater in that

age group than all others combined. Investigations have generally shown that the frequencies of dystocia and stillbirth are two to four times greater for heifers than for older cows.

Philipsson (1976b) reported significant differences between Swedish Friesian cows and heifers for mean frequencies of calving difficulty, stillbirth rate and birth weight. The mean frequencies of calving difficulties were, for heifers: 15.7 percent; cows (parity $\geqslant$ 2), 4.8 percent. The stillbirth rates were 6.5 percent and 2.5 percent, respectively, while the birth weights and gestation lengths of calves of cows exceeded those of heifers by 3.1kg and 1.0 days, respectively.

Philipsson (1976b) observed that results from studies on first calvings are somewhat conflicting, but there seem to be higher frequencies of calving difficulty and stillbirths when heifers are very young (two years or younger) or old (greater than three years). Absher and Hobbs (1968), working with Angus and Hereford cattle, found that 64 percent of heifers under two-years-old at calving required assistance compared to 41.0 percent of heifers over two years (p<0.10). Both figures are much greater than the incidences reported in New Zealand, but the difference between the age groups is noted.

Among the dam components affecting calving performance and stillbirth rate, parity appears to be by far the most important single cause of variation (van Dieten, 1963; Dreyer, 1965; Freeman, 1975; Remmen, 1975; Schlote et al., 1975). van Dieten (1963) concluded from his study, however, that it is probably the mere fact that the process of parturition takes place for the first time that makes the difference between heifers and cows rather than age itself. Philipsson (1976b) considered that other factors such as further growth and skeletal development after first calving also have a positive influence on subsequent calving performance. The higher frequencies of dystocia and stillbirths at low calving ages may be largely dependent on poor development, caused by unsuitable feeding relative to the chosen calving age. However, results from studies by Brännäng et al. (1975) on monozygotic twins, calving at different ages, but at the same weight, indicate that there is also a positive effect of aging itself on calving performance, independent of body weight.

(vi)   Year and season of birth

The effect of the plane of nutrition of the dam on the birth weight
of the calf is to be examined in detail (Section 1.3 xi). The season of
birth is likely to influence the birth weight of the calf indirectly through
the nutritional plane of the dam and also by any concomitant changes in
gestation length. Alexander et al. (1960) concluded from a review of a
number of studies that the calving period is quite short relative to the
time taken for seasonal changes to occur and hence the seasonal influence
is minimal.

Everett and Magee (1965) analysed birth weights and gestation lengths
of 1064 Holstein calves under Northern Hemisphere conditions, found
significant effects of year and season of birth on birth weight, but not on
gestation length. Calves born from September to March (Northern Hemisphere
winter) averaged 0.72kg heavier than calves born from April to August
(Northern Hemisphere summer). Knapp et al. (1940) observed that the
seasonal variation in the birth weights and gestation lengths of Beef and
Milking Shorthorns was non-significant (1.3kg at most). Among the Beef
Shorthorns the largest calves were born in the autumn months and these had
the longest gestation periods.

In contrast to their review, the results of a study by Alexander
et al. (1960) showed significant (p < 0.01) year differences for birth
weight. The major influencing factor appeared to be a drought year accom-
panied by an extremely low plane of nutrition imposed as a treatment. The
effect of these austere conditions was a reduction in mean birth weight of
2.3kg in the Hereford herd. An important point made by the authors was
that while the birth weight of calves varied from year-to-year, the effects
of the various other factors influencing birth weight did not differ between
years. Their general observation was that birth weight seemed to be little
affected by environmental conditions unless they were extremely severe.

Those workers who reported non-significant effects of year on the
birth weight of calves included O'Mary and Coonrad (1972); Burris and
Blunn (1952) where management was considered to be relatively uniform; and
Burris et al. (1964).

Several workers have discussed the effect of time of calving on birth
weight as it operates during the calving season, and most have concluded

that birth weight can be expected to increase as the season progresses.
Alexander et al. (1960) reported that, on average, birth weight increased
by 0.43kg for each 10 days during the calving season resulting in a total
average increase of 3.9kg for the 10-week calving period. The effect,
however, was slight as indicated by the size of the correlation coefficient
reported (0.19) between birth weight and weaning age. Only 3 percent of
variation in birth weight was due to the time of calving, compared to 6 per·
cent for the weight of the dam.

Drewry et al (1959) reported a correlation between birth weight
and calf age at sampling of -0.50, which suggests, more strongly than the
regression of -0.04kg per day reported by Koch and Clark (1955a), that
calves with heavier birth weights were younger at time of sampling. It
has been suggested by Koch and Clark that any differences exhibited as a
seasonal effect are due to improving pasture conditions, or a longer
gestation length with progression of the calving period. Singh et al.
(1970) reported a non-significant influence of the month of birth although
concurred with other published reports that calves born later in the season
were slightly heavier at birth, and also grew faster than calves born
earlier.

If some seasonal effects on birth weight have in fact occurred and
birth weights have been seen to increase in the winter period especially,
then the effect of season on calf survival, as affected by birth weight,
gains some importance. Bar-Anan et al. (1976) reported that among heifers,
both the incidence of difficult calving and peri-natal mortality were high
in winter and low among summer calvings. Studying stillbirths in range
cattle, Woodward and Clark (1959) observed that season of birth had no
effect on the incidence of dystocia and that difficult calvings were quite
uniformly distributed throughout the calving season. Calf mortality rates
were not affected by season or year in the reports of Laster and Gregory
(1973); Laster et al. (1973) and Sagebiel et al. (1969). The year effect
significantly (p<0.05) influenced calf mortality in the reports of Smith
et al. (1976) and Dearborn et al. (1973), although the latter authors
acknowledged that since age at first breeding was confounded with year of
birth, part of the year effect may have been due to age of cow.

Concluding this section of the influence of season and year on calf
birth weight, it appears that both effects may operate to a limited degree
with year effects expected to be larger than season of year effects.

(vii) The maternal environment

The degree of control of birth weight possible via any manipulation of the dam will be dependent on the proportion of variation in birth weight attributable to the dam, and in the long term, any response to selection this genetic ability of the dam may exhibit. Everett and Magee (1965) have described the birth weight and gestation length of a calf as being influenced both by the maternal ability of its dam and by the genes contrib- uted to the calf by the sire and dam. Maternal ability may be defined as environmental and genetic factors other than the calf's genes, such as nutrient supply, which influence birth weight or gestation length. It may be considered to be environmental from the point of view of the calf althoug its effect is genetically determined to some extent.

Bogart (1959) has examined pre-natal growth, and considered that the size of the mother appears to have a large effect on birth weight, possibly due to a transmission to her offspring of a sample of her own genetic potential for growth and adult body size which could cause her offspring to grow more rapidly during pre-natal life. The author described the classic experiment conducted by Hammond (1935) using reciprocal crosses of the Shir and Shetland breeds of horses. The Shire dam produced a crossbred foal of 53kg at birth compared to the 17kg birth weight of the Shetland mare's foal. The factors proposed as influencing the discrepancy included foetal nutrition, cytoplasmic inheritance of the egg produced, and the level of growth hormone secreted by the pituitary of the mother.

Whatever the cause of the greater size of the young at birth from larger females, there appears to be some influence other than the genetic constitution of the young, since both foals should have had similar genetic ability for growth.

Koch (1972) has found that reciprocal crosses among Angus, Hereford and Shorthorn cattle have illustrated differences which exist for post- natal maternal influences, but generally these differences have lacked significance so far as birth weight is concerned. Sagebiel et al. (1973) found that maternal effects were largely non-significant in a crossbreeding situation except for male calves from a Charolais-Hereford cross. Similarly other crossbreeding studies involving British beef breeds have failed to find a significant amount of maternal influence on birth weight (Gaines et a: 1966; Gerlaugh et al., 1951; Gregory et al. 1965).

Some reciprocally-crossed dairy breeds, as reported by Donald et al.

(1962), did show significant differences among the birth weights of the crossbred progeny. However, although reciprocal crosses provide evidence that differences in maternal effects on birth weight and weaning gain are real, they are not too helpful in quantifying relative variation attributable to maternal effects.

Biometrical aspects for assessing relative contributions from maternal and individual genetic effects on variation in growth for beef cattle were shown in path coefficient diagrams by Koch (1972); Willham (1963); and Koch and Clark (1955d).

An estimate of total maternally related variation and covariation is derived by comparing maternal half-sib with paternal half-sib correlations. Koch and Clark (1955b) have expanded the comparison. The relationship among maternal half-sibs differ from those of paternal half-sibs because of the additional influence through the maternal environments provided during the pre- and post-natal periods. There is no direct measure of the influences included in the maternal environments; these can be inferred only from observation and by comparing the relationships when the effect has been excluded with those where it is included, such as paternal half-sibs compared with maternal half-sibs.

From data collated by Koch (1972), the average correlation among paternal half-sibs for birth weight was 0.11; the average maternal half-sib correlations among all calves was 0.25; and of adjacent calves, 0.29. Thus, maternally-related variation accounted for 14 to 18 percent of the phenotypic variance in birth weight.

Everett and Magee (1965) reported a high negative genetic correlation between genetic ability and maternal ability for birth weight and gestation length. Koch (1972) placed the correlation at -0.44 after collation of data from several origins. Philipsson (1976c) recorded a value of -0.53 for birth weight and -0.56 for gestation length. The negative correlation indicates an antagonism between the genes for prenatal growth and the genes conditioning the intra-uterine environment for heavier foetal weights (direct and maternal effects). Further support for a negative correlation of this sort has come from studies by Deese and Koger (1967) and Roman et al.(1970).

The relationship is two-fold in effect. First, the size of the maternal environment component is seen to compensate for the strength of the genetic ability for growth possessed by the calf. Calves of weak potential for intra-uterine growth will be met with a favourable environment, and stronger growing calves will be met with a less favourable environment. This is the major reason for the poor response to selection for birth weight when the selection is based on the performance of the dam. Most of those who have studied the relationship have indicated that the genotype of the calf marginally exceeds the maternal environment in importance with respect to birth weight, mainly because of the influence of the sire through inheritance (Philipsson, 1976c).

Secondly, the relationship ensures that, where the maternal environment is affected by the influence of the prevailing nutritional and climatic effects on the dam, the calf is able to cope with its altered uterine environment by becoming more or less competitive for circulating nutrients.

(viii)   The heritability of birth weight

Heritability estimates have been presented by breed and method of determination (see Table 2.5). Pre-natal growth in terms of birth weight and gestation length is seen to be moderate to highly heritable; support for high heritability values is found in the variation in the average birth weight of sire groups. Quesenberry (1950) reported a range of 33kg to 42kg in the average birth weight of sire groups of an unstated breed of calves. This variation would not be expected to be so great unless the bulls used differed in the inheritance they contributed for pre-natal growth. Bogart (1959) considered this would indicate that genetic influences among these cattle were greater than environmental influences as factors affecting pre-natal growth.

It has been reported that the heritability of birth weight is moderate to high in relation to other productive traits and therefore it shows response to selection. Further, it is an indication of the strength of the relationship which may be expected between the recorded birth weight of a sire and the birth weight of his progeny. It is impossible to say, however, how much change in the birth weight or gestation length could occur without affecting the survival of the foetus, which in turn, may limit the modification possible in either trait (Jafar et al., 1950).

Table 2.5

The heritability of birth weight

Breed	h^2 estimate	Method of estimation	Reference
Angus	0.27	paternal half-sib	Baker (1974)
Angus	0.17	regression	Brown and Galvez (1969)
Hereford	0.36		
Angus, Hereford	0.22		Burris and Blunn (1952)
Shorthorn	0.25		Dawson et al. (1947)
Holstein	0.22		Everett and Magee (1965)
Hereford	0.45; 1.00		Gregory et al. (1950)
Santa Gertrudis	0.55		
Sahiwal	0.13		Harricharan et al. (1976)
Brahman	0.35		
Hereford	0.35; 0.42		Koch and Clark (1955 b, c)
Angus	0.89		Koger et al. (1975)
Hereford	0.88		Loganathan et al. (1965)
Angus	0.99		Meade et al. (1959)
Hereford	1.00		
Angus	0.30		Swiger et al. (1962)
Hereford	0.37		
Criollo	0.24		Verde and Bodisco (1974)
Santa Gertrudis	0.67		Willis and Wilson (1974)
Hereford	0.42	Sire on progeny regression	Knapp and Nordskog (1946)
Hereford	0.53		Knapp and Clark (1950)
Hereford	0.67		Lasley et al. (1961)
Hereford	0.72		Shelby et al. (1954)
Hereford	0.54		Shelby et al. (1960)
Hereford	0.44	Dam on progeny regression	Koch and Clark (1955c)
Hereford	0.23	Intra-sire correlation	Knapp and Nordskog (1946)

On the other hand, the factors associated with calf survival, including degree of difficulty at calving, peri-natal mortality incidence, and stillbirth rate, have been shown to have a very low heritability whether measured as a trait of the cow (0.3 to 2.4 percent) or of the calf (0.0 to 4.5 percent) (Philipsson, 1976a; Bar-Anan et al., 1976; Dearborn et al., 1973). These low heritability estimates were indications that pre- and post-natal survival traits are largely influenced by environmental or non-additive genetic sources of variation, and would not respond to either natural or artificial selection (Dearborn et al. 1973).

(ix)   The repeatability of birth weight

Alexander et al. (1960) have defined the repeatability of a trait as the proportion of the variance among cows each with one record which is due to permanent differences among the cows. It may also be regarded as the correlation between repeated records by the same individual, and this latter approach is the one used in the discussion of birth weight (and gestation length) in cattle. Obviously, traits such as birth weight occur only once in an animal's lifetime and are repeatable only when considered a characteristic of the cow.

From the review of Pleasants (1974), repeatability may be calculated for birth weight in either of two ways, but neither takes account of the variations in gestation length.

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

Botkin and Whatley (1953), working with Hereford cows, reported a repeatability of birth weight of 0.18, as determined by intra-class correlation between weights of calves from the same dam, while the regression of all subsequent records on the first record was 0.14. Willis and Wilson (1974) also used the two methods of repeatability estimation and obtained values of 0.22 by intra-class correlation and 0.24 by regression of later on earlier records.

Koch and Clark (1955b) reported a range of values from the literature of -0.03 to 0.25, and they presented a value of 0.26, calculated by the intra-class correlation method. Meade et al. (1959) reported values of 28 percent for the Hereford herd studied and, for the Angus herd, a figure of 35 percent. Alexander et al. (1960) reported a repeatability

value of 0.25, and Plasse et al. (1968) obtained a value of 0.27 for a Santa Gertrudis herd.

If repeatability is to be used as a guide to prospective birth weights of calves then its reliability as a technique requires examination. Since the variance among individuals is partly composed of the permanent environmental differences peculiar to the individual, then understandably the permanent differences in environment attributable to the dam will have much greater influence on birth weight than on weaning weight. Hence the repeatability of weaning weight could be expected to be lower than the repeatability of birth weight and this was observed among sheep studied by Blackwell and Henderson (1955). Gregory et al. (1950), however, found the repeatability of yearly performance of the cow to be much lower for birth weight than for gain or weaning weight. These authors found the repeatability of birth weight was higher when corrections were made for the sex of the calf. This point indicated that repeatability of birth weight is low because its accuracy as a predictor of future performance is restricted by the influence on birth weight of major variables such as age and parity of dam, sex of calf, sire of calf and maternal environment.

The magnitude of the effect of sire on repeatability estimates was indicated by Jafar et al. (1950) who found for gestation length, a trait correlated with birth weight, that the repeatability estimate was 0.29 if the cow was mated to a different bull for each pregnancy. If the cow was mated to the same sire each time this "repeatability" would be increased to 0.41.

Botkin and Whatley (1953) concluded that if birth weight is used as a measure of a cow's production, selection on the basis of the first record would not be very accurate. Furthermore, in the strictest sense, the repeatability estimates derived apply only to conditions similar to those in which they were obtained, although the similarity of different estimates of repeatability of the various traits in beef cattle indicates the estimates can be applied to a wider range of conditions.

(x)   Sire of calf

That breed differences exist for birth weight and gestation length is well established, and differences between breeds of sire mated to a single dam breed have been studied and reported widely, inter alia Carter

et al. (1975); Haycock (1973); Laster and Gregory (1973); O'Mary and
Coonrad (1972); Smith et al. (1976).

In this Section the emphasis is placed on examining the proportion
of phenotypic variation in birth weights which may be attributed to the
sire of the calf. The usual methods of estimating this proportion have
been to conduct comparisons between individual sires of the same breed
mated to a large population of cows varying in age and parity, and usually,
though not necessarily, of the same breed as the sires. Reports in the
literature have provided evidence that successful measurement of differ-
ences between sires of a breed may be made in a crossbreeding situation
provided the dam breed, or breeds, are allocated evenly to each sire (Koger
et al., 1975; Dunn et al., 1970).

It was seen (Section 1.3 viii) that the heritability of birth
weight was moderate to high, indicating that a response to selection for
it exists (Bosman and Harwin, 1966). Frahm et al. (1975) have reported
that after six years of (indirect) selection for birth weight, calves
sired by young, selected Hereford bulls were 5.9 percent heavier at birth
than calves sired by the foundation sires. Gianola and Tyler (1974) were
of a similar opinion that the traits of birth weight and gestation length
could be easily modified by mass selection of sires. The poor response
to selection among dams for birth weight has already been discussed.

This evidence of heritability estimates and selection responses
indicates clearly that variation in calf birth weight due to sire exists.
Several reports in the literature add further experimental confirmation;
significant differences between sires within a breed were noted by
Andersen and Plum (1965); Bosman and Harwin (1966; $p < 0.01$); Brownson
(1974); Knapp and Nordskog (1946); O'Mary and Coonrad (1972); O'Mary
and Hillers (1976: $p < 0.05$); Philipsson (1976c; $p < 0.001$).

Gianola and Tyler (1974) found that among the Holstein-Friesian
calves of their study, sire accounted for 7.6 percent of the phenotypic
variance of birth weight, and 13.6 percent for gestation length. Brown
and Galvez (1969) demonstrated that sire effects accounted for 9 percent
of the variation in birth weight in Angus calves and 20 percent in Herefords.
Schwark and Oehler (1973) showed that, for male and female calves, 6.76
percent and 9.07 percent, respectively, of variance in birth weight could

be attributed to the sire. In that study the dam contributed 32.37 percent of the variance in calf birth weight.

In so far as dystocia has been linked with oversize at birth, and high birth weights, it is appropriate to note that Philipsson (1976c) reported a variation among Swedish Friesian bulls as sires of between 3 and 26 percent for frequency of calving difficulty. With respect to the time elapsed for the parturition process, O'Mary and Coonrad (1972) found significant differences (p <0.05) between Charolais sires in their effect on the length of the parturition process with a range of sire means from 28.8 to 82.2 minutes. Likewise, a significant difference (p <0.05) between Angus sires was due to the mean range of 17.0 to 41.4 minutes.

Smith et al. (1976), working with Hereford and Angus dams, and seven sire breeds, examined factors related to calving difficulty. They reported that after average within breed differences in birth weight were removed, among sire variability in dystocia level was still highly significant. The nature of this remaining variation was not known, but differences in calf shape were suggested as accounting for a part of it.

The results obtained by Philipsson (1976c) indicated that, for the elimination of calf losses due to dystocia, the most rapid breeding results would, in the short term, be obtained if bulls mated to heifers were tested for their calving performance. The low heritability of dystocia (as determined by paternal half-sib correlation) and the high variability between sires within breed for dystocia indicate that the selection of sires for mating with maiden heifers, especially, should be made on an individual sire basis.

Those who found non-significant sire effects on calf birth weight have included Dawson et al. (1947); Burris and Blunn (1952) and Burris et al. (1950).

Among those who have indicated an influence of the sire of the calf on its gestation period have been Alexander (1950); Gerlaugh et al. (1951); Jafar et al. (1950); Rife (1948); Rife et al. (1943).

Britto (1973), working with Zebu bulls in Cuba, found significant differences between sires, with gestation lengths ranging from 288.15 to 294.15 days. Among eight Hereford bulls, Rice et al. (1954) found a

significant (p<0.01) variation in gestation length from 284.0 to 289.6 days.

One of the implications of a measurable sire effect on gestation length and birth weight is that the calf controls its gestation period and the initiation of the birth process, for obviously the sire of the calf cannot directly influence the maternal environment and the part it plays in parturition (Laird and Hunter, 1977).

(xi)   The pre-calving nutritional regime of the dam

Under normal New Zealand management practises, beef-breeding herds are pasture fed throughout the year and hence are subject to seasonal variation in feed availability. The period of greatest concern to the herd manager is during the winter and early spring when animal consumption most nearly equals the amount available, both as pasture and reserves, and may even exceed it. It is usual in New Zealand for winter feeding to be the most expensive input of the year and any endeavour that will reduce this overhead cost of the maintenance of the cow ensures that the enterprise will be able to support the maximum number at that time in order to take advantage of abundant pasture growth at other times. It has been well documented (National Academy of Sciences, 1970; Agricultural Research Council, 1965) that feed requirements during early- and mid-pregnancy are low relative to those required in lactation, and hence the main concern is the maintenance of the cows themselves.

With respect to feeding gestating beef cows, the amount of pasture available will determine whether a period of reduced intake will occur naturally, or whether the feed level may be sufficiently high as to warrant intervention by the herd manager in order to artificially limit food intake. In many of the reports in the literature relating to both situations the studies were designed to determine primarily the response of calf birth weight to pre-calving manipulation of the intake of the dam. The secondary considerations were the effect of reduced birth weight on the incidence of dystocia, and also the effect of the pre-calving plane of nutrition on the productivity of the cow, including the pre-weaning performance and weaning weight of the calf, and the milk production and rebreeding performance of the dam.

The major New Zealand studies relating to the influence of winter nutrition throughout the last two trimesters of gestation on calf birth

weight and herd performance have been conducted by Hight (1966, 1968b, c).

Hight (1966) found that among 122 mixed-age Angus cows, a low plane of nutrition from 83 days pre-calving until parturition induced a cow live weight loss of 0.66kg per day so that immediately pre-calving, cows on a low plane were approximately 10 percent lighter than at the start of the treatment, compared to an approximate 12 percent live weight gain in cows fed a high plane.

Calf birth weights were 20 percent (5.4kg) lighter among the calves of cows fed the low plane than among the calves of cows fed a high plane, and the difference had increased to 16.5kg at weaning. Hight found no significant difference between the nutritional groups for percentage of cows conceiving in the subsequent breeding season.

In a later study, Hight (1968c) found that the effect on birth weight of feeding Angus cows a low plane of nutrition in the early gestation period could be largely offset by feeding an increased plane of nutrition for a period before expected calving date. Two groups of cows fed a low plane were fed a high plane 8 and 3 weeks, respectively, before calving, and the former group had birth weights which were 1.6kg (6 percent) higher than the latter group. Nevertheless, the cows on the low planes had average birth weights lighter by 7 and 13 percent, respectively, than a group fed a high plane continuously. The author found, however, that across treatments, the effects of nutrition on birth weights were partially confounded with positive residual effects of previous nutritional studies conducted with the animals (Hight, 1968b).

From his study, Hight (1968c) concluded that the effects recorded in his trial, were likely to represent the maximum differences that could be produced in cow and calf production, since substantial live weight reductions of the mature beef cows could not be made during the early stages of undernutrition unless food intake was severely restricted. In contrast, the high plane cows showed only small live weight gains prior to calving despite attempts to increase this by feeding autumn-saved pasture and hay to appetite.

Cow mortality was increased by a low plane of nutrition pre-calving although those which died were not always in the poorest condition or the lightest in the group. Calf deaths were also greatly different between

treatments (HP:1; LP:6), the deaths being diagnosed as caused by
starvation. Hight considered that the higher mortality rate of calves
of three- and four-year-old cows fed on a low plane of nutrition pre-
calving, compared with those of older dams indicated that the younger
cows may be more susceptible to undernutrition and so should receive
preferential feeding near the time of calving.

An important mechanism operating to protect the calf from a
prolonged nutritional stress, besides a compensatory hypertrophy of the
area of placental contact, appears to be a change in the proportion of
conceptus comprised by the calf. Studies have shown that the calf
normally comprises about 51 to 54 percent of the conceptus; under
nutritional stress this proportion may rise to as high as 66 percent
(Ewing et al., 1966; Joubert, 1954; Ryley, 1961).

Furthermore, studies by Hight (1968c); Joubert, 1954; Pinney
et al. (1972); and Smithson et al. (1966) have shown a strong compens-
atory mechanism (residual effect) in cows restricted more than one year
where an improved efficiency of utilization of nutrients, especially with
respect to the growth of the gestating foetus, leads to a lesser effect
of low planes of nutrition imposed in subsequent years. In addition,
Joubert (1954) found that, among Jersey and Jersey-cross heifers,
pregnancy improved the efficiency of utilization of intake and offset some
of the effect of the restriction on calf birth weight, inspite of the need
for the continued growth of the dam in addition to that of the foetus.

Turman et al. (1964) have shown that extremely high levels of energy
intake reduced the life-span and impaired the milking ability of the beef
female as well as being excessively costly. Extremely low levels resulted
in poor reproductive performance, low milk yields and light weaning weights.
Jordan et al. (1968) obtained results which indicated that the protein
supplementation of the dam's ration has an effect on birth weight only
under extremely low levels of intake.

Other workers who have shown that energy rather than protein intake
during late pregnancy exerts the greater influence upon the birth weight
of the calf have included Blaxter (1957); Wagnon and Carrol (1966); and
Wiltbank et al. (1962).

Because pregnant breeding cows in New Zealand graze pasture, the foregoing findings have relevance in that they confirm that the levels of pasture consumed will be related to cow performance. Cow live weight change as a measure of cow performance will reflect energy levels consumed, since protein levels have not been found to be critically low in relation to the amounts of energy available under normal mixed-sward conditions.

There have been numerous studies reported in the literature which have evaluated the influence of a restricted level of intake of the dam upon the birth weight of its calf, and any effect that this level has had on calving difficulty, especially due to dystocia or calf oversize. The findings have been almost equally distributed between a positive signific-ant effect of nutritional level on calf birth weight, and no significant effect. There were very few studies reviewed, however, where the plane of nutrition, when limited, significantly reducedthe incidence of calving difficulty. Some who did report a reduced level of calving difficulty were Arnett et al. (1971); Bond and Wiltbank (1970); and Christenson et al. (1967).

From the Oklahoma Agricultural Experimental Station, Turman et al. (1964) reported that the two levels of nutrition, namely, a high plane (less than 5 percent loss of live weight including weight lost in the conceptus at parturition) and low plane (20 percent or more live weight loss including loss due to the conceptus) had a marked effect ($p < 0.01$) on the birth weight of calves of two-year-old heifers (8.4 percent reduction). Despite the lowered birth weights, the incidence of calving difficulties was not reduced. It is also important to note, especially as regards the subsequent performance of young dams, that weaning weight was significantly ($p < 0.01$) reduced, that the time to first oestrus was significantly increased (93 vs 56 days), that conception rate suffered, and that calving interval, or the time between first and second calves, was increased by one month, all as a result of the pre-partum nutritional restriction.

From an Australian experiment involving Hereford heifers calving first as three-year-olds, Hodge and Rowan (1970) reported a significant ($p < 0.01$) effect upon calf birth weight as a result of varying the nutritional regime during the last 160 days of gestation. There were no significant differences between the three treatments imposed for incidence of dystocia, nor was the birth weight of any group related to the likelihood of stillbirths.

Corah et al. (1975), working with first- and second-calving
Hereford dams found that heifers restricted in their pre-partum energy
intake had lighter calves at birth, but calves were born with the same
degree of calving difficulty as those of adequately-fed dams. More
calves from nutritionally-deprived heifers died at or near birth and the
surviving calves were lighter ($p < 0.05$) at weaning. There was also a
tendency for a higher percentage of adequately-fed heifers to show oestrus
by 40 days post-partum, thereby increasing the proportion of females
cycling during the breeding season.

Others who have studied the influence of plane of nutrition on
young, low-parity cows and heifers and found a significant birth weight
reduction without any change in the incidence of dystocia have included
Corah et al. (1973); Laster (1973); and Ryley (1961).

Hodge et al. (1976), using Hereford first-calving three-year-old
heifers, imposed three levels of grazing nutrition to evaluate calving
and subsequent performance. During a period of twelve weeks pre-calving
significant differences ($p < 0.01$) between groups developed as a result of
a weight loss in one group of 2.75 percent and weight gains in the other
two groups of 2.86 and 11.61 percent. Calf birth weight was reduced
slightly and non-significantly by the low plane of nutrition, and inspite
of a small reduction in calf birth size, the incidence of dystocia did
not differ between groups. Calf mortality and stillbirths were greater as
a result of restricted nutrition. These authors considered the effort and
endurance of the heifers as they calved were adversely affected by the
levels of undernutrition required to achieve a reduced calf birth size.
Young (1968) has found that severe dietary restrictions may cause a
failure of pelvic tissues to relax.

An experiment conducted by Tudor (1972) using mixed-aged Hereford
cows involved treatments imposed approximately 105 days pre-calving (180
days after mating). As a result of the regimes imposed, a mean loss of
65kg, or 17.5 percent of body weight of cows on a low plane ration,
significantly reduced the average birth weight of the calves by 6.8kg, or
21.9 percent, compared to the high plane group which had an 8 percent gain
in live weight over the same period. There was a non-significant effect
on the number of dystocias or cows with retained placentae.

A majority of the studies in the literature have reported the influence of winter nutrition on the birth weight of calves of first-calving heifers and low parity cows largely for the good reason that calving difficulties occur mostly in immature females. Any results obtained from such investigations are likely to have relevance to mature cow herds only if it is appreciated that a portion of the feed intake of young cows is required for continuing growth and physiological development. Many of the reports have shown significant effects on birth weight of calves, calving difficulty, rebreeding and weaning per-formance of first-calving heifers where differences between groups in live weight gain over the pre-calving period existed, not necessarily only where actual weight losses occurred. However, weight losses in mature cows of up to 15 or 20 percent have been recommended by Lamond (1970) as possible without serious economic loss. An important facet that has emerged is that the reduction of birth weight was seldom seen to result in easier parturitions and any restriction severe enough to affect the birth weight usually affected post-partum performance of young dams and calves as well.

In conjunction with the earlier evaluation of other factors affect-ing calf birth weight (including the age and parity of the dam and the sire of the calf) it can be concluded from the discussion of the influence of the plane of nutrition of the dam on calf birth weight that ideally, robust cow condition at calving can be achieved, increasing the vigour of the dam during parturition, and without precipitating dystocia.

Indications have been that this can be achieved by restricting pregnant cows early in the gestation period to promote a live weight loss from autumn of about 10 percent, then offsetting the live weight depression with elevated nutrition prior to expected calving date (1 to 2 months, dependent on the breed of calf and live weight loss of dam).

Among maiden heifers and immature cows the selection of the sire of the calf is extremely important, especially among breeds known to be prone to dystocia due to high birth weights.

2.   Calf Weaning Weight

   2.1   Introduction
        The discussion of factors affecting the birth weights of calves
has established that the control of weight of calf at birth is largely
by the genotype of the calf. The variation reported as a result of
environmental influences is small under all but extremes of nutrition
and climate. After birth, however, it will be seen that the stable
environment provided the calf by the dam pre-partum even to her own
detriment, no longer exists, and that there is much between-dam variation
in the balance between lactation and body weight gain or recovery. Further-
more, the ability of gestating cows to tolerate the restricted intakes of
winter pasture and conservates discussed in the section concerning birth
weights (Section 1.3 xi) ceases because of the high energy demands of
lactation and simultaneous preparation for rebreeding.

        At weaning a major change in diet is experienced by the calf since
the milk portion is removed, a situation aggravated by the breaking of
the dam-offspring bond. The age most normally chosen is approximately
200 days, although the age spread will obviously depend on the length of
the calving period. Therefore the age of the calf influences its weaning
weight and will be discussed in Section 2.2 (iii), together with methods
for correcting to a constant age basis.

        It is appropriate to establish early in the discussion the close
relationship between weaning weight and average daily gain from birth to
weaning. Koch and Clark (1955a) obtained genetic and phenotypic correl-
ations of 0.98 between average daily gain and weaning weight, while
Lehmann et al. (1961) reported figures for the two correlations of 0.93
and 0.97, respectively.

        To appreciate the implications of the factors which influence
weaning weight and pre-weaning weight gain, a brief evaluation of the
importance of these two traits is required. If calves are slaughtered at,
or soon after weaning, the consequences of superior maternal ability,
largely manifested as milk production, will either be the heaviest progeny
at constant age, or the shortest time to slaughter at a constant weight
(Walker, 1963).

        In view of the dependence of the calf upon the dam before weaning,

it is important to evaluate weaning weight with respect to post-weaning average daily gain (PWADG) because of the markedly different environment experienced after weaning. Almost without exception studies have found that weaning weight and average daily gain from birth to weaning were negatively correlated with PWADG, and highly, positively correlated with final weight (at 12, 15 or 18 months-of-age).

The magnitude of the findings of Brinks et al. (1964; Table 2.6) may be regarded as representative of associations between weights at various ages of calf reported elsewhere in the literature where the relation of pre-weaning performance to post-weaning performance was usually strongly negative (Brumby et al., 1963; Jeffery and Berg, 1972; Klosterman et al., 1972; Mason, 1951).

Despite the negative regression of gain from weaning to 21 months on weaning weight (b = -0.32), Brumby et al. (1963) found that calves heaviest at weaning were also the heaviest at 21 months (b = +1.0). Support for a weight advantage at weaning continuing to be maintained comes from Swiger (1961); Neville et al. (1962b); Christian et al. (1965); Drennan (1971b) and Tonn (1975).

A major reason for the poor relationship between PWADG and measures of pre-weaning gain and weaning weight is the partial masking of the genetic ability for growth during the pre-weaning period by the milk production of the dam. After weaning, the calf's genetic potential for growth may be expressed, and the negative relationship between pre- and post-weaning gain suggests a compensatory growth effect operates (Brumby et al., 1963; Tonn, 1975). Jeffery and Berg (1972a) have found that PWADG is more closely related to birth weight than it is to weaning weight; this was suggested as being further evidence for the masking by pre-weaning maternal environment of the calf's potential for growth.

The implications of most of the above findings are that the optimization of weaning weight is desirable if final carcass weight is to be maximized, as is usually the case. However, the efficiency of utilization of intake is expected to be greater among animals of lighter weaning weight because of expected superior PWADG and lesser body maintenance requirements. Klosterman et al. (1972) were able to confirm this from results of a study where, among three breeds and their crosses, Hereford cows produced lighter calves at weaning than either Angus, Charolais or crossbred dams whereafter Hereford calves exhibited the greatest post-

Table 2.6

Genetic, environmental and phenotypic correlations

among traits at various ages of Hereford cattle.

From: Brinks et al. (1964)

age	Correlated trait	Gain, birth to weaning	Weaning weight	Gain, weaning to 12 months	12 months (final weight)
Birth weight	G	0.46	0.60	0.07	0.56
	E	0.08	0.28	0.14	0.32
	P	0.23	0.41	0.11	0.42
Gain, birth to weaning	G		0.99	−0.23	0.67
	E		0.98	−0.16	0.71
	P		0.98	−0.19	0.69
Weaning weight	G			−0.20	0.71
	E			−0.13	0.75
	P			−0.16	0.73
Gain, weaning to final weight (12 months)	G				0.55
	E				0.56
	P				0.56

weaning performance.

The objective of producing high calf live weights at weaning has been found to be detrimental when applied to potential breeding females. Christian et al. (1965), working with Hereford cows and progeny, found that there were consistent negative associations of dam's weaning weight with all measures of milk and butterfat production, whereas the calf's weaning weight was positively correlated with dam's production.

2.2 Factors Affecting Pre-weaning Performance and Weaning Weight of the Calf

(i) Breed

The two numerically superior beef breeds in New Zealand, Angus and Hereford, have been widely used in trials overseas as well. It has generally been found that the superiority of the Hereford breed over the Angus at birth (approximately 5kg) is reversed by weaning, being mostly influenced by the greater milk production measured in Angus dams than Herefords (Dunn et al., 1965; Melton et al., 1966; Smith et al., 1976). Sellers et al. (1970) reported that Hereford calves exhibited greater growth potential only if offered creep feed, but in a situation of depending entirely on their dams' milk and pasture grazing for nourishment, Hereford calves did not perform as well as Angus calves as measured by weaning weight.

Among those to confirm Angus calves to be heavier than Herefords at weaning under comparable conditions have been Dunn et al. (1965); Humes et al. (1975); Jeffery et al. (1971b); Lindsay et al. (1970); Meade et al. (1959); Rhodes et al. (1970); and Smith et al. (1976). Some who found that calves of Hereford dams exceeded the weaning weights of calves of Angus dams were Baharin and Beilharz (1975); Boston et al. (1975); Cunningham and Henderson (1965a); and Melton et al. (1966).

The New Zealand study of Carter et al. (1975) compared ten sire breeds, all crossed with Hereford and Angus mixed-age cows. The six-month weight of Angus-sired calves was 157kg. As deviations from an index of 100 = 157kg, the other breeds were: Hereford, 105; Friesian,112; Jersey, 99; South Devon, 110; five European breeds (Charolais, Limousin, Simmental, Main Anjou, Blonde d'Aquitaine), 111.4. In terms of sire breed,

Hereford calves were superior to Angus calves for weaning weight (7kg);
the rankings were reversed by breed of dam with calves reared by Angus
cows being 6kg heavier at six months than those reared by Hereford cows.

Among the European breeds to be studied in comparison with
Hereford and/or Angus dams has been the Charolais. Melton et al. (1966)
related the superior performance of calves from Charolais dams to the
greater milk supply they received than Hereford and Angus calves.
Carpenter et al. (1973) also used the Charolais breed in a comparative
study with Herefords and found in favour of Charolais calves, for 205-day
weaning weight, of 261kg vs 219kg.

Among several straight and crossed breeds of dam, Jeffery et al.
(1971) found that, holding age of dam, and age and sex of calf constant,
breed of dam differences explained an additional 23 percent of total
variance in average daily gain to weaning in both years of the study, and
similarly for weaning weight. The differences were largely due to milk
yield differences, for when corrected for milk yield, breed of dam accounted
for only 0.8 to 2.6 percent of total variance in pre-weaning calf
performance.

Sagebiel et al. (1974) compared straight breeds and reciprocal
crosses of the Charolais, Angus and Hereford breeds. Across all bull
breeds, Charolais cows produced calves that gained significantly faster
pre-weaning, and weighed significantly more at weaning than either Angus
or Hereford cows. However, when 205-day calf weaning weight was expressed
as a percentage of metabolic cow weight, Angus dams were significantly
superior to both the Charolais and the Hereford dams, these latter two
were comparable in this regard.

Kropp et al. (1972) and Holloway et al. (1975) compared in
consecutive years, respectively, two-, then three-year-old Hereford and
Holstein cows on range and in drylot, with Charolais, the sire breed.
The birth weights of calves of the three-year-old Holstein dams were 16
percent (44kg vs 38kg) heavier than Hereford calves, and by weaning the
difference had increased to 22 percent (330kg vs 270kg). The authors
considered the breed differences in weaning weight were consistent with
breed differences in milk yield. They found, however, that the additional
weight weaned by Holsteins over Herefords was not without cost since the
former consumed 33 to 40 percent more feed in drylot and had a reduced
rebreeding performance compared to the Herefords.

(ii) Sex

The review of factors affecting birth weight showed that male calves are normally heavier at birth than females. Studies have revealed that male calves are also heavier at weaning than females, continuing the advantage obtained at birth augumented by superior average daily live weight gain (Koch et al., 1959; Rollins and Guilbert, 1954).

Castration to produce steers involves the introduction of a third sex category. Most reports have placed steer performance above that of heifers and below that of bull calves, although the time of castration is important but is frequently not stated in the literature. Furthermore, the decision to castrate is at times, based on selection, either for size, or as progeny of non-tested sires, and therefore may implicate genetic inferiority for weight gain as well as the physiological effect of castration itself (Cundiff et al., 1966a).

Among Angus calves, Tanner et al. (1970) found that bull calves had a non-significant advantage over steers in pre-weaning average daily gain (0.86 vs 0.84kg per day, respectively), but that steers gained significantly (p <0.05) more per day than heifers (0.84 vs 0.79kg per day, respectively). Brinks et al. (1961) reported the difference in average daily gain to weaning between Hereford bull calves, and steers castrated at 45 or 145 days, as about 1 percent, or 0.02kg per day. Bull calves gained 0.048kg per day (6 percent), and steers 0.039kg per day (5 percent) more rapidly than heifer calves.

Koch et al. (1959) reported an average sex difference of 0.05kg per day between bulls and heifers while Marlowe and Gains (1958) found that bull calves gained about 4 percent faster than steers, which in turn gained 8 percent faster than heifers. Berg (1961) used Least Squares estimates of weight per day-of-age among 655 Angus calves to find that male calves gained approximately 0.045kg per day more than females at weaning.

Others who have published means from analysed data for average daily gain and weaning weights where males (bulls or steers) were superior to females have been Fahmy and Lalande (1972); Koch and Clark (1955a); Lindsay et al. (1970); Hight (1966, 1968); Moin et al. (1975); Singh et al. (1970); Srinivasan and Martin (1970); and Vesely and Robison (1971).

Differing shapes of the growth curves of the two sexes, male or female, have been implicated by Loganathan et al. (1965) and Neville (1962) where the rate of extra gain by bull or steer calves over heifers increased with age. Koch et al. (1959) held that the growth curve was curvilinear in shape for males and approaching linearity for females. The extent of the difference by way of superiority expressed by males appears to be influenced by a sex by environment interaction. Koch and Clark (1955a) presented data which indicated that male calves were restricted more by younger dams (three- to five-year-olds) than female calves, since the differences between the sexes increased marginally with increasing age of dam. Harwin et al. (1966) found a sex by age of dam interaction where the weaning weight of heifer calves out of two-year-old Hereford dams averaged 21.3kg lighter than heifer calves out of mature Hereford dams. The difference between bull calves from the two groups of dams was 31.8kg. The authors considered the differential response was associated with the greater growth potential of male calves, tending to make them more susceptible to pre-weaning limitations in nutritional environment provided by the dam. Pahnish (1958) also found a greater age-of-dam effect on bull than heifer calves.

Among Hereford cows, Carpenter et al. (1973) found a sex by maternal environment interaction where cows with male calves were significantly more efficient in production. Production efficiency was significantly associated with milk yield and negatively associated with feed consumption and weight change during lactation. Jeffery et al. (1971) found higher milk yields to be associated with male calves in one season and lesser production in the next. Despite the lower milk yield of the dams with male calves in the second year, male calves performed better than the female calves for average daily gain to weaning.

Cundiff et al. (1966) found an effect of type of management on the differences between sexes, with male calves responding better to creep feeding than females. Marlowe et al. (1966) found similar results with creep-fed Angus and Hereford bull calves, but the 6 percent superiority of steers over heifers when non-creep fed was the same as the difference between these sexes in a creep fed group.

(iii)   Age of calf at weaning

Most studies of suckled beef calves have reported weaning age within the range 180 to 250 days with the most frequent ages being 180,

Table 2.7

The effect of the sex of the calf on weaning weight

Breed	Weaning age (days)	Average weaning weight (kg)	Sex effect			Reference
			Bull	Steer	Heifer	
Hereford,Angus	205	189	+15	-5	-10	Cundiff et al. (1966)
Angus	205	166		+10	-10	Deutscher and Whiteman (1971)
Hereford	182	172	+6		-6	Koch and Clark (1955a)
Hereford	210	163	+12		0	Lasley et al. (1961)
Angus	205	182	+6		-6	Meade et al. (1959)
Hereford	205	170	+6		-6	
Hereford	205	166	+4		-4	Rutledge et al. (1971)
Hereford	263	219		+2.5	-2.5	Singh et al. (1970)
Hereford	200	182		+5.5	-5.5	Smith et al. (1976)
Angus	200	190		+5.5	-5.5	
Angus	205	199	+6	+3	-9	Tanner et al. (1970)
Hybrid	200	212	+20		-20	Taylor (1967)

200, 205 or 210 days. The practical need to wean calves at a determin-
ant time leads to age differences among calves, adjustment for which is
necessary if the comparison of weaning weights is to be valid. The
formula most commonly used is:

$$\left(\frac{\text{Actual weaning weight} - \text{birth weight}}{\text{age in days}} \times \text{common age}\right) + \text{birth weight}$$

This method assumes a linear rate of growth from birth to weaning
and has been seen to maladjust the weight of calves from the extreme age
groups. Minyard and Dinkel (1965) reported that younger calves tended
to be over-adjusted while older calves were penalized. The authors
compared the above method of correcting for age with a multiplicative
factor computed by linear regression of weight on age, both of which
showed a substantial reduction in regression and correlation coefficients.
Others to use the above adjustment method were Bernard et al. (1973);
Brinks et al. (1962); and Swiger et al. (1962).

The factors causing the growth rates of calves to deviate from
linearity have been extensively discussed in the literature and the
reported deviations are numerous. For instance, Swiger et al. (1962)
reported a linear regression of age from birth to 130 days, but a
significant (p <0.05) curvilinear effect from 130 to 200 days. They
found that as the summer progressed, and pasture quality deteriorated,
older calves were directly affected, and very young calves indirectly
affected through the milk supply of their dams. Under such conditions
adjusting weaning weight for the regression of weight on age could
introduce a bias.

Similarly, Drennan and Bath (1976b), working with Hereford calves
in Northern Ireland found that later born calves suffered more from a
rising risk of infection by gastro-intestinal parasites.

Generally, older calves appear to maintain their weight advantage
although they tend to grow at a curvilinear growth rate compared to
younger calves, growing at more nearly linear rates (Brinks et al., 1962;
Drewry et al., 1959; Johnson and Dinkel, 1951; Koch and Clark, 1955a;
Neville, 1962).

The evidence obtained indicates that care should be taken in according great significance to corrected weights beyond 30 days either side of the mean weaning age because of the marked changes in range environment that can occur in that time (Johnson and Dinkel, 1951).

The age of a calf at weaning has managerial implications. From the point of view of calf growth, the calving to weaning period is dependent on the milk supply of the dam, itself seen to be dependent on the available energy (Section 3.4 i). Obviously then, calving is likely to be timed to slightly precede the peak of pasture production so that pasture growth is greatest at the time of highest milk demand of the calf. The study of Walker (1963) already discussed in this Section, indicated the importance of calving early in the growing season, for if calves are weaned at constant time, as is the normal practice, oldest calves are also the heaviest. Hight (1966, 1968b) working with groups of 122 and 114 mixed-age Angus cows reported increases in the weaning weights of calves of 0.63kg (1966) and 0.77kg (1968b) for each extra day of age of calf.

Mason (1951) discussed the importance of calf age at weaning in relation to its dependence on the dam for milk. Older calves have been observed to be less reliant on their dams, and therefore less prone to nutritional stress at weaning time.

(iv)   Age and parity of the dam

Maiden heifers may be mated to calve first at two-, or three-, and infrequently, at four-years-of-age, while calving at three years may be regarded as usual in New Zealand beef breeding herds. A uniparous cow may be considered as being two- to three-years-of-age and to progress in parity with age thereafter. Reports in the literature frequently refer to age-of-dam effects only, thereby implying by omission that parity is commensurate with age.

The repeatability of birth weight was not found to be large and therefore was not likely to be significantly biased by selection of dams for related traits (weaning weight and pre-weaning gain). However, attention was drawn by various workers to the opportunity for age-of-dam effects on weaning weight and average daily gain to be confounded with selection pressure for those traits. Brinks et al. (1962) stated that

if selection among cows was practised on the weaning weights of their
calves, the small positive correlation between mature weight of cows
and the weaning weight of their calves would cause the means of the
older, more selected age groups to be slightly larger than those of an
unselected population of similar age groupings. Cunningham and Henderson
(1965b) suggested selection for weaning weight and average daily gain at
young ages of dam may be identified by a tendency for the variances of
average daily gain (and weaning weight) to decrease with increasing age
of dam indicating that cows in the upper age bracket are genetically
more alike than cows in the population as a whole.

Koch and Clark (1955a) have discussed the influence of age of dam
on calf weaning traits. If pre-weaning growth of the calf is influenced
by the genes transmitted from the dam and the maternal environment
provided the calf by the dam, then apart from genetic variation in calf
growth potential attributable to the sire of the calf, changes in pre-
weaning performance by successive calves are presumably attributable to
changes in the size, weight and physiological maturity of the dam, in
turn influencing the maternal environment provided. Rutledge et al.
(1971) found milk production by the dam to be among significant effects
on 205-day calf weight, although age-of-dam effects were non-significant.
The authors conceded that effects due to age of dam are expressed
primarily through differential milk production.

The review of birth weights revealed that maturity of dam for that
trait is reached at about 6-years-of-age. Most reports have placed
optimum weaning weights from dams of a similar age although 7-, and 8-
years-of-age have been cited in some instances.

Cunningham and Henderson (1965a) reported that pre-weaning perform-
ance improved with age of dam in a curvilinear fashion to a maximum at
7 to 10 years. Among those to verify maturity of dam at 6-years-of-age
have been Brinks et al. (1962); Hohenboken and Brinks (1969); Knapp
et al. (1942); Swiger et al. (1962); and Tanner et al. (1970).

The workers who recorded the highest pre-weaning performance of
calves of 7-year-old dams included Knox and Koger (1945); Koch and
Clark (1955a); Marlowe et al. (1965); and Singh et al. (1970).

That eight years were required before maximum productivity was

attained was found by Minyard and Dinkel (1965); Rhodes et al. (1970) and Vesely and Robison (1971).

There has been almost universal agreement that the greatest weaning weight or average daily gain differences have been measured for dams between the ages of three and four years. Some who reported significant age-of-dam differences in this respect were Berg (1961), studying average daily gain in a commercial Angus herd; Brinks et al. (1962); Cundiff et al. (1966): Jeffery et al. (1971b); Koch and Clark (1955a); and Swiger et al. (1962). Brownson (1974) found from data collected from a Hereford herd between 1965 and 1970 that the greatest difference between ages for calf pre-weaning performance was between cows of two- and three-years-of-age. Some of those who found greatest differences occurring between three- and four-years-of-age did not calve the heifers at two-years-of-age.

With respect to age at first calving, Bernard et al. (1973) reported that heifers calving first at three-years-of-age raised calves 7.7kg heavier than heifers calving first at two-years-of-age (p <0.10). Pinney et al. (1972) also found differences in favour of three-year-olds vs two-year-olds bothas first calvers, although again the differences failed to be significant. The findings of Cundiff et al. (1966b) have importance as far as marketability of weaner stock is concerned where calves of two-year-old cows were more variable in weaning weight than those in subsequent age-of-dam groups.

In addition to the lower weaning weights from maiden heifers (two- and three-year-olds), rebreeding performance is also seen to suffer most in that age group as a result of lactational anoestrus (Koger et al., 1962). To this end, Hight (1968a) has advocated preferential feeding of younger cows near calving and during lactation to avoid calf mortality and a high proportion of cows not in-calf the following year.

Pope (1967) reported that as age of dam increased so the weaning weight differences between high and low planes of winter nutrition within age of dam became less until the fifth calf crop (7- or 8-years-of-age) when the calf crop weaned was reduced by approximately 5 percent by a low plane of nutrition pre-calving. Harwin et al. (1966) and Vernon et al. (1964) reported the interaction between age of dam and years (good vs poor)

Table 2.8

Linear and Quadratic regressions of weaning weight and average daily gain on cow weight

Breed of dam	Weaning weight regression coefficient kg increase calf wgt/kg increase cow wgt.	Average daily gain kg/day / kg dam wt.	Reference
Hereford	0.05[a] 0.07 - 0.11[b]	0.00022[a] 0.00046[b]	Benyshek and Marlow (1973)
Hereford	0.0438 (linear)*; 0.082 (linear)* -0.0005 (quadratic)		Edwards and Bailey (1975)
Hereford	0.0978		Ewing et al. (1967)
Shorthorn	0.0674		Fahmy and Lalande (1972)
—	0.0073 - 0.1165		Fitzhugh (1965)
4 breeds, 4 hybrids	0.0728 N.S. (1966) 0.186 ** (1967)	0.00026 N.S.(1966) 0.00089 ** (1967)	Jeffery et al. (1971b)
20 assorted breeds	0.1177		McDonald and Turner (1969)
4 (B.indicus × B.taurus)	-0.0005 (linear) -0.00035 (quadratic)		Moin et al. (1975)
Hereford	0.07 (N.S.)		Neville (1962)
Angus	0.085		Tanner et al. (1965)
Hereford	0.049		
3 breeds	0.0426		Urick et al. (1971)
	The correlation (cow weight with calf weight at weaning)		
Hereford	0.12		Brinks et al. (1962)
—	0.11		Clark et al. (1958)
4 breeds, 4 hybrids	0.29 (1966); 0.35 (1967)		Jeffery et al. (1971b)
Hereford	0.08		Rutledge et al. (1971)
Hereford	0.03		Singh et al. (1970)
Hereford	0.34		Tanner et al. (1965)
Angus,Charolais,Hereford	0.16[c] 0.21[d]		Urick et al. (1971)

N.S. Not significant   a unadjusted cow weights   c unadjusted calf weight
 *   p < 0.05   b adjusted cow weights   d adjusted calf weight
**   p < 0.01

to be highly significant with greater age of dam differences in poor
years.

(v)   Weight and size of dam

Despite a positive relationship between the weight of the dam and
the birth weight of its calf recorded in the literature, weight of dam
was seen to account for only a small percentage of the variation in
birth weight. With respect to weaning weight it is seen again that
the relationship between weight of dam and pre-weaning performance of
the calf is not strong, but generally positive (Table 2.8). The influence
of cow weight per se contrasts markedly with the strong negative relation-
ship between the weaning weight of the calf and the weight change
exhibited by the dam during the lactation period. This will be discussed
later. Furthermore, any association of birth weight with calf weaning
weight is considered to be independent of cow body size (Jeffery and Berg,
1972b).

Jeffery and Berg (1972b) evaluated several measurements of beef
cow size as related to progeny performance among 173 cows (breeds
included Hereford- and Angus-Galloway crosses; Angus- and Galloway-
Charolais crosses) and found that across breed and age of dam, each
additional 10kg post-calving weight of dam resulted in approximately
0.7kg additional weight of calf weaned (the correlation between the
weight of dam and calf weaning weight was 0.34; $p < 0.01$). The amount
of additional variance in average daily gain of calf to weaning explained
by post-calving cow weight was small ranging between 0.4 and 1.1 percent,
compared to the 2.9 percent of the variance explained by wither height of
the dam. In this connection a 1cm increase in height of dam was assoc-
iated with an increase in weaning weight of progeny across all breeds of
0.97kg. Pre-weaning gain of the calf was more highly correlated with cow
weight at weaning ($r = 0.45$, $p < 0.01$); height of dam at withers
($r = 0.50$; $p < 0.01$); and heart girth of dam ($r = 0.58$; $p < 0.01$) than
with post-calving cow weight.

Tanner et al. (1965) studied the effect of post-calving cow weight
on 180-day weight of 385 Hereford calves, and the effect of dam weight at
weaning on the weaning weight of 518 Angus calves and found that the
relationship between Angus dam and calf weight was linear (8.5kg per
100kg increase in dam weight) whereas Hereford dam weight exhibited a
curvilinear influence on calf weight (4.9kg per 100kg increase in dam

weight). Preston and Willis (1974) have suggested the greater milking ability of the Angus breed as the reason for the difference between these two breeds in this respect.

Similar trends of a linear Angus dam weight influence and/or a curvilinear Hereford dam weight influence have been found by Godley and Tennant (1969) and Edwards and Bailey (1975).

Among those to find a significant influence of dam weight on calf weaning weight were Tonn (1975) who studied the Kenyan Boran breed, and Melton et al. (1966) who studied pre-weaning performance in calves of the Angus, Hereford and Charolais breeds. Fahmy and Lalande (1972) studied 892 Shorthorn calves and found that, within age and parity of dam, the heaviest dams weaned the heaviest calves. Neville (1962) found no significant influence of weight of dam on either 120- or 240-day weight of 135 Hereford calves which confirms the findings of Singh et al. (1970) with the same breed. Lindsay et al. (1970) reported that among the calves of 20 Angus, 21 Polled Hereford and 20 Shorthorn dams, calves weaned by cows in the 409 - 454kg range weaned heavier calves than those in the 545 - 614kg range by an average of 31kg.

Contributors to the literature on the subject of the merits of size of dam are many. The study of Kress et al. (1969) indicated that height at withers can be considered an indicator of the skeletal size of the cow and is positively associated with efficiency when age and weight at calving are held constant. The ratio of weight to height at withers is negatively related to efficiency. Larger cows may produce less milk per unit body weight, but their maintenance requirements are less per unit body weight. Hence they are just as efficient, or possibly more efficient than smaller cows in producing calf weight at weaning (Brody and Cunningham, 1936).

Kosterman et al. (1972) reported that of the breeds (Hereford, Angus and Charolais) and their crosses studied, larger cows (548kg vs 389 and 465kg) had greater weight to height ratios and weaned signif- icantly heavier calves than the other two groups. The relative efficiencies were comparable in terms of weight of calf weaned per unit weight of Total Digestible Nutrients consumed. Carpenter et al. (1973) reporting an individual feeding trial among Hereford and Charolais dams found that mature size of dam did not significantly affect either pre-

Table 2.9

Correlations of calf weaning weight and average daily
gain with dam's milk yield

Breed	Weaning weight	Average daily gain	Reference
Angus	0.70	0.31 – 0.79	Brumby et al. (1963)
Hereford	0.48**	0.50**	Christian et al.(1965)
–		0.68,0.70**,0.78	Drennan (1971b)
Angus		0.45	Franke et al. (1975)
Hereford		0.41	
–	0.75 – 0.91		Furr (1962)
Assorted breeds and crosses		0.73 – 0.83**	Gleddie and Berg (1968)
Afrikaner	0.64		Heyns (1960b)
Assorted breeds and crosses		0.78, 0.76	Jeffery et al. (1971b)
Angus	0.67 – 0.81**		Klett et al. (1965)
Angus			
Charolais	0.58**	0.22**	Melton et al. (1966)
Hereford			
Hereford	0.81		Neville (1962)
Hereford		0.64 – 0.70	Neville et al.(1960)
Hereford		0.41	Stobbs and Brett (1976)
3 breeds, 4 crosses		0.88	Totusek et al.(1973)

** p <0.01

weaning performance by calves or the efficiency of maternal production, although in both instances, the smaller cows tended to have an advantage.

Urick et al. (1971) maintained that where increased size is the result of selection and breeding to increase the efficiency of feed conversion, a reduction in cow size to reduce maintenance costs will not be the most profitable selection objective. Furthermore, it is to be expected that cows of larger mature skeletal size will transmit genetic ability for that trait to their progeny with concomitantly higher growth rates expected within the limitations of milk production.

(vi)   The maternal environment

Maternal effects are environmental so far as their influence on offspring is concerned, but they are determined by genetic and environmental factors (Section 1.3 vii). With respect to pre-weaning performance and weaning weight, evidence for the existence and extent of maternal environment comes from experiments which measure known components such as milk production, by reciprocal crossing or cross-fostering among breeds or types and by the comparison of observed correlations with theoretical expectations for various kinds of relatives (Koch, 1972).

Reported correlations of weaning weight and pre-weaning performance with the milk yield of the dam have been tabulated (Table 2.9). There was a tendency for the correlation between monthly lactational yield and monthly growth rates to decline as lactation progressed (Brumby et al., 1963; Koch, 1972; Neville et al., 1960; Rutledge et al., 1970, 1971). This phenomenon is explainable by the increasing dependence of the calf on pasture and/or supplementary rations, and the decline in lactation, partly due to reduced calf demand and partly to seasonal influences.

The value of milk and its relationship to calf gains have been seen to be greatest during the first 60 days of the calf's life although the importance of milk to 240 days of age was shown by Drewry et al. (1959) and Neville (1962) when more than 60 percent of the total variance in 8 and 6 month weight, respectively, was due to differences in milk consumption. Brumby et al. (1963) recorded a figure of 50 percent.

Drennan (1971) has related calf performance to the units of milk produced. From less-than-mature cows producing approximately 7kg of milk per day a 1kg increase in daily milk production resulted in a 9 to 12kg

increase in calf gain to weaning. Jeffery et al. (1971) recorded 5kg
of milk on average from cows of mixed and many breeds and found that a
1kg increase in daily milk production was associated with an increase
of between 11 and 14kg in calf weaning weight. Among dairy cows
producing up to 14kg milk per day, Plum and Harris (1971) recorded a
3.1kg increase in calf gain (from birth to 190 days) per 1kg increase
in daily milk production.

The use of reciprocal crosses to evaluate the differences which
occur between breeds for maternal ability have been widely documented.
Baharin and Beilharz (1975) have reviewed some of the literature on this
subject. From their own study of the Angus, Hereford and Friesian
breeds and their reciprocal crosses, the authors have reported that
purebred Hereford calves performed better before weaning than Angus
contemporaries. However, in the reciprocal crossing of the two breeds,
calves from Angus dams grew faster than calves from Hereford dams up to
weaning. These observations were supported by the United States findings
of Cundiff (1970); Gregory et al. (1965); and Long and Gregory (1974)
evaluating the same breeds. Studying the lactational performances of
Angus and Hereford dams, Klett et al. (1965) and Melton et al. (1967)
confirmed that Angus cows are capable of producing more milk than
Herefords.

In New Zealand, Hight et al. (1971, 1973) reported that the use of
Friesian sires and Angus cows increased the weaning weights of calves by
8.6kg, but the use of Friesian dams with Angus bulls increased weights by
29.0kg. An estimate of heterosis of 2.2 percent was obtained for weaning
weight, but was considered to be minor compared to the large maternal
effect of the Friesian cows.

Sagebiel et al. (1974) found that Hereford by Charolais crossbred
calves were significantly heavier (p <0.01) at weaning when reared by
Charolais rather than Hereford dams. Whereas Hight et al. (1971, 1973)
found that Friesian dams were also of superior efficiency to the Angus
dams, Sagebiel et al. (1974) found the relative efficiencies of Hereford
and Charolais dams, when weaning weight was expressed as a percentage of
metabolic cow weight, to be similar.

Significant, positive effects of maternal heterosis on weaning
weight were also shown by Cundiff et al. (1974) and Cundiff, Gregory and

Koch (1974) where an increase of 14.8 percent in weaning weight per
cow mated was shown by the crossbred cows additional to the 8.5 per-
cent advantage of the crossbred calves.

Koch (1972) has acknowledged that such methods provide real
evidence for the existence of maternal effects, but they are not
helpful in quantifying the relative variation attributable to maternal
effects. The author has given a concise description of the method of
the evaluation of maternal effects from a comparison of theoretical
and observed correlations among relatives. The major relationships
compared were paternal and maternal half-sibs and the fact that
maternal half-sib correlations generally were much larger than paternal
half-sib correlations suggests a large maternal effect. Petty and
Cartwright (1966) estimated that total maternally related variation and
covariation accounted for 29 to 38 percent of the phenotypic variation
in the gain from birth to weaning.

The negative genetic correlation involving maternal ability has
special concern with regard to the performance of the female offspring
of high producing dams. Estimates of the genetic correlation between
maternal and individual effects on weaning weight, or pre-weaning gain
ranged between -0.28 and -0.70 with an average value of -0.55. Mangus
and Brinks (1971) indicated that heifers out of young dams subsequently
produced heavier calves at weaning than heifers out of mature cows.
They interpreted this to mean that high levels of milk in dams had a
detrimental effect on the heifer's future productivity, or conversely,
that low levels of milk from young cows were beneficial to future product-
ivity of their female offspring. A cyclic trend in weaning weights over
four generations was inversely related to the producing ability of the
grand-dams.

Totusek (1968) compared the weaning weights of calves of heifers
reared under different systems and found that early weaned (140 days),
unsupplemented heifers, produced 10kg more calf than heifers weaned at
240 days and creep fed to that age. Christian et al. (1965) reported
that weaning weights of Hereford heifers were negatively correlated with
measures of their milk production.

From Fort Robinson data, Koch (1972) reported that a comparison
of the regression coefficients from offspring-dam and offspring-sire

regressions for gain from birth to weaning yielded a large negative value (-0.24) supporting the hypothesis of negative direct effects between maternal values, or large negative dominance covariance.

Bishop et al. (1975) gave evidence that the negative relation between milking ability of the dam and that of her daughter would tend to reduce the response to selection. Warwick (1970), cited by Barton (1970), has suggested that it may be necessary to wean potential replacement heifers early and raise them on medium planes of nutrition in order to smooth the cyclical weaning pattern of females.

(vii)   Sire

Most workers who have studied the effect of sire on the pre-weaning performance of the calf have confirmed measurable sire effects. The sire contributes half of the calf's genetic potential for growth and therefore its influence on measured calf performance is to be expected despite the very high influence of the maternal environment provided by the dam (50 percent of the variance in weaning weight - Brumby et al., 1963; Jeffery et al., 1971b). Harricharan et al. (1976) and Brumby et al. (1963) have indicated that the influence of sire upon weaning weight increases with increasing weaning age, which is predictable from the recorded decline in dependence of the growing calf upon the milk supply of the dam.

The data of Brown (1960) did not support this contention because the percentage of variance in calf weight attributable to sire declined as the pre-weaning period progressed. That author studied two Angus herds and one Hereford herd under range conditions and reported signif-icant (p <0.01) sire effects at 60, 120, 180 and 240 days-of-age. At weaning (240 days) the amount of total variance associated with the sire was less than 6 percent (Hereford 5.1 percent; Angus 3.4 and 1.7 percent), and less than 11 percent of total variance in calf weight was associated with sire at any stage. The greater proportion attributed to Hereford sire progeny than for the Angus sire may have been due to a lesser milk supply by Hereford dams than Angus dams, although milk production deter-minations were not made. Furthermore, the differences between sires within breed, for the average of their progeny performance were greater for Hereford sires (53.1kg) than Angus sires (35 and 37.7kg).

Studying reciprocal crosses among Angus, Charolais and Hereford cattle, Sagebiel et al. (1974) found that bull breed was a significant source of variation for 205-day weight, but not for pre-weaning gain - the former appears to have been caused by a carry-over effect of sire breed on birth weight. Brownson (1974), and Bosman and Harwin (1966) also found significant sire effects on weaning weight (p <0.01) in Herefords, but not for average daily gain.

Tanner et al. (1970) found sire effect to be a significant source of variation for 205-day weaning weight among Angus bull, steer and heifer calves. Within years the magnitude of differences among sires ranged between 13.2 and 21.2kg depending on the sex category. Among 443 Hereford calves studied by Rice et al. (1954) the between sire-group differences amounted to 19.4kg, the sire effect on weaning weight being significant (p <0.01).

The review of Mason (1951) revealed that progeny tests have confirmed significant differences between sires in the weaning weights of their steer progeny. Heritability estimates were lower for weaning weight than for birth weight, although, citing Knapp et al. (1942), it was indicated in the review that sire differences accounted for 14 percent of the variation in weaning weight compared with only 10 percent of the variation in birth weight.

With respect to testing for the magnitude of sire effects, Al-Mallah (1975) observed higher heritability estimates in female than male calves suggesting that heifer progeny provide more effective genetic discrimination between sires than male progeny at early ages. The literature review of Pahnish et al. (1964) lends support where the mean heritability estimate from the weaning weights of female calves was twice as great as that for male calves (0.51 vs 0.23). From their own study with Hereford cattle those authors found sire effects on the weaning traits of bull calves to be non-significant (p> 0.05) and to be reflected in the low heritability estimates obtained for weaning weight for the sex ($h^2 = 0.01$).

Minyard and Dinkel (1965) and Hight (1966) have reported signif-icant sire effects.

(viii) <u>Year and season of birth</u>

In New Zealand beef cows normally calve in the spring rather than in the autumn. Some of the studies reported in the literature involved housing the gestating or lactating cows indoors to avoid harsh winter climates (Sellers <u>et al.</u>, 1970). Care has to be exercised in extrapolating conclusions based on the pre-weaning performance of calves from dams confined in this manner.

The discussion on birth weight has indicated that calves born later in the season tend to maintain the weight advantage at birth and have the heaviest weaning weights (Singh <u>et al.</u>, 1970; Koch and Clark, 1955). Furthermore, calves born in the autumn/winter period tended to have heavier birth weights than those born in the spring/summer period. (Everett and Magee, 1965; Knapp <u>et al.</u>, 1940). The literature was divided on the significance of yearly variation in birth weights.

With respect to pre-weaning gains, Marlowe <u>et al.</u> (1965) reported significant (p<0.01) year effects, but these appeared to be very strongly linked to breed since the best year for the Angus calves studied was the poorest year for the Herefords.

Jeffery and Berg (1971) reported yearly variation in the milk yield of the cows studied which resulted in a modified average daily gain of the calves reared. Compared with the herd performance of 1967, the cows in 1966 produced 0.98kg more milk per day average, and weaned calves 10kg heavier even though the calves were eight days younger.

Among Angus bull, steer and heifer calves, Tanner <u>et al.</u> (1970) recorded year effects as important sources of environmental variation in 205-day weight. A significant year by sex interaction measured in pre-weaning growth rate and weaning weight by those authors was also observed by Cooper <u>et al.</u> (1965) and Linton <u>et al.</u> (1968). Brown (1960) found that 6 to 8 percent of the variation in weaning weight at 240 days was accounted for by year of birth of the calf.

Among those to confirm the existence of measurable or significant year effects have been Bosman and Harwin (1966, pre-weaning gain; p <0.01); Brownson (1974, weaning weight; p <0.01; Franke <u>et al.</u> (1965, pre-weaning gain; p<0.01); and Parker <u>et al.</u> (1966, weaning weight: p <0.01).

Evaluating seasonal effects from 13,937 adjusted weaning weight records of Hereford and Angus calves collected between 1959 and 1962, Cundiff et al. (1966b) have found that variation in weaning weight was only slightly greater for calves born in the spring than for calves born during late autumn. The variation among calves born during the summer was greater (p <0.05) than that for calves born in the spring even though the average weaning weights were lower.

Bogart (1959) collated reports which indicated that at the Oregon Agricultural Research Station, U.S.A., time of calving was important even when breeding was restricted to a three-month period because earlier calves gained weight more rapidly than later calves.

Linton et al. (1968) obtained data from 4,770 Hereford calves between 1958 and 1965 from a Wyoming location. Data were grouped by the four seasons of birth, and both year and season of birth were significant (p<0.01) for 180-day weaning weight. Season of birth, however, accounted for less than 1 percent of the total variance in weaning weight. Marlowe et al. (1965) also studied the seasonal fluctuation in calf pre-weaning performance and found that calves dropped in mid-spring (March to April) made the fastest gains, and those in the autumn (August to September) the slowest, the difference being 0.11kg per day.

(ix)   Heritability

Most of the estimates for weaning weight have been determined by paternal half-sib correlation (Table 2.10).

The average heritability of birth weight was seen to be 0.50, and the findings of Philipsson (1976c) were that the genotype of the calf was relatively more important in determining calf birth weight than were the genetically controlled maternal effects. With pre-weaning performance and weaning weight, the heritability estimates are considerably less, being approximately 30 percent (Lasley et al., 1961; Warwick, 1958), and it has been shown that the genetic potential of the calf is greatly masked by the maternal environment provided by the dam (Bogart, 1959).

(x)   Repeatability

The repeatability of weaning weight as a trait of the dam has been estimated as being generally greater than that for birth weight. While the accuracy of predicting birth weights on the basis of herd performance is restricted by the influence of major variables such as age and parity

Table 2.10

The heritability of weaning weight

Breed	h^2 estimate	Method of estimation	Reference
		Paternal half-sib correlation	.
Angus	0.24		Baker (1974-75)
Hereford	0.43		Brinks et al. (1964)
Brahman-Angus	0.0^a; 0.19^b		Dawson et al. (1954)
Shorthorn	0.35		Fahmy and Lalande (1972)
Hereford	0.26; 0.52		Gregory et al. (1950)
Unstated	0.28		Knapp and Clark (1947)
Unstated	0.12		Knapp and Nordskog (1946)
Hereford	0.24		Koch and Clark (1955)
Hereford	0.11		Lasley et al. (1961)
Hereford	0.39		Longathon et al. (1965)
Angus	0.72		Meade et al. (1959)
Hereford	0.33		Minyard and Dinkel
Angus	0.32		(1965b)
Hereford	0.05^a; 0.23^b		Pahnish et al. (1964)
Unstated	0.23		Shelby et al. (1955)
Angus	0.20		Swiger et al. (1962)
Boran	0.30		Tonn (1975)
Hereford	0.50		Vesely and Robison (1971)
		Sire-progeny regression	
Angus and Hereford	0.14		Cundiff et al. (1975)
Brahman-Angus	0.0		Dawson et al. (1954)
Unstated	0.30		Knapp and Nordskog (1946)
Hereford	0.25		Koch and Clark (1955b)
		Offspring on dam	
Shorthorn	0.12		Fahmy and Lalande (1972)
Hereford	0.11		Koch and Clark (1955b)
Hereford	0.31		Vesely and Robison (1971)

a = male   b = female

of dam, sex of calf, sire and maternal environment, weaning weight
has been seen to be largely dependent on maternal environment. Koger
(1948) and Gregory et al. (1950) have reported the high repeatability
of dam's milk production and the consequent reliability of predicting
future performance.

The discussion on birth weights revealed a range of reported
repeatability values of -0.03 to 0.29. The repeatability of weaning
weight is taken as 0.45 in the dam productivity index, employed by
Mangus and Brinks (1971) and devised by Lush (1945). Support for this
estimate comes from many of the literature values reported (Table 2.11).

The lower repeatability values obtained for Angus than Hereford
cows for weaning weight has been widely encountered in the literature.
Boston et al. (1975) recorded values for Angus and Hereford dams of
0.29 and 0.59, respectively, and Sellers et al. (1970), values of 0.19
and 0.27, respectively. For pre-weaning average daily gain, Taylor
et al. (1960) reported values of 0.36 and 0.50 for Angus and Hereford,
respectively.

Not all have concurred: Minyard and Dinkel (1965) reported the
repeatability in Herefords and Angus as 0.42 and 0.52, respectively.

Hohenbroken and Brinks (1970) have related the lowered repeat-
ability of Angus with respect to Hereford dams to behavioural differences
where Angus cows are tolerant of itinerant suckling by the calves of
other cows. Boston et al. (1975) indicated that the higher estimates
obtained for Hereford than Angus dams probably meant more permanent
variation among average performances of the Hereford cows, as well as
the obscuring effect of Angus cross-fostering.

Boston et al. (1975) have also discussed the reliability of
repeatability estimates for pre-weaning growth and weaning weight, and
concluded that the culling of cows on the basis of the performance of
their first calf would be expected to be more effective for increasing
the herd average productivity of Hereford than Angus cattle. On the
basis of their analysis, progeny performance in the first year served
as a reliable predictor of cow performance to five years in both breeds,
but were of limited value beyond that time.

Table 2.11

The repeatability of weaning weight

Breed	Age at weaning (days)	Repeatability estimate	Reference
Angus	-	0.27	Boston et al. (1975)
Hereford		0.50	
Hereford	210	0.43	Botkin and Whatley (1953)
Hereford		0.49	
Angus	210	0.48	Cunningham and Henderson (1965a)
Hereford		0.28	
Angus	165	0.26	Hohenboken and Brinks (1969)
Hereford	180	0.52	Koch (1951)
Hereford	180	0.34	Koch and Clark (1955)
Angus	205	0.16	Meade et al. (1959)
Hereford		0.42	
Angus	190	0.42	Minyard and Dinkel (1965)
Hereford		0.52	
Hereford	240	0.51; 0.34	Rollins and Wagnon (1956)
Angus	205	0.19	Sellers et al. (1970)
Hereford		0.27	

Minyard and Dinkel (1965b) considered repeatability estimates reliable enough to allow selection early in a cow's life. Since cows at both extremes, i.e., very high or very low producers, contribute much more to the repeatability of weaning weight than those near the average, the very low producers can be culled on the basis of first records with little risk of culling good cows.

Cunningham and Henderson (1965b) and Sellers et al. (1970) have stressed the adjacency of records when regressing records of late calves on early calves of a dam where degree of adjacency is determined by the years of separation of each record. It appeared that the predictive value of early records for production in later life was not as great as is often assumed and little emphasis was given repeatability estimates made on records more than two years apart.

(xi)   The nutritional regime imposed on the dam and
        the dam's weight change during lactation

Because of the large influence of the dam on the weaning weight of the calf, the nutritional environment provided for breeding cows throughout the year has attracted much interest. The levels of winter feed offered gestating cows appears to have an influence on the pre-weaning performance of calves equivalent to the nutritional plane given cows after calving.

Hight (1968b) has examined the effects on cow and calf performance of both pre- and post-calving planes of nutrition among mixed-age Angus cows. Apart from hay fed to the appetite of high plane cows during the winter all animals were pasture fed. Imposing high and low planes both before and after calving, so that four categories were established (high-high, high-low, low-high, low-low) Hight measured highly significant (p < 0.001) differences between high and low plane groups for calf weaning weight, of 17.3kg for the pre-calving levels of nutrition and 16.3kg for the post-calving levels of nutrition. On the basis of this evidence that author considered the pre-calving nutritional effect to be of approximately equal importance to post-calving nutrition.

An earlier trial reported by Hight (1966) revealed that a 5.4kg difference between the birth weights of calves of cows fed similar high and low planes to those described above, had increased by weaning time

to 16.5kg. The difference in weaning weight represented the combined effects of maternal nutrition and a residual effect on lactation of the different planes of nutrition during pregnancy.

Having established from the 1966 study that pre-calving nutrition of the dam has a significant effect on calf weaning weight , Hight (1968c) proposed to offset the effects of severe winter nutrition by a short period of elevated feeding (eight or three weeks) prior to calving. Post-calving all cows were run together. While the birth weights of calves from cows fed to a low plane before calving remained significantly less (p<0.001) than those of the cows fed a high plane, by weaning, calf weights were not significantly different, favouring the calves of dams fed a high plane by not more than 5.9kg (corrected mean value).

Similar to the study by Hight (1968c), Turman et al. (1964) studied the effects of high or low planes both before and after calving, but used first-calving, yearling-bred, Hereford heifers. The importance of the level of feeding before calving was established, since the difference between the weaning weights of the calves of the group fed a high plane before calving and a low plane after calving, and the second group fed a low then high plane, favoured the high plane-low plane group. Of the 14.5kg difference, 6.4kg was explained by a heavier birth weight. The improved maternal ability was largely due to the measured differences in milk production.

Corah et al. (1975) conducted a similar study with first-calving Hereford heifers and their results substantiated the findings of Turman et al. (1964). They added an important consideration that the survival ability of calves from restricted dams was reduced, further curtailing the overall weaning performance of the low-plane group.

Among 60 first calving, three-year-old Hereford heifers in Australia, Hodge et al. (1976) also substantiated the findings thus far concerning the importance of pre-calving nutrition. Furthermore, rebreeding performance (as final conception rate) was seen to be depressed by the pre-calving level of nutrition, despite post-calving levels sufficient to produce weight gains in all animals. A recent study by Morris (1976) measured the return to exhibition of oestrus and the calving interval of Angus mixed-age cows, 61 located near Palmerston North

and 207 at Whatawhata. That author stressed the need for particular attention to be given to the pre-calving nutrition of gestating dams, while for the first 40 days post-partum, cows can be fed to maintain their weight.

Among those to confirm the importance of pre-calving levels of nutrition with respect to mothering ability and subsequent calf pre-weaning performance and weaning weight were Bellows et al. (1972); Christenson et al. (1967); Dunn et al. (1965); Falk et al. (1975); Harris et al. (1965); Hironaka and Peters (1969); Kropp et al. (1972). In addition Renbarger et al. (1964), found that the effects of poor feeding levels among yearling-bred Hereford heifers were not recovered by liberal feeding after calving. Many of these studies involved young, first-calving heifers, and from the discussion earlier on age-of-dam effects, the differences between treatment groups for weaning weights could be expected to be less with advancing age of dam (Pope, 1967).

From the Oklahoma studies of Pinney, Stephens and Pope (1972) evidence was obtained where the effects of depressed winter feeding levels were compensated for. The authors reported the study of lifetime effects of winter supplemental feed level on range Hereford beef cows and found that among two-year-old, first-calving heifers, weaning weights were slightly depressed by winter weight losses in the gestating animals. Repeated the second winter, the treatments failed to significantly affect the weaning weights of calves of the then three-year-old cows. The percentage calf crop and longevity of dams on the low plane of nutrition approached a significantly greater level than for the high or medium plane groups among which, neonatal mortality contributed most to depressed weaning percentages.

Other workers who compared reduced planes of nutrition before calving with normal or high planes, and failed to find any significant influence on calf weaning weight through the live weight differences of the dams, included Drennan and Bath (1976b); Holloway et al. (1975); Neel et al. (1972); Parker et al. (1966); and Vaccaro and Dillard (1966). In all of these studies either the cow live weight differences between groups obtained before calving were small, or the live weight of animals in the groups on the low planes were not significantly below their autumn weight in any part of the gestation period.

Baker and Barker (1975), working with 48 Hereford-Friesian cross

cows, were among the very few who reported highly significant ($p < 0.001$)
cow live weight changes between groups as a result of winter nutrition
(high plane gain, 0.1kg/day; low plane loss, 0.9kg/day) yet no
significant difference in calf growth rates (0.9 _vs_ 0.8kg per day,
respectively).

The effects of pre-calving planes of nutrition have been
discussed and generally seen to be significant in their influence on
weaning weights. Also of major importance to pre-weaning performance
of calves and their weaning weights is the change in weight of the dam
during lactation. Most reports have indicated an inverse relationship
between rate of cow weight gain and calf daily gain.

Gregory _et al_. (1950) reported values of -0.12, and -0.34 for the
correlations of calf gains with cow gains from birth to weaning in two
Hereford herds studied. Brinks _et al_. (1962) considered that cows
gaining the most (or losing the least) during the grazing season tend
to produce slower-gaining calves. Cows gaining the most during the
suckling period do so at the expense of milk production and consequently
wean lighter calves.

While Hight (1966) had initially studied the influence of pre-
calving plane of nutrition among mixed-age Angus cows, he suggested that
the live weight increases observed in the experiment during the pre-
weaning period indicated insufficient development of the inherent capacity
of the animals for milk production in order to produce milk at the expense
of their own live weight gain. The results and discussion of Hironaka and
Peters (1969) largely supported this contention where the gains of cows
wintered on a low plane exhibited greater summer gains than their counter-
parts fed a high plane and consequently weaned calves consistently
lighter than did cows on a high plane before calving.

Singh _et al_. (1970) studied the relationship between cow weight
change during lactation and calf growth rates among 619 Hereford dam-
calf pairs over six years. The authors reported a regression of pre-
weaning average daily gain of calves on the ratio of cow weight change
to the weight at parturition (percentage change in body weight) of
-0.003, meaning a calf gain of 0.03kg per day faster for every 10 percent
its mother lost of her weight. The difference between the pre-weaning

average daily gain of calves whose mothers lost weight and those whose mothers gained during lactation was highly significant ($p < 0.01$).

Vaccaro and Dillard (1966) relating dam's weight and weight changes to calf growth rates in Hereford cattle found that cows which lost most during the whole experimental period (pre- and post-calving) tended to produce the fastest-gaining calves from birth to 180 days-of-age. England et al. (1961) found a similar and significant relationship between cow weight change during the suckling period and calf weight gains, and considered that cows gaining weight in early lactation are poor milkers that may give sufficient milk in early lactation, but have inadequate milk flow later with consequent poor calf gains after approximately 60 days-of-age.

Verification of these phenomena comes from studies reported by Carpenter et al. (1973), working with Hereford and Charolais calves; Melton et al. (1966); Tewolde et al. (1976) studying Angus and Hereford cow traits; and Joubert (1954) studying the Jersey, Friesian, Beef Shorthorn and Afrikaner breeds in Africa.

Among those who did not find that weight changes occurring in the dam post-calving were related to calf performance were Baker and Barker (1975) and Godley and Tennant (1969).

3.   The Milk Production of Beef Cows

   3.1   Introduction
        The review of factors affecting the pre-weaning performance
of the calf strongly implicated variation occurring in the milk
production of the dam as being responsible for the greatest part of
the variation seen to occur in weaning weight (50 to 60 percent;
Drewry et al., 1959; Neville, 1962).

        The optimization of weaning weight by the efficient use of
pasture offered the lactating dam will be modified by the appetite
of the calf, which appears to be governed by its age, sex, and weight
or size.   It is to be expected that draw-off by the calf reaches a
peak as it increases in age, and before there is any appreciable
supplementation of the diet from pasture.   Studies have shown this
to occur between one- and three-months-of-age, although the amount of
milk required for gain at this stage has varied.   Therefore attempts
to measure the milk production of the dam need to be tailored to meet
these conditions as far as is possible.

        The evaluation of the influence of maternal environment on
weaning weights (Section 2.2 vi) inferred that while the response
among beef breeds of the pre-weaning gain of the calf to the amount
of milk produced was essentially linear, calves suckling higher-
producing dams generally made the least gain from a given volume of
milk.   The magnitude of expected calf response to beef cow milk pro-
duction may be gauged from the findings of Drennan (1971b) who reported
regression coefficients for daily gain of calf on the milk yield of
Hereford-Shorthorn cross cows of 0.059, 0.045 and 0.057 for three
consecutive years.

        Neville (1962) reported a figure of 12.5kg milk per kilogram of
gain, as did Drewry et al. (1959).   A conversion figure of 8.06kg milk
per kilogram of calf gain during the first eight-weeks-of-age was
found by Montsma (1960).

        Much lower figures of milk required per kilogram of calf gain
reported by Melton et al. (1967) have suggested more efficient use of
the milk consumed.   The authors reported unadjusted figures for milk
produced during the suckling period on total calf gain of 5.7 for Angus,

5.2 for Charolais and 4.7 for Herefords. It was also suggested by
these authors that levels of pasture consumed by the calves additional
to milk, the solids content of the milk, and maintenance requirements
of the larger Charolais calves were regions of possible variation in
performance between the breeds. A similar conversion figure of milk
to calf live weight of 4.8 in the first 60 days of life of Angus calves
was reported by Bond and Wiltbank (1970).

Because of the high dependence of the calf on the dam's milk
supply before three-months-of-age, and because of the proportion of
the diet comprised of milk in that period, values given in the
literature for the amount of milk required per kilogram of calf gain
at an early age are greater than those pertaining to later in the
suckling period. Drewry et al. (1959), working with Angus cattle
estimated the weight of milk required per kilogram of calf gain in the
first, third and sixth months of lactation to be 12.5kg, 10.8kg and
6.3kg, respectively.

Studying 135 Hereford cow-calf pairs, Neville (1960) found a
decline in the regression coefficients for calf daily gains on daily
milk production for four consecutive 60-day periods. The regression
values were 0.064, 0.055, 0.044 and 0.048, respectively. Assuming
that a linear rate of increase in calf live weight occurred, the
diminishing contribution of milk to the diet of the calf is evident.
However, the correlation coefficients reported (r = 0.061 to 0.070;
p < 0.01) indicated the strong association of calf growth with milk
production throughout the suckling period. Barton (1970) collated
data of eight studies in the literature. The size of the correlations
reported between milk production and the growth rate of the calf
tended to decrease marginally as lactation proceeded and almost always,
high levels of significance were accorded the correlations.

The strong association between milk production late in the
suckling period and calf gains reported by most workers suggests that
factors such as summer dryness, and subsequent pasture depletion, while
leading to reduced milk production, also restrict calf gains from the
grazing component of the diet, thereby maintaining a significant level
of dependence of the calf on the dam. Pasture quality is important in
determining the significance of the milk component of the diet, for
Walker (1963) found that among Angus and Angus-dairy cross calves, ample

high-quality pasture meant a non-significant correlation between milk
yield and calf growth rate after 12 weeks-of-age.

3.2   The Relation Between Milk Composition and Calf Gain

Evidence provided by Preston and Willis (1974) has indicated that
care is required in selecting the method of milk removal for constituent
analysis. Beef cows milked as though they were dairy animals by Cole
and Johannson (1933), and Dawson et al. (1960) produced milk with a fat
content of about 4 percent. Sampling techniques applied to suckled beef
cows by Melton et al. (1967) and Christian et al. (1965) returned milk
fat estimates of less than 3.7 percent.

Many reports have confirmed the reliability of milk-yield-only
determinations in measuring variation in the dam's contribution to the
pre-weaning performance of her progeny when yields have been compared
with assays of milk composition (Blanchard et al., 1966; Christensen,
1968; Holloway et al., 1975; Rutledge et al., 1971; Serwanja et al.,
1969; Totusek et al., 1973; Wilson et al., 1969). This conclusion is
important for the reliability of the method of milk determination by
calf suckling to be discussed later and referred to as the weigh-nurse-
weigh method.

While there is little extra variation in calf pre-weaning
performance to be measured by a determination of milk composition above
that attributable to milk yield per se, it has been well established
that the amounts of total solids, total protein and total milkfat are
also highly correlated with calf growth (Jeffery and Berg, 1971;
Lamond et al., 1969; Melton et al., 1966; Totusek et al., 1973).
These high correlations of total amounts of constituents with calf
performance are not to be confused with the low negative correlations
of calf performance with percentage of constituents, which have been
equally well documented (Jeffery and Berg, 1971; Klett et al., 1965;
Serwanja et al., 1969).

3.3   Estimation of the Milk Production of Beef Cows

The most commonly used method for milk estimation is the calf
suckling technique known as weigh-nurse-weigh (WNW) which derives its

name from the procedure followed after cows have been separated from their calves for a predetermined period. Calves are weighed when hungry, allowed to suckle until feeding has ceased, and then reweighed.

The method is a measure of the capacity of the calf for milk and hence can be expected to return lower estimates before 30 days-of-age of calf when cow production could be measured by other techniques to be high (hand milking with oxytocin injection; Saul and Morgan, 1976). In this connection, Totusek et al. (1973) measured a small variation in milk yield at 30 days whereafter increasing variation measured was likely to be due to individual cow differences in the persistency of lactation.

The duration of the separation period for the WNW method appears to be important, especially at younger ages of calf when appetite can be expected to be less than dam's supply. Studies have been made of the suckling behaviour of calves (Drewry et al., 1959; Walker, 1962) and it was seen that the number of times suckling occurred (between 3 and 5 times per day) decreased with increasing age of calf, meaning that the interval between sucklings (200 to 350 minutes) increased with calf age.

It was generally observed that, unless disturbed, the suckling of calves during the night was negligible. On the basis of this evidence, the most reliable procedure to gauge 24-hour calf milk consumption is one of two to three sucklings during the day time preceded by separation during the night. Deutscher and Whiteman (1971) reported a method of estimating the milk consumption of the calves of Angus-Holstein cross and Angus heifers three times at six-hourly intervals when less than 6 weeks-of-age, and twice per day at twelve-hourly intervals when the calves were older.

Many reports in the literature, where the WNW method was used, employed two, twelve-hour separations before suckling to give 24-hour milk yield estimates (Rutledge et al., 1971; Turman et al., 1964). Others separated the calves for up to five hours, suckled to empty the dam's udder to the calf's appetite, then separated the animals for a further 12 hours before weighing the calves, nursing for 20 to 30

minutes, and reweighing (Bond and Wiltbank, 1970; Corah et al., 1975; Neville, 1962; Oxenreider and Wagner, 1971).

With respect to how often the method should be used, Totusek et al. (1973) found that reliable estimates of total milk yield of cows may be made by obtaining a limited number (2 to 4) of daily estimates placed through the suckling period, a conclusion in support of the findings of Jeffery and Berg (1971).

The major advantages associated with the method have been seen to be the greater rate of making estimates of the milk production of suckled beef cows compared to other methods, and the presence of the calf to stimulate let down. However, some difficulties have been encountered with fractious animals of susceptible ages or breeds, as Reynolds et al. (1967) reported when Brahman cows frequently did not permit their calves to suckle in close proximity to humans.

Pleasants (1974) suggested that some refinement of procedure is necessary to minimize error variation when older calves may complete suckling rapidly and defaecate or urinate before younger calves are ready for their second weighing. Munford et al. (1964) contended that holding cows in yards to restrict grazing time constitutes a stress which may reduce milk yield at the subsequent milking. The authors suggested therefore that the period of test should not extend beyond six hours. Dickey et al. (1971) reported from 977 measurements of the milk yield of Angus and Hereford dams that data obtained by WNW method were highly ($p < 0.01$) dependent on the length of the period of separation of cows and calves.

Walker (1963), at Ruakura, conducted a procedure of total separation of one group of calves, allowing suckling only at 5.00 a.m. and 3.30 p.m., and weighing calves before and after nursing. This group was compared with a control group run with dams by the weight gains exhibited by each. From the very close, and slightly higher gains measured in the former group was derived support for the reliability of the WNW method as an estimation of the milk yield, and thus maternal contribution, received by the "plunket group" of calves.

Exogenous oxytocin injections have been employed in some studies to stimulate milk secretion. A major disadvantage in the procedure is

the time and labour requirement, both of which exceed those of the
WNW method. Among those to use oxytocin injections have been Falk
et al. (1975), who removed the subsequent milk secretion by teat
catheter; Klett et al. (1965) who milked the Angus and Hereford cows
with a portable milking machine; and Lamond et al. (1969) who also
employed the teat catheter extraction procedure.

Schwulst et al. (1966) measured the residual milk after the
suckling of Angus cows by administering oxytocin and withdrawing the
milk by machine. The amount of residual milk present in early
lactation led to an error in estimating total cow production if only
milk consumption was used. At the two- and three-week observations
the average residual milk was 15 and 11 percent, respectively, of the
total milk measured. This decreased to 6 percent by the fifth week of
measuring. The reasons postulated were either increased consumption
of the calf, or cows being refractory to oxytocin.

If total cow productivity is to be measured the method appears
to have an application. If, however, the relationship between calf
growth rate and the dam contribution is required, then the calf-suckling
method appears satisfactory for measuring variation between lactating
animals.

Hand-milking techniques, especially where calves have been allowed
to suckle half the udder at each determination, on a WNW basis, have also
been employed. (Christian et al., 1965; Rutledge et al., 1972; Totusek
et al., 1973). Totusek et al. (1973) found that a high correlation
between hand milking and the WNW method existed (r = 0.95) although the
totally hand-milking technique tended to under-estimate the amount of
milk removed by the calf in the totally calf-suckled situation, probably
because of its failure to stimulate the release of comparable amounts of
endogenous oxytocin. The 24 beef cows of mainly Angus, Hereford and
Shorthorn breeding produced average daily milk yields of 4.54kg over the
210-day period as estimated by hand milking and 5.85kg as estimated by
WNW procedure.

Saul and Morgan (1976) studied the milk production of two-year-
old Hereford and Friesian cows. They found that although the WNW method
of milk yield determination was more highly correlated with calf growth
rate from birth to weaning than hand milking used with a pre-milking

injection of oxytocin, both methods were highly correlated with calf
growth rate (r = 0.92 and 0.84, respectively).

3.4   The Lactation Curve

It is generally agreed that the milk production of cows increases
to a peak some weeks after parturition and declines from then until
weaning. The rate of decline during lactation has been the focus of
several studies (see Figure 2.1).

Gifford (1953) provided evidence indicating that the peak of milk
production among dairy cows generally occurs approximately four weeks
after calving. McDonald et al. (1966) considered 45 days to be a
typical interval between calving and peak lactation. Dawson et al.
(1960) found the peak milk production among 30 Beef Shorthorn cows to be
at the end of their second month of lactation when their highest average
production for a 28-day period was 10.3kg per day (range 5.6 to 16.1kg
per day). Production then declined towards weaning when the average
28-day production was 6.2kg with a range of 2.7 to 10.9kg.

Totusek et al. (1973) found that the milk yield on the 24 beef
cows studied as determined by WNW increased rapidly in the first 4 weeks,
progressed more slowly towards a peak at 7 weeks, remained constant for
a further 3 weeks then showed a gradual decrease towards the end of
lactation. The reported mean production figures were 6.58kg milk per
day at 70 days, 6.44kg at 112 days and 5.85kg at 210 days. The relatively
flat lactation curve reported is also typical of the type indicated by
the data presented by Drewry et al. (1959) where the highest average daily
milk yield was measured 3 months after calving.

A milk yield determination by hand milking reported in the same
study by Totusek et al. (1973) returned maximum production at the first
monthly estimate, and thereafter declined at a constant rate. The hand
milking results appeared biased by a failure of some animals to completely
adjust to human contact.

Gleddie and Berg (1968) measured a linear decline in milk yield
by oxytocin injection-mechanical extraction technique among Angus,
Hereford, Galloway and Angus-Galloway cross females, the regression of
milk yield on time being 0.02kg per day. Deviation from linearity was
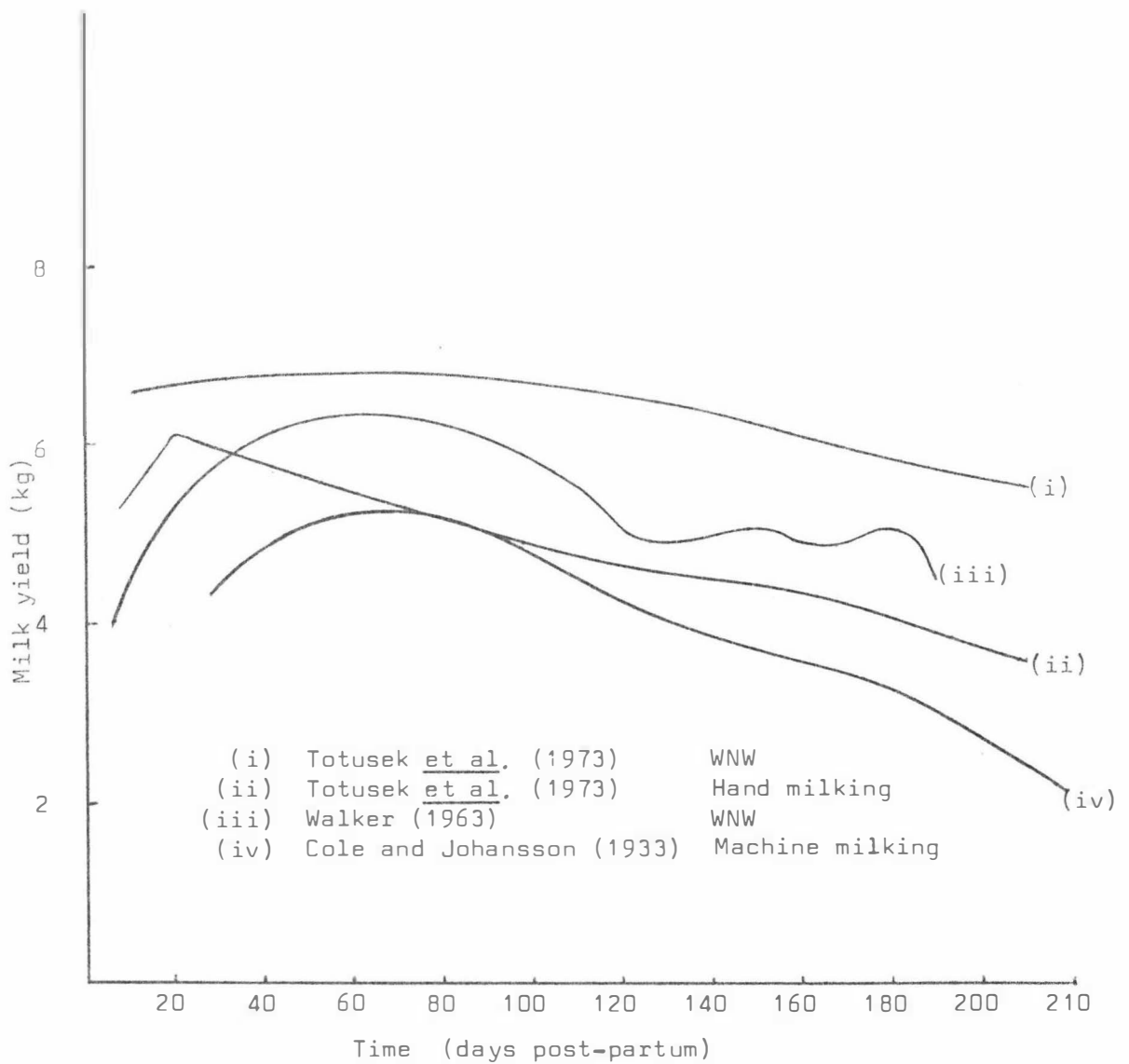
Figure 2.1 The lactation curve of beef cows

The following legend appears within the figure:

(i)   Totusek et al. (1973)   WNW
(ii)   Totusek et al. (1973)   Hand milking
(iii) Walker (1963)   WNW
(iv)   Cole and Johansson (1933)   Machine milking

Axes: Milk yield (kg) versus Time (days post-partum)

not significant, accounting for only 3 percent of the variance in milk yield.

Gleddie and Berg (1968) discussed the persistency of lactation as affected by calf draw-off and have suggested that consumption by calves of less than the dam's potential milk yield in the first month would result in a subsequently decreased milk yield. By the second month of lactation the calf would still be heavily dependent on milk as the nutritional source and the yield of the cow would presumably have become equated to some extent with the appetite of the calf. This is likely to be an explanation of the gentle curve of the WNW-determined milk yield of Totusek et al. (1973) compared to the sharply peaked curve obtained by the hand-milking procedure.

The explanation for a decline in the lactation curve towards weaning is likely to be found in the falling dependence of the calf upon the dam as pasture consumption plays a greater role in calf live weight gain (Brumby et al., 1973; Melton et al., 1967). However, the strong association between total milk yield and calf weaning weight already discussed (Section 3.1 i) draws attention to the observations of Drewry et al. (1959) and Walker (1962) that the interval between sucklings increased, and the number of sucklings decreased as the season progressed, prompting a suggestion that persistency may also be related to a combination of the frequency of udder evacuation and the proportions of circulating maternal hormones induced by the frequency of the suckling stimulus. Drennan and Bath (1976a) gave evidence from studies with sheep which indicated that ewes suckling twin lambs have greater milk yields than those suckling singles. Similar observations have been made with cattle (Topps et al., 1974; Drennan, 1971).

From the milk-production records of 15 Angus and 15 Hereford cows, Klett et al. (1965) suggested that beef cattle are more flexible in their milk production response to changing feed level than is generally recognized. The opposite appears to exist for B.indicus cattle under tropical conditions where milk yields have been observed to be insensitive to changes in the environment, cows tending to gain weight at the expense of milk production (Lampkin and Lampkin, 1960).

3.5 Factors Affecting Milk Yield

(i) Pre- and post-partum nutrition

Many of the studies conducted to examine the influence of pre-calving plane of nutrition on birth weight, continued to monitor cow productivity after calving in terms of liveweight change, calf growth rate and milk yield. Most studies in which an influence of nutrition on milk yield was measured also indicated that the level of pre-calving nutrition has greater significance than the level after calving, barring interference from climatic extremes.

A study of dairy cows reported by Hutton and Parker (1973) involved 30 sets of identical-twin Jersey and Jersey crossbred cows, including 17 sets of two-year-olds. The plane of nutrition during late pregnancy was determined by changes in live weight during the four weeks before parturition. One half of the cows were pasture fed to gain an average 23kg live weight (7 percent), the other were fed to remain at virtually constant liveweight over this period.

An average dry matter intake of 60 percent compared with 100 percent (14 Mcal. ME per day) of the estimated requirements for metaboliz-able energy (ME) during the last month of pregnancy was associated with a 7 percent lower live weight at calving, 9 percent less milk, and 14 percent less milkfat at the end of the first 8 weeks of lactation. (There was no significant difference, however, between the group mean calf birth weights).

Two post-calving stocking rates were imposed ("moderate" and "heavy") and in contrast to the pre-calving level of intake, restricting available dry matter after calving had virtually no effect on milk yield in the first year, and in the following year, a lesser effect than differences due to pre-calving feeding. There was no significant inter-action between the level of feeding before and after calving and milk yield.

Hutton and Parker (1973) cited further published evidence of significant effects of pre-calving nutrition on the milk yields of dairy cows (Campbell and Clayton, 1966; Foot et al., 1963; Patchell, 1957). The reviews of Broster (1971, 1972) clearly demonstrated the long-term effects on the lactational performance of feeding dairy cows

well in late pregnancy and early lactation,

Powell and Matravers (1975), however, considered there may be dangers in attempting to make too close a comparison of the responses of dairy and beef cows to feeding because quite different levels of nutrient intake and milk output are generally involved. The authors conducted a winter-housing experiment involving 40 North Devon-British Friesian cross cows and 10 heifers of this cross. Feeding silage, or silage plus barley, to low and high plane groups, respectively, a significant difference between the amount of cow weight lost in the groups between early December and calving in March was obtained. By retaining high and low rations post-calving, but switching half of each group to the alternative level, the authors were able to measure cow weight changes during lactation and estimated 24-hour milk yield (WNW method).

The results indicated that the pre-calving planes of nutrition influenced estimated 24-hour milk yield more than did post-calving levels although not significantly so (pre-calving treatment difference, 1.4kg milk per 24 hours; post-calving treatment difference, 0.8kg milk per 24 hours).

The flexibility of beef cattle in the response of milk yield to changing feed levels noted by Klett et al. (1965) was also detected by Joubert (1954). Bonsma (1951) found an appreciable increase in the milk yields of range cows even at the end of the lactation as a result of the rise in feed values of the pasture during the summer. Pleasants (1974) obtained evidence from the comparison of the performance of cows on a sawdust pad with a hill-pasture wintering system that cows tended to increase their milk production when removed from the pad, approximately 30 days post-partum, and moved to hill pastures under what were possibly less stressful conditions. Lamond et al. (1969) have also observed significant differences in the weight of milk produced under different feeding systems.

Not all reports have confirmed significant pre-calving nutritional effects on subsequent milk yields. Drennan and Bath (1976a) studied mixed-age Hereford-cross cows under two experiments, where silage was fed to promote a control group weight gain of 45kg (8.9 percent) in the first

experiment and 13kg (6.2 percent) in the second. The restricted groups
experienced weight losses of 18kg (3.5 percent) and 31kg (6.2 percent)
in the first and second experiments, respectively.

In both experiments, cows fed at the restricted level during
late pregnancy gained significantly ($p < 0.01$) more live weight during
the subsequent pasture grazing period. The milk production of the dams
as determined by WNW was not affected by the pre-calving plane of
nutrition. Drennan and Bath (1976a) considered that the milk production
of their beef cows was probably limited by the ability of the calf to
consume all available milk early in lactation, which subsequently led to
a reduced yield.

(ii)   Weight of dam

Most of the reports in the literature where weight of dam was
considered for its influence on milk yield have indicated a small
positive association between the two (Dickey et al., 1970; Rutledge
et al., 1971).

The isolation of weight of dam effects on milk yield is complic-
ated by the partial relationship between cow weight and age. Jeffery
and Berg (1971a) reported correlations between age and post-calving
cow weight of 0.73 and 0.76.

The manner in which breeding females are reared to mature size
and weight has been discussed by Swanson (1967) who reported several
studies where identical twins were used to measure the detrimental
effects on milk yield later in life of overfeeding heifers at younger
ages. The poor development of the mammary tissue was given as a major
contributor to poor lactational performance in over-fed females.

From normal beef cattle management procedures, several studies
have reported the relationship between weight of dam and milk produced.

Jeffery and Berg (1971a) presented a simple correlation between
post-calving cow weight and milk yield of several beef breeds of cows
of 0.28 and 0.38. The importance of cow age in its effect on milk
yield through cow weight was seen where, together, these two traits
explained 15.3 percent (1966) and 21.1 percent (1967) of the variance

in milk yield. Holding cow age constant, post-calving cow weight
explained an additional 0.0 (1966) and 8.5 percent (1967) of the
variance in milk yield. With the effect of cow age removed the
authors found that post-calving cow weight had little effect on milk
yield in the first year, but in the second year of the study, the
regression coefficient was significant ($p < 0.01$; $b = 0.01$) meaning
that an increase of post-calving cow weight of 10kg could be expected
to increase milk yield by 0.1kg per day.

The supporting literature review of Jeffery et al. (1971a)
indicated that dairy breeds show greater response to cow weight
increases than can be expected from breeds of beef cattle. The
authors concluded that the inconsistency of the relationship between
body size and milk yield reported in their own study indicated that
selection for body size would give very little assurance of any
associated increase in milk yield.

Cowan et al. (1974) obtained results which suggested that animals
genetically or environmentally capable of reaching a higher live weight
at first calving will produce more milk than animals of lower live
weight. This superiority tends to decrease with subsequent lactations.
Significant positive relations between live weight at calving and milk
yield were also obtained by Miller et al. (1973) and Hickman et al.
(1971).

(iii) Age and parity of dam

The close association of weaning weight with milk production
allows much of the discussion of the effects of age and parity of dam
on pre-weaning performance of calves (Section 2.2 iv) to be extra-
polated to this section. Reports in the literature clearly indicate
increased milk production with age to maturity at between six- and
eight-years-of-age (Gifford, 1953; Melton et al., 1966; Tewolde et al.,
1976). Rutledge et al. (1970) reported that milk yields of 279
lactations by 193 Hereford dams exhibited a quadratic response with age,
with the maximum at 8.4 years. A later paper by these authors (Rutledge
et al., 1972) of the same data indicated that a similar shape of the
lactation curve existed for each of the various ages of dam.

Jeffery et al. (1971a) presented a curvilinear effect of cow age

on milk yield with a levelling off after the third lactation (five-
to six-years-of-age). The correlations of milk yield with age of
dam, however, were measured to be quite low (r = 0.32; 0.22), and
a second publication by the authors (Jeffery et al., 1971b) suggested
there is considerable variation in milk production between cows of
similar age and breed. Milk yield alone explained 56 to 59 percent of
the total variation in average daily gain of calf to weaning; when
cow age was included in the model, the amount of additional variance
of calf performance explained by milk yield was reduced by approximately
12 percent.

It was indicated earlier in this review that age at first
calving affected weaning weights, with agreement that heifers calving
first at three-years-of-age raised heavier calves than those calving
first at two-years-of-age. The review of literature by Cowan et al.
(1974) discussed age at first calving with respect to milk yield and
found conflicting evidence. Furthermore, the relationship between age
and weight at first calving is likely to greatly modify the relationship
of either to milk yield (Hickman et al., 1971).

The greatest difference between parities of dam for weaning
weight was seen between first and second calves. This was also observed
by workers who studied the influence of this trait of the dam on her
milk production (Christian et al., 1965; Holloway et al., 1975). This
is again indicative of the strong association between the yield of milk
and the weaning weight of the calf.

(iv)   Sex and birth weight of calf

The literature is divided on the influence of sex of calf on milk
production of the dam. It would appear that the generally accepted
superiority of the male over the female calf for pre-weaning performance
is not necessarily related to the milk yield of the dam. This suggests
that the efficiency of utilization of milk and pasture, and the quantity
of pasture consumed by the calf are also significant sources of
variation between the sexes.

Melton et al. (1967) reported that bull calves reared by Angus,
Charolais and Hereford cows removed 0.58kg more milk per day by WNW
determination than heifer calves. The sex difference declined progress-
ively during lactation to 0.10kg per day. The difference between the

dams of the two sexes for total lactational milk yield was non-
significant (703.1kg for males; 649.9kg for females) although the
gain of male calves was significantly (p <0.01) superior to that of
the females.

Dickey et al. (1970) reported that male calves of Angus cows
removed significantly more at determination times than female Angus
calves, while the difference between the sexes for the Hereford dams
was not significant. Rutledge et al. (1971) reported a significant
superiority of the milk yield of dams suckling female calves amounting
to 56kg more milk over a 205-day lactation.

The confusion over the sex dominance for milk yields is added to
by the year by sex of calf interactions reported by Pleasants (1974)
and Jeffery et al. (1971a, b). The former author reported higher
consumption of milk by bull calves in the first year of the experiment
(1970) and greater consumption by females in the second year. The
changed climate between years was discussed in relation to the possible
mechanism producing this effect.

Gleddie and Berg (1968) reported no significant sex effect on
either the milk production by cows, or the milk composition. Others to
find sex differences to be non-significant have been Christian et al.
(1965) and Wilson et al. (1969). The work of Hughes (1972) suggested a
cow age by sex of calf interaction with male calves being more dominant
for milk consumption at younger ages of dam.

The relationship between birth weight and milk consumption has
been reported by some workers as a reason for greater milk consumption
by male calves.

The findings of Melton et al. (1967) of greater milk consumption
by males, especially early in the lactation, was supported by the
authors with the findings of greater birth weight of bull calves,
averaging 2.7kg more than heifer calves. Cartwright and Carpenter (1961)
observed that bull calves also tend to nurse more frequently and may
thereby stimulate greater milk production.

Rutledge et al. (1971) found that, despite the greater production

of milk by cows rearing female calves, the linear regression of total
milk yield on calf birth weight was 0.51, and indicated that heavier
calves at birth demanded more milk from the dam.

The study of Jeffery et al. (1971a) showed a positive correlation
of birth weight with total milk yield of 0.18 and 0.11, but birth weight
explained only 0.0 to 2.4 percent of the total variance in milk yield.
The authors concluded that birth weight in their study was not an
important factor in influencing the milk yield of the dam.   The
conclusion is supported by the findings and discussion of Christian et al.
(1965) and Gleddie and Berg (1968).

The findings of Drewry et al. (1959) probably best indicate the
expected relationship between the birth weight of the calf and milk
yield in their reporting of a correlation between average daily milk
production and the birth weight of the calf in the first month of
lactation of Angus cows of 0.43, the relationship declining with time to
be r = 0.29 at 3 months and r = 0.12 at 6 months.

This tenuous relationship appears to preclude definite conclusions
about the influence of sex on milk yields, since marginally higher birth
weights measured in bull calves, giving a suckling advantage early in
life, may be subsequently reversed by a sex by environment interaction.

(v)   Breed of dam
Table 3.1 collates data published in the literature.   Reports
comparing beef with dairy breeds were included to illustrate the large
genetic differences which exist.   The small amount of extra variance in
productivity accounted for by compositional differences, discussed
earlier, means that, despite the high correlation of total solids and
total constituents with calf weaning weight, between breed comparisons
may be safely made on a yield-only basis.

Willham (1972) considered the average milk yield from three British
beef breeds (Angus, Hereford and Shorthorn) to be approximately 2.8kg per
day.   This would appear to be a conservative evaluation since most of the
literature reports returned appreciably higher daily production data
(Table 2.12).

The discussion on weaning weight, especially the sections on breed

Table 2.12

The effect of breed of dam upon milk yield

Breed	Age (years)	Reported production by breed (kg)	Lactation length (days)	Significance level of differences between breeds	Reference
A	M.A.	1407	180		Cole and Johansson (1933)
Beef Shorthorn	M.A.	2207	245		Dawson et al. (1960)
A, A × Hn	2	795 (4.0/day), 1136 (5.7/day)	200	**	Deutscher and Whiteman (1971)
A, Hd	M.A.	2.58/day, 2.56/day			Dickey et al. (1970)
Hd, Hd × Hn, Hn	3	1460 1930 3470	240	**	Holloway et al. (1975)
A, Hd		5.8/day 4.6/day		**	Jeffery et al. (1971a)
A, Hd	M.A.	3.9/day 2.9/day	240		Klett et al. (1965)
Hd, Hn	2	5.8/day 12.0/day			Kropp et al. (1972)
A, C, Hd	M.A.	698 834 607	175	**	Melton et al. (1966)
A, C, Hd	M.A.	664 784 581	175	**	Melton et al. (1967)
Hd	M.A.	10.2/day			Neville et al. (1960)
A, B, Brangus	3	3.1/day 2.8/day 3.4/day			Reynolds et al. (1967)
A, B, Brangus	4	3.8/day 3.2/day 3.8/day			
Hd, Hn					Saul and Morgan (1976)
A	M.A.	6.7/day			Serwanja et al. (1969)

A = Angus   M.A. = Mixed Age   ** = p <0.01
Hd = Hereford
Hn = Holstein   B = Brahman
C = Charolais

86

(Section 2.2 i) and maternal environment (Section 2.2 vi), has already implicated the superiority of the Angus breed over the Hereford breed for milk production. Among those confirming the superior performance of the Angus breed have been Dunn et al. (1965), who found that Angus cows produced approximately 1kg per day more milk than Hereford cows at all stages of lactation as determined by WNW. Omar (1974) found a milk production advantage for Angus over Hereford dams of approximately 2kg per day which was relatively consistent throughout the 205-day lactation.

Data were provided which indicated that Beef Shorthorn cows can be expected to produce similar quantities of milk as Angus cows. Schwulst (1969) gave daily production figures for Angus of 6.9kg; Shorthorn, 6.9kg; and Hereford, 6.4kg.

The European beef breeds, especially the Charolais, have exhibited greater milk production potential than British beef breeds (Melton et al., 1966, 1967; Klosterman et al., 1972) which is expected in view of their development as "dual purpose" breeds in European rural communities.

The study of Reynolds et al. (1967) has confirmed that B.indicus breeds exhibit inferior milk yields to B.taurus breeds, although the authors included a most important consideration relating to the milk yields of all beef breeds. Because of the considerable variation which occurs naturally within breed, milk production comparisons have limited value.

The size of the heterosis effect in crossbreeding appears to be dependent on the degree of genetic similarity between breeds. Where crossbreds of beef breeding have been compared with the straightbreds, crossbreds have usually exhibited milk yields superior to those of either straightbreed. Support for this phenomenon has come from the crossing of Angus and Hereford breeds as reported by Klosterman et al. (1972) and Jeffery et al. (1971a). Where there is large genetic dissimilarity the heterotic effect is small compared to the difference between the perform-ance of the high- and low-producing breeds, and crossbred production is located between that of the two parent straightbreeds. Kropp et al. (1972) and Holloway et al. (1975) have clearly demonstrated the phenomenon in their studies of Hereford, Holstein and Hereford-Holstein cross heifers.

C H A P T E R   T H R E E

MATERIALS AND METHOD

1.   Source of Data

(i)   Year One, 1975 - 1976

The experimental herd was located at Massey University's No. 3 sheep farm, "Tuapaka" of 462 ha. Tuapaka is situated southwest of the Manawatu Gorge, on the northern Tararua range, and is exposed to the prevailing westerly wind. The steepness and low soil fertility of the property make it largely unsuitable for any enterprise other than breeding.

The experimental herd consisted of 71 first-calving Angus heifers, 47 of which were bought in to complete the experimental group, the remainder being reared from birth on the property. At the start of the experiment, 8 animals were diagnosed barren and were removed. A further 9 animals were excluded from the calving analysis because of lateness to calve, loss of calf at or after calving, and other misadventure. The three origins of birth, Massey (22 heifers), Hawke's Bay (20) heifers, and Wairarapa (12 heifers) enabled the evaluation of differing autumn weight in its influence on the same traits as the treatments imposed, namely the weight of the calf at birth, during the pre-weaning period and at weaning, and the milk consumption by the calf.

The evaluation of the effect of the pre-calving plane of nutrition involved a switchover design with the switchover point being approximately 3 weeks before the onset of calving (that is, 6 weeks before the average calving date) and 70 days after the treatment groups were segregated. The groups were thus identified as HP-LP (18); LP-HP (17); and HP-HP (19) where the figures in parentheses indicate the number of heifers in each treatment group.

Prior to the commencement of treatment all heifers were run together following normal hill country set-stocking practises. When treatments were imposed, each treatment group was still set stocked, but at rates sufficient to produce the desired live weight changes. A turnip crop was incorporated in the feeding regime. The low plane of nutrition

was implemented by close forward grazing by ewes, followed by a stocking rate applied to the LP-HP heifers sufficient to cause a live weight loss of approximately 0.3kg per day for 70 days.

All heifers were identified by eartag and were allocated equally within the origin groups to the treatments, by matching the eartag number with a set of random numbers. The randomization procedure was carried out on 1 May, 1975, although the commencement of treatments did not occur until 8 May, 1975. The starting live weights were those taken on 1 May. For the purposes of simplification of management, the two high plane groups were run together for most of the time, distinction being made only for the purposes of statistical analysis. At the time of separation one group was fed on the turnip crop.

The live weight change of the heifers was monitored on a fort-nightly basis although not all treatment groups were necessarily weighed together. The 6 coincident weighing days were, in days from the start of the trial, 0 (1 May); 25 (26 May); 42 (12 June); 56 (26 June); 70 (10 July); 85 (25 July). The analysis of data from the pre-calving live weight of the heifers includes the weighing on 25 July as the last day of complete subgroups, 21 days before average calving date (15 August). Calving began on 30 July and no further birth weights were recorded beyond 12 September, after which date 2 late calvers were removed from the experiment.

For each heifer, the nutritional treatment ceased immediately prior to calving when parturition was considered imminent and such animals were removed to a common calving paddock. Each calf was weighed within 24 hours of birth and identified by numbered eartag. The weight was taken by suspending the calf by a leather sling from clockface scales attached to an iron bar supported by two people.

After calving the heifer and its calf were combined with mature cows and their calves in herds according to the day of birth of the calf. Additions to Herd A ceased when it was considered to have sufficient animals for managerial manipulation of pasture growth and Herd B began. This in turn was later closed and Herd C was created. The herds were run separately and each one included heifers and their

calves from each of the autumn live weight and treatment groups.

Live weight data were collected between calving and weaning from the heifers and their calves. Because the first three weighing days were associated with the estimation of milk consumption the interval between weighings was regular (20 days). Managerial complications aggravated by the Christmas period disrupted the regularity of the weighings and after the final milk determination at 60 days post-partum, those days common to all herds were 95, 120, 165, 180 days post-partum and weaning at 210 days. It should be noted that all weighing days except weaning reflected the age of the calf within herd and hence for each herd occurred on a different calendar date.

The estimation of milk consumption of the calf was made on three occasions by the weigh-nurse-weigh (WNW) method. The calf was separated from its dam at about 4 pm on the day preceding the estimation, and was suckled at about 9 am on the day of the estimation, giving a separation time of approximately 17 hours. The amount of milk determined by the method was taken as the production of the dam for the purposes of evaluating the influence of studied effects, although the figure was dependent on the appetite of the calf.

It was intended at the instigation of the experiment to obtain data on the rebreeding performance of the heifers after calving. Complications with the bull team, especially with respect to the fertility of one of the bulls, precluded the evaluation of this trait. A study of the reproductive performance of mature Angus cows (from 4- to 11-years-of-age) on the same property as the current experiment has been undertaken by Morris (1976).

The 1975-1976 collection of data terminated at weaning on 11 March, 1976 when the average age of calf was 210 days.

(ii) Year Two, 1976-1977
Observation was made of the performance of the heifers in their second year of production in order to estimate the size of the residual effects which may have persisted to that stage. The principal effects of interest were the treatment imposed before first calving, and autumn live weight during the first pregnancy.

After their first calf was weaned on 11 March, 1976, the heifers
were run on the hill with the mature cows and were subjected to a level
of nutrition to produce a loss of weight during the early winter period.
The intention was to incur a weight reduction of about 10 percent of
the weight of the heifer at weaning by the first week of June. From
that time it was proposed to increase the weight of the animals by
increasing the level of pasture offered to attain the initial weight by
calving.

At first the imposition of a harsh treatment through a high
stocking rate was required to promote a loss of weight. By 12 June,
the weight decline amounted to 8 percent of the weight recorded on
1 April. From that date until calving, which began on 27 July, the
heifers were fed to regain their initial weight.

At birth the weight of the calf was measured in the manner
described at Part (i) of this Section.

The data analysed in this study included the weight of the heifer
during the 1976 gestation period obtained on three occasions, namely
1 April, 12 June and 27 July. The birth and weaning weight of the calf
was also used in this study. The experiment was terminated at weaning
on 11 February, 1977, when the average age of calf was 163 days.

The live weight of the heifers was measured on other occasions,
at 3-weekly intervals, and are included in data intended for the
evaluation of other trial work on the property. Similarly the allocation
of the cow and her calf to one of three herds was made as described
earlier. The reduction of the numbers in each subclass by this stage
of the experiment precluded the incorporation of the effect of the herd,
1976, in the least squares model (Model 3.2) because of instability due
to the low subclass numbers.

2.   Method of Analysis

The procedure used in this study was the least squares analysis
of data with unequal subclass numbers as outlined by Harvey (1975).
Only linear fixed effects were included in the models.

1.   Year One, 1975 - 1976
(i)   The weight of the heifer after the start of the
experiment and before calving

The mathematical model:

$$Y_{ijkm} = \mu + o_i + t_j + s_k + b \, (x_{ijkm} - \bar{x}) + d_1 \, (z_{ijkm} - \bar{z}_1)$$
$$+ d_2 \, (z_{2jkm} - \bar{z}_2) + d_3 \, (z_{3jkm} - \bar{z}_3)$$
$$e_{ijkm} \ \ldots \ (3.1)$$

where:

Y_{ijkm} is the observation on the mth individual within the
k^{th} sex of calf, within the jth treatment, within
the ith origin.

μ is a general mean

e_{ijkm} is the error peculiar to each Y_{ijkm}

b is the linear regression coefficient of the weight of the
heifer on the day of birth of her calf (x_{ijkm})

and   d is the linear regression coefficient of the weight of the
heifer within origin on the autumn live weight of the
heifer. The origin is specified by the subscript of d and z.

The subscripts:

i = 1 to 3 where Origin 1 = Massey

2 = Hawke's Bay

3 = Wairarapa

j = 1 to 3 where treatment 1 = HP-LP

2 = LP-HP

3 = HP-HP

k = 1 or 2 dependent on the sex of the calf

   where 1 = male, 2 = female

(ii)   The weight of the heifer at the start of the
       experiment (1 May, 1975) and the birth weight of the calf

The mathematical model:

$$Y_{ijkl} = \mu + o_i + t_j + s_k + b\,(x_{ijkl} - \bar{x}) + e_{ijkl} \quad \ldots \quad (3.2)$$

where:

Y_{ijkl} is the observation on the lth individual within the
k^{th} sex of calf, within the jth treatment, within
the ith origin.

μ is a general mean

e_{ijkl} is the error peculiar to each Y_{ijkl}

b is the linear regression coefficient of the weight of the
   heifer, or the weight of the calf at birth, on the date
   of birth of the calf (x_{ijkl})

the subscripts are as in Model (3.1).

(iii) The post-calving weight of the heifer, the milk
       consumption of the calf, and the weight at weaning
       of the heifer and of the calf

The mathematical model:

$$Y_{ijklm} = \mu + o_i + t_j + s_k + h_l + b\,(x_{ijklm} - \bar{x}) + e_{ijklm} \quad \ldots \quad (3.3)$$

where:

Y_{ijklm} is the observation on the mth individual within the
l^{th} herd, within the kth sex of calf, within the jth
treatment and within the ith origin of dam.

μ is a general mean

e_{ijklm} is the error peculiar to each Y_{ijklm}

b is the linear regression coefficient of the trait on the date of birth of the calf (x_{ijklm})

the subscripts i to k are as in Model (3.1)

and l = 1 to 3 where   1 corresponds to Herd A,

2 to Herd B

and   3 to Herd C

2.   Year Two, 1976 - 1977

(i)   The weight of the heifer during the pre-calving period and the weight of the calf at birth and at weaning

The mathematical model applied to these traits was Model (3.2).

The models may be written in matrix terms as

$$y = Xb + e$$

where:

y is a (n × 1) vector of n observations

X is a (n × p) matrix, where p is the number of effects defined in the model

b is a (p × 1) vector of parameters which are unknown and are being estimated

e is a (n × 1) vector of unknown random error effects in which the elements are assumed to be normally and independently distributed such that the expected value of e_i is zero, the variance of $e_i = \sigma^2 I$, where I is an (n × n) identity matrix, and the covariances between any pair of e's are zero.

The method of least squares was used to estimate the b's. This involves choosing an estimator of b which minimizes the sum of squares of the deviations of the observations (y_i) from their expected values.

Assume $y = Xb + e$

and $E(e) = 0$

then $E(y) = Xb$

and $e'e = (y - Xb)' (y - Xb)$

$= y'y - 2b'X'y + b'X'Xb$

Choosing as the estimators $\hat{b}$ that value of b which minimizes e'e involves differentiating e'e with respect to the elements of b (Searle, 1966, 1971). Equating the differential to zero and express-ing the resulting equations in terms of $\hat{b}$, the following equations are obtained:

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

They are known as the normal equations. Provided $(X'X)^{-1}$ is of full rank they have the unique solution for $\hat{b}$ of

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

Whenever X'X is not of full rank, the solution of the equations does not give a unique value for $\hat{b}$, the estimator of b.

In this study, the equations were not of full rank. To obtain a solution for $\hat{b}$, a restriction was applied to make the X'X matrix of full rank. The restriction applied was that the estimates within a given group summed to zero. In terms of Model(3.1) this would be

$$\sum_i \hat{o}_i = \sum_j \hat{t}_j = \sum_k \hat{s}_k = 0$$

Inversion of the reduced matrix gave a generalised inverse from which the sums of squares for each effect were calculated. The method of calculating the sums of squares by the direct method and the analysis of variance were described by Harvey (1975).

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

where

$\hat{B}'$ is a row vector of the constant estimates for a given set

Z^{-1} is the inverse of the segment of the inverse of the variance -

covariance matrix corresponding, by row and column, to this set of constants

$\hat{B}$ is a column vector of the set of constants

The standard errors of the least squares means were obtained as follows:

$$s_{\hat{\mu} + \hat{a}_i} = \sqrt{(C^{ii} + C^{11} + 2C^{1i})\ \hat{\sigma}^2_e}$$

Where: $\hat{a}_i$ is the least squares estimate

C   is the inverse element of the reduced (X'X) matrix specified by its superscripts

$\hat{\sigma}^2_e$ is the error mean square

With the restriction that the sum of the constant estimates sum to zero within each set, the least squares means and their standard errors were computed from the constants and the inverse elements. The constant and the inverse elements for the last effect in each class were computed by conforming to the restriction that the rows and columns within the set sum to zero.

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

C H A P T E R   F O U R

RESULTS AND DISCUSSION

1.   The Effect of the Pre-calving Plane of Nutrition

(i)   The pre-calving live weight of the heifer

The least squares differences and least squares means for the
live weight of the heifers following the allocation to treatment
groups on 1 May, 1976, is shown in Table 4.1. The live weight of the
heifer is also presented within treatment graphed against time in
Figure 4.1.

There was no significant difference between the groups for the
first 25 days of the experiment (26 May). After that date the effect
of the restricted nutrition on the heifers of the LP-HP group became
significant at day 42 (12 June). The difference, however, was not
obtained by the depression of the live weight of the LP-HP group, but
rather from more favourable conditions promoting growth in the two
high plane groups. The New Zealand Gazette (1975: Appendix 1)
indicated that May was a particularly warm month with rain in the
third week inducing pasture growth after a dry month of April.

The increase in weight exhibited by the high plane groups was
not the same and a weight difference between them of 2.8kg (non-
significant) developed. The difference, which continued until the
switchover of treatments at day 70 (10 July), occurred largely because
the two high plane groups, ostensibly grazed together, were divided,
to have one group on a turnip crop. The managerial decision was to
continue feeding in this manner until the bordering pasture region was
grazed completely.

Between days 42 and 56 the difference between the low plane and
the two high plane groups increased as the latter continued to make slow
live weight gain while the low plane group lost 8.8kg in 14 days.

Between day 56 (26 June) and the day of treatment switchover,

Table 4.1

The least squares differences, least squares means and standard errors for the effect of planes of nutrition on pre-calving heifer weight (kg)

Treatment	No. of Records	L S D Mean S E Start of trial (1 May, 1975)		L S D Mean S E 25 days (26 May, 1975)		L S D Mean S E 42 days (12 June, 1975)	
HP-LP	18	- 0.4	382.0 ± 5.7	+ 0.2	383.2 ± 1.4	+ 2.8	388.6 ± 1.2
LP-HP	17	- 2.3	380.1 ± 6.0	+ 0.6	383.6 ± 1.4	- 4.4	381.4 ± 1.3 [a]
HP-HP	19	0.0	382.4 ± 5.4	0.0	383.0 ± 1.3	0.0	385.8 ± 1.1
		56 days (26 June, 1975)		70 days (10 July, 1975)		85 days (25 July, 1975)	
HP-LP		+ 2.5	392.0 ± 0.9	+ 0.8	382.1 ± 1.3	-19.7	376.0 ± 4.4
LP-HP		-16.9	372.6 ± 0.9 [a]	-19.1	362.2 ± 1.4 [a]	-20.7	375.0 ± 4.6
HP-HP		0.0	389.5 ± 0.9	0.0	381.3 ± 1.3	0.0	395.7 ± 4.2 [a]

Note: (i)   Superscripted values significantly different from unsuperscripted values at 1% level.

(ii)   L S D = Least squares differences.

(iii)   S E   = Standard error of least squares mean.
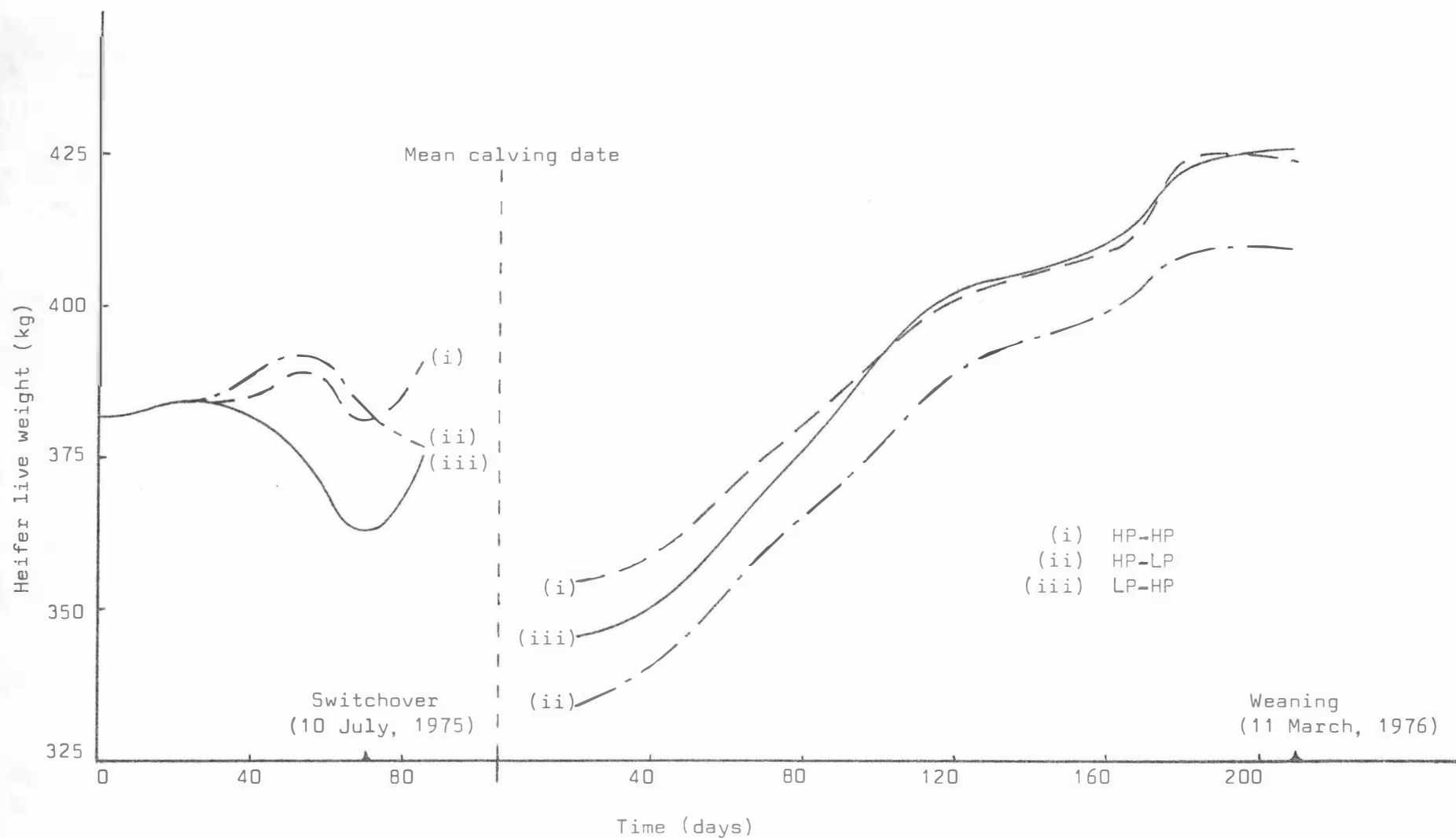
Figure 4.1 Heifer live weight versus time from start of experiment to calving, and from calving to weaning (Influence of plane of nutrition before calving)

day 70 (10 July), very cold frosty conditions prevailed reducing pasture growth. Furthermore, the end of the month of June and the whole of the month of July were notable for their unusually high frequency of south-easterly to south-westerly winds. These conditions seemingly had a considerable detrimental effect on all treatment groups in the 14-day period. The mean live weight loss in the LP-HP group in that period was 10.4kg and among the two high plane groups the loss was only marginally less (HP-HP: 8.2kg; HP-LP: 9.9kg) despite the higher plane of nutrition offered. In view of the expected increase in appetite of the heifers at this stage from foetal demand, the virtually equal live weight loss among all groups is difficult to explain. The strong winds accompanied by low temperatures probably reduced the inclination of the heifers to search for food, which aggravated the live weight reduction through heat loss resulting from the persistent air currents. The unadjusted data of the live weight of the LP-HP group at day 64 of the experiment substantiate that the decline was in fact a real live weight loss and not an experimentally induced error at weighing on day 70.

The live weight loss which occurred to 10 July from the start of the experiment is shown in Table 4.4. It is seen that the net live weight change of the HP-LP, LP-HP and HP-HP groups was +0.0, -0.26 and +0.02 kg/day, respectively, between the start of the trial and the 70-day weighing. It has already been indicated that weight loss did not begin until after day 25. Thus with respect to the live weight changes between day 26 and day 70, the estimates for the three treatment groups become -0.02, -0.48 and +0.04kg/day, respectively. It will be observed, then, that the objective of 0.5kg/day loss of weight in the LP-HP group was almost attained. The intended weight gain of 0.5kg/day among the heifers of the high plane, however, did not eventuate, largely because of the marked live weight decline between days 56 and 70 that has already been described.

After the two nutritional groups, LP-HP and HP-LP had been switched to their respective second level of feeding, the two high plane groups (LP-HP and HP-HP) gained weight at comparable rates (0.85 and 0.96kg/day, respectively). As intended, the HP-LP group lost weight at a rate of 0.41kg/day to be 6.0kg below autumn starting weight by 25 July, two weeks before the onset of calving. However, the weight decline in this group did not begin at day 70, but rather at day 56,

6 weeks, instead of 4 weeks before the onset of calving for the
reason of the climatic influence previously described. The period
of weight loss was thus more extended than originally intended, and
at an overall rate of 0.5kg/day. Occurring at a time when the growth
of the foetus was rapid, the extended period of loss presented a
better opportunity to depress birth weight, but confused the opport-
unity to draw conclusions from the previously intended 3- to 4-week
live weight depression period.

Snow fell in the third week of July, which may have contributed
to the loss of live weight in the HP-LP group after switchover by
increasing cold stress. The climate did not appear to influence the
weight gain of the two high plane groups, however. The final week of
July leading up to calving was unusually warm and contrasted with the
earlier part of the month which had extremely cold temperatures,
accompanied by strong west to south-west winds (New Zealand Gazette,
1975; Appendix 1).

The weight of the heifers at the final complete weighing day
before calving is seen in Table 4.1.

The manner in which the weight changes were achieved in the
period from the start of the experiment to calving in the HP-LP and
LP-HP groups contrasted markedly, but the final weight of the two groups
was practically equal (HP-LP 1kg heavier). Both groups weighed less
than their starting weight by, LP-HP: 5.1kg (-1.3 percent) and HP-LP:
6.0kg (-1.6 percent), which contrasted with an increase in live weight
of 13.3kg (+3.5 percent) in the HP-HP group. The difference between the
HP-HP + LP-HP groups was 20.7kg (Table 4.4; Item 3) or 5.5 percent.

It is important to consider in this context that the heifers
were still immature physiologically, as the weight change after calving
indicated (Table 4.3). To accommodate a growing foetus and exhibit zero
weight change implies an actual body weight decrease in an animal. All
calves had a birth weight in excess of 25kg and it is evident that a
large amount of body reserve in the growing heifer, especially those in
the LP-HP, and HP-LP groups, was required to nurture the conceptus of
which the foetus comprised the greater part.

Much larger losses of live weight have been recorded by others

Table 4.2

The least squares means, least squares differences and standard errors of least squares means for calf birth weight, 1975, from three-year-old heifers

Source	No. of Records	Least squares differences	Least squares mean (kg)	Standard error
General mean	54		26.50	$\pm$ 0.44
Treatment:				
HP-LP	18	-2.1	25.7	$\pm$ 0.8
LP-HP	17	-1.9	25.9	$\pm$ 0.8
HP-HP	19	0.0	27.8	$\pm$ 0.7 ns
Autumn weight of dam: (origin effect)				
Massey	22	0.0	26.6	$\pm$ 0.7
Hawke's Bay	20	+1.3	27.9	$\pm$ 0.7 ns
Wairarapa	12	-1.6	25.0	$\pm$ ▇.9
Sex:				
Male	23	+1.0	27.0	$\pm$ 0.7
Female	31	0.0	26.0	$\pm$ 0.6
Regression: birth weight on calving date (kg/day)			0.039	$\pm$ 0.038

Note: Statistical significance: (i) ns $0.05 < p < 0.10$

(ii) The influence of sex, and the regression of birth weight on calving date were not statistically significant.

(Hight, 1966, 1968b; Joubert, 1954; Ryley, 1961; Turman et al.,
1964) who studied immature heifers with the intention of causing a
depression of birth weight under extremely adverse nutritional
conditions. The objective of the present experiment was to gauge
the influence of normal management practises on calf birth weight by
inducing a 5 percent live weight depression in the dam at either of
two stages of gestation.

(ii)   The birth weight of the calf

The least squares differences for the effect of pre-calving
treatment of the dam on the birth weight of the calf were found to
be non-significant (0.05 < p < 0.10) and not in excess of 2.1kg.

The HP-HP group had the heaviest calves at birth (27.8kg). The
LP-HP treatment group had calves 1.9kg lighter (6.8 percent) and the
HP-LP group had calves 2.1kg (7.6 percent) lighter than the HP-HP
group. The standard error values given in Table 4.2 indicate that
there was large variation within treatment groups, the range of which
approached the magnitude of the least squares differences. Variation
of such magnitude reduced the significance level that could be
accorded the results.

The practical implication of a difference between the HP-HP and
HP-LP groups of 2.1kg attracts attention. It did not appear to affect
the viability or growth and suckling performance of the calves. In
view of the divergence of the stocking rates required to produce the
heifer weight difference obtained, either the lower limit of tolerance
in the HP-LP group was reached below which large birth weight depression
would have occurred, or the severe restriction of this group which would
have been needed to further reduce the birth weight of the calf would
have jeopardized the post-calving performance of the dam, including her
rebreeding activity. Because of the small difference in birth weight
between the LP-HP and HP-LP groups, despite the differing feeding
regimes in the last 1 to 2 months of gestation, it appears that the
second alternative applied.

It has been well established from the review of literature
(Chapter Two) that difficult calvings occur much more frequently in
primiparous heifers than in all other age groups combined and thus the

incidence of calving difficulty among the heifers of the present
study attracted examination. Among the 54 parturitions in the
recorded period of 44 days, 3 calves were involved in difficult
calvings, 2 of which recuired assistance. 2 calves died from dystocia
including 1 of the assisted calves; both dead calves were males.
The birth weight of all of these calves were above the means for any
of the groups, being 27.2kg (female), 30.8kg and 33.1kg (males).
The nutritional group in which the death occurred was the LP-HP
group with the other assisted birth being in the HP-LP group. There
was no calving difficulty in the HP-HP group. In view of the lesser
birth weight means for the HP-LP and LP-HP groups than the HP-HP group
it would thus appear that the dystocias were isolated occurrences.
Therefore it could not be stated conclusively that one nutritional
treatment was more closely associated with dystocia than another in
this study.

The review of literature indicated that birth weight is the
most important causative factor of dystocia, and among the very small
number of dystocias in the current study support for that observation
is found. It was not possible in the present study to determine
gestation length so this precludes any conjecture about a possible
association of extended gestation length with increased birth weight
and dystocia.

(iii) The post-calving live weight of the heifer
In the preceding discussion it was established that the influence
of pre-calving nutritional levels on the weight change of the heifer was
highly significant yet did not promote significant differences between
treatments in the birth weight of the calves.

The influence of the pre-calving plane on post-calving live
weight of the heifer is illustrated in Figure 4.1. Table 4.3 contains
data from the four main weighing days after calving, although there were
four others which were also common and contributed to Figure 4.1.

The difference between the weight of the heifer on the last
weighing day before calving and the first weighing day, 20 days after
calving, within treatment group, is seen in Table 4.4 (item 8) and the
relative differences may be gauged from Figure 4.1. The comparison

Table 4.3

The least squares differences, least squares means and standard errors for the effect of winter planes of nutrition on pre- and post-calving heifer weight (kg)

Treatment:

	N R	L S D	Mean S E Start of experiment (1 May, 1975)	N R	L S D	Mean S E 42 days (12 June, 1975)	N R	L S D	Mean S E 56 days (26 June, 1975)
HP-LP	18	- 0.4	382.0 $\pm$ 5.7	18	+ 2.8	388.6 $\pm$ 1.2	18	+ 2.5	392.0 $\pm$ 0.9
LP-HP	17	- 2.3	380.1 $\pm$ 6.0	17	- 4.4	381.4 $\pm$ 1.3 [a]	17	-16.9	372.6 $\pm$ 0.9 [a]
HP-HP	19	0.0	382.4 $\pm$ 5.4	19	0.0	385.8 $\pm$ 1.1	19	0.0	389.5 $\pm$ 0.9

	N R	L S D	Mean S E 70 days (10 July, 1975)	N R	L S D	Mean S E 85 days (25 July, 1975)	N R	L S D	Mean S E 20 days post-partum
HP-LP	18	+ 0.8	382.1 $\pm$ 1.3	18	-19.7	376.0 $\pm$ 4.4	16	-22.9	331.1 $\pm$ 7.6
LP-HP	17	-19.1	362.2 $\pm$ 1.4 [a]	17	-20.7	375.0 $\pm$ 4.6	17	- 8.6	345.4 $\pm$ 8.3
HP-HP	19	0.0	381.3 $\pm$ 1.3	19	0.0	395.7 $\pm$ 4.2 [a]	16	0.0	354.0 $\pm$ 9.6

	N R	L S D	Mean S E 95 days post-partum	N R	L S D	Mean S E 165 days post-partum	N R	L S D	Mean S E 210 days post-partum (weaning, 11 March, 1976)
HP-LP	16	-13.3	372.9 $\pm$ 8.0	16	-10.6	400.3 $\pm$ 9.0	16	-16.2	408.0 $\pm$ 9.0
LP-HP	17	- 0.5	385.7 $\pm$ 8.8	17	+ 0.8	411.7 $\pm$ 9.9	17	+ 1.8	426.0 $\pm$ 9.9
HP-HP	16	0.0	386.2 $\pm$ 10.1	16	0.0	410.9 $\pm$ 11.4	16	0.0	424.2 $\pm$ 11.5

Note: (i)   Superscripted value significantly different from unsuperscripted values at 1% level.
      (ii)   N R = Number of records per treatment group.
     (iii)   L S D = Least squares differences.
      (iv)   S E = Standard error of least squares mean.

which attracts the greatest interest is that between the LP-HP and HP-LP groups. The birth weight of the calves in these two groups was effectively equal (25.9kg and 25.7kg, respectively). However, the net weight loss over the 40-day calving period was 29.8kg in the LP-HP group and 45.0kg for HP-LP. It appears that the heifers of the HP-LP group experienced considerably more trauma at parturition than the LP-HP heifers which may have decreased the weight of the heifers even further before recovery in live weight began. Furthermore, it is feasible that the LP-HP heifers had already fully adjusted to a high plane and thus continued to make weight gain after calving. The HP-LP group, when transferred to a higher plane after parturition, evidently required a period to adjust adequately. Hight (1966) observed that a period of preconditioning to a higher plane of nutrition from a low one may be needed for the effective utilization of all that is eaten.

The HP-HP group did not experience any major stress during the experimental period apart from an 8.2kg drop in 14 days between days 56 and 70 of the pre-partum period. The metabolism of this group of heifers was probably less attuned to the efficiency of usage of food than the LP-HP group and consequently exhibited less live weight gain during the immediate post-partum period.

In the absence of data relating to the weight of the heifer at calving it is not possible to comment on the percentage of the products of conception comprised by the calf. It is possible that the HP-HP group lost significantly more weight at parturition than the HP-LP and LP-HP groups after the latter groups had compensated for nutritional stress by reducing the amount of conceptus - not - foetus in the manner described by Ewing et al. (1966), Joubert (1954) and Ryley (1961).

At no stage after calving did the tests of significance reveal any significant difference between the heifers of the pre-calving treatment groups despite live weight differences as large as 23kg (20 days post-partum, HP-LP vs HP-HP). Undoubtedly the comparisons were not statistically significant in such cases because of the large variation which occurred within treatment groups as indicated by the standard errors of the least squares means. It is suspected that much of this came from the climatic change which occurred during the 44-day calving period (30 July to 12 September). The linear regression of heifer weight

on date of parturition was used to correct for time since parturition
to the weighing day in question. However, the procedure may have
failed to adequately adjust the weight of the heifers calving at
either end of the period. This would occur if the growth of the
heifers was curvilinear, not linear. The end of July was character-
ised by warm temperatures and sunny days, while during early August
rain and gale force winds were prevalent. This inclement weather
cleared towards the end of that month and was followed by dry conditions
in early September (New Zealand Gazette, 1975; Appendix 1). It is
feasible that correcting by linear regression for the adverse weather
conditions in the middle of this period did not allow sufficiently for
the more favourable conditions at the extreme ends.

With respect to the weight of the heifers from 20 days post-
partum to weaning, there appeared to be a trend associated with the
influence of the treatments imposed, although at no stage were the
differences significant. The HP-HP group maintained a weight advantage
over the LP-HP group which diminished rapidly between 60 days post-
partum (6.3kg) and 90 days post-partum (0.5kg), and the LP-HP group
became heavier at 120 days post-partum. These two groups were of
comparable weight from 120 days to weaning at 210 days post-partum.

The HP-LP group weighed consistently less than the HP-HP or
LP-HP groups (see Figure 4.1). Table 4.3 indicates that the difference
of live weight between the HP-LP, and HP-HP heifers did not change
greatly throughout the post-calving period, where a 22.9kg deficit was
reduced to 16.2kg at weaning.

The period between 20 days post-partum and weaning involved
average daily live weight gains for the treatment groups of HP-LP:
0.41kg/day; LP-HP: 0.43kg/day; HP-HP: 0.37 kg/day. These average
daily gains were calculated by the difference between the weight at
either end of the period, divided by the number of days. Care is
required in interpreting such constants because of fluctuations in the
environment causing a deviation from linear growth. The purpose of
their calculation was to compare them with the pre-weaning weight and
weaning weight of the calf and the milk consumption estimates. It will
be recalled that, in the literature, evidence was provided which
indicated that the greatest live weight gain of the calf among beef

Table 4.4

Treatment means for heifer live weight (kg), heifer live weight changes as differences
between least squares means (kg/day), and differences between treatments

	Treatment means			Differences	
	HP-LP	LP-HP	HP-HP	HP-HP minus HP-LP	HP-HP minus LP-HP
1 Start of treatment (1 May, 1975) (kg)	382.0	380.1	382.4	+ 0.4	+ 2.3
2 Treatment switchover, 3 weeks before calving (10 July, 1975) (kg)	382.1	362.2	381.3	- 0.8	+19.1 **
3 Pre-calving (25 July, 1975) (kg)	376.0	375.0	395.7	+19.7 **	+20.7 **
4 Live weight change, start to switchover (70 days) (kg/day)	0.00	-0.26	+0.02		
5 Live weight change, switchover to pre-calving (15 days) (kg/day)	-0.41	+0.85	+0.96		
6 Live weight change, start to pre-calving (85 days) (kg/day)	-0.07	-0.06	+0.16		
7 Post-calving (20 days) (kg)	331.1	345.4	354.0	+22.9	+ 8.6
8 Live weight loss, pre-calving to post-calving (calving period) (kg)	44.9	29.6	41.7		
9 Weaning (11 March, 1976) (kg)	408.0	426.0	424.2	+16.2	- 1.8
10 Live weight change, post-calving to weaning (kg/day)	+0.41	+0.43	+0.37		

Note: Significance level ** $p < 0.01$.

animals during the suckling period was associated with the least gain in the dam.

(iv)   The milk consumption of the calf

The least squares differences and least squares means for the effect of the pre-calving plane of nutrition on milk consumption as determined by WNW are seen in Table 4.5. There was no significant difference between the treatment groups for daily milk consumption, and there was large within-group variation. In many instances the standard errors were of equal or greater magnitude than the least squares differences.

It is suspected that factors associated with the age of the dam, such as temperament and the strength or weakness of the mothering instinct among these first-calving heifers influenced the milk determinations in this study. The discussion of the influence of autumn weight on estimation of milk consumption evaluates the problems associated with temperament more fully, where there appeared to be differing responses among the three origin groups to the WNW method.

Within all treatment groups the milk consumption measured was within the values reported in the literature (see Table 2.12) although those studies of first-calving Angus heifers generally returned smaller values than those found in the present study. None of the groups showed the highest consumption levels at the same time and therefore they require separate description.

The HP-LP group demonstrated its peak milk consumption at 20 days and then declined very marginally thereafter. This early peaking of lactation may involve more than one factor. The birth weight of the calves of the HP-LP heifers was marginally lower than in the other groups and therefore they may have tended to remove less milk in the early stage of lactation, leading to a fall off in the production of the dam in the first 60 days rather than an increase in that period. Furthermore, any flexibility in the ability to recover earlier milk production levels in this particular group may well have been eroded by the depletion of body reserves over the last part of gestation. The preference given by the maternal organism to repair and maintain its body ahead of lactation is well documented (Brinks et al., 1966; Singh et al., 1970; Vaccaro and Dillard, 1966). The weight gain exhibited by

Table 4.5

The least squares differences, least squares means and standard errors for the effect of pre-calving treatment of the dam on the milk consumption of the calf

	No. of records	Milk consumption (kg)					
		L S D Mean S E 20 days post-partum		L S D Mean S E 40 days post-partum		L S D Mean S E 60 days post-partum	
Treatment:							
HP-LP	15	+0.08	4.13 $\pm$ 0.21	-0.12	4.03 $\pm$ 0.34	-0.40	4.06 $\pm$ 0.58
LP-HP	14	+0.17	4.22 $\pm$ 0.23	-0.42	3.73 $\pm$ 0.38	+0.88	4.61 $\pm$ 0.65
HP-HP	16	0.00	4.05 $\pm$ 0.22	0.00	4.15 $\pm$ 0.36	0.00	3.74 $\pm$ 0.62

Note: (i) None of the differences between treatment groups was statistically significant.

(ii) L S D = Lease squares differences.

(iii) S E = Standard error of least squares mean.
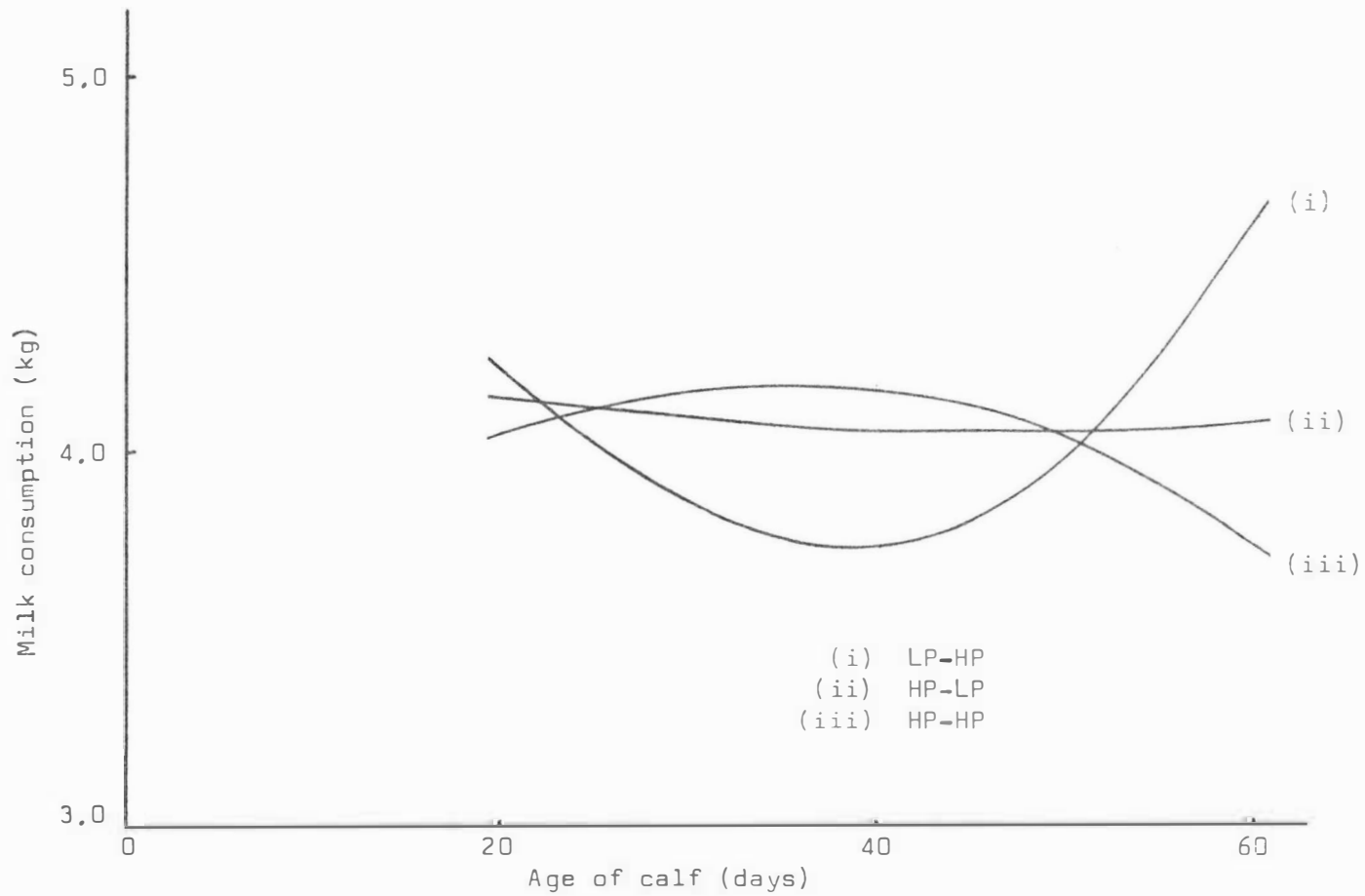
Figure 4.2 Milk consumption of the calf _versus_ the age of the calf
(Influence of plane of nutrition of dam before calving)

this group of heifers was certainly the greatest of any of the three
groups in the 60-day period.

The LP-HP group exhibited a close association between the
weight change of the heifer, the weight change of the calf and the
milk consumed. At the 20-day milk determination the group exhibited
the highest yield to the calf of any of the treatment groups (difference
non-significant). After that time the heifers of the group showed a
live weight gain of 4.3kg while the weight change of the calves was
21.8kg. At day 40, the milk yield of the heifers of this group was the
lowest.

Between 40 and 60 days the weight change of the heifers was
14.2kg, three times larger than in the preceding 20-day period, and the
calf weight change was 11.5kg, half as great as in the preceding 20-day
period. At the 60-day milk yield determination the LP-HP heifers again
yielded the most amount of milk to the calf of any of the three groups.

Hence, when the weight increase of the dam was greatest, the milk
yield and calf growth were greatly reduced. The explanation for the
depression of milk yield at 40 days, and also the subsequent live weight
change of the calf, in deference to the increased live weight gain of
the heifer is not apparent, but appears to be related to the pre-calving
plane of nutrition since the other two treatment groups did not exhibit
this trend.

The heifers of the HP-LP treatment group also exhibited a pattern
of association between the live weight gain in the heifer and her milk
yield where the greatest heifer weight gain was associated with the
lowest amount of milk consumed. However, unlike the LP-HP group, which
exhibited a trough at 40-days post-partum, the HP-HP group showed a peak
at that time. The small difference in milk yield between the 40-day
estimation for the HP-HP group and the yields at 20- and 60-day determin-
ations indicated a gentle lactation curve, a pattern substantiated by
other experimental findings from the WNW method (Drewry et al., 1959;
Totusek et al., 1973).

In spite of the LP-HP group having superior milk yield at 20- and
60-day estimations, the change in the live weight of the calf between 20
and 40 days, and 40 and 60 days, favoured the HP-HP group above the other
two groups.

Table 4.6

The least squares differences, least squares means and standard errors for the effect of winter treatment imposed on the dam on the pre-weaning and weaning weight of the calf (kg)

	No. of records	L S D	Mean S E	L S D	Mean S E	L S D	Mean S E
		Birth		20 days of age		40 days of age	
Treatment:	B W						
HP-LP	18 16	-2.1	25.7 ± 0.8	-1.6	47.5 ± 1.3	-2.3	59.1 ± 1.8
LP-HP	17 16	-1.9	25.9 ± 0.8	-1.4	47.7 ± 1.4	-2.2	59.2 ± 1.9
HP-HP	19 17	0.0	27.8 ± 0.7	0.0	49.1 ± 1.4	0.0	61.4 ± 1.9
		60 days of age		95 days of age		120 days of age	
HP-LP		-5.9	80.1 ± 2.2	-4.3	107.5 ± 3.1	-3.4	130.1 ± 4.0
LP-HP		-6.1	79.9 ± 2.3	-5.9	105.9 ± 3.3	-6.2	127.3 ± 4.2
HP-HP		0.0	86.0 ± 2.3	0.0	111.8 ± 3.4	0.0	133.5 ± 4.3
		165 days of age		180 days of age		210 days of age (weaning)	
HP-LP		-3.6	157.5 ± 4.4	-4.1	174.5 ± 5.5	-4.6	178.8 ± 5.6
LP-HP		-5.1	156.0 ± 4.7	-6.2	172.4 ± 5.8	-3.8	179.6 ± 5.9
HP-HP		0.0	161.1 ± 4.7	0.0	178.6 ± 5.9	0.0	183.4 ± 6.0

Note: (i) No. of records B = number of calves at birth W = number present at all other weighings.

(ii) L S D = Least squares differences.

(iii) S E = Standard error of least squares mean.

(iv) None of the differences between treatments groups was statistically significant.

(v)   The weight of the calf during the pre-weaning
       period and at weaning

The least squares differences and least squares means for the
effect of the pre-calving plane of nutrition of the dam on the growth
of her progeny are presented in Table 4.6. Table 4.4 (item 10)
indicates the average daily live weight increase of the heifers over
the pre-weaning period.

The live weight of the calf before and at weaning was not
significantly influenced by the treatment imposed on the dam before
calving. The least squares differences, however, indicate that the
performance of the calves from the HP-HP heifers was superior to that
of the calves of the other two treatment groups.

The birth and weaning weights of the LP-HP group were heavier
than in the HP-LP group (difference non-significant), although the
calves of the latter group were marginally heavier during the period
from 60- to 180-days-of-age.

The difference between the HP-LP and LP-HP groups for calf
rearing ability is a reflection of the difference in weight changes
which occurred. The live weight gain of the former group of heifers
during the lactational period was 10.4kg (0.05kg per day) less than
that of the latter group, and this was reflected in the weaning weight
advantage of the calves of the HP-HP heifers over those of the LP-HP
heifers of 3.8kg.

The comparison of the HP-LP group with the HP-HP group also
confirms the inverse relationship that has been found between the live
weight gain of the dam and the weaning weight of the calf (Brinks et al.,
1962; Gregory et al., 1950; Singh et al., 1970). The HP-LP group
gained 7.7kg more than the HP-HP group but weaned calves which were
4.6kg lighter.

The LP-HP heifers gained slightly more weight than the HP-LP
group as well as weaning slightly heavier calves. It appears that
this superior efficiency of the LP-HP heifers was derived from their
enforced low plane early in gestation followed by a high plane,
compared with the enforced low plane late in gestation as experienced
by the HP-LP group.

(vi)   Discussion

This study has involved a comparison of two forms of experimental work that have been reported in the literature to date. The work of Hight (1968c) involved combining a low plane of nutrition in the early winter with an elevated plane either 3 or 8 weeks before calving. He showed that the 8 weeks of high-plane feeding offset the effect of the low plane on birth weight more than did 3 weeks of elevated feeding.

Earlier work by Hight (1966, 1968b) and other reports from over-seas studies, including those of Corah et al. (1975); Holloway et al. (1975); Falk et al. (1975) and Wiltbank et al. (1962) have involved investigations similar to the HP-LP feeding regime of the present study. The experiments of the authors mentioned above included the objective of obtaining divergent live weights in the cows by calving time by feeding either a high or low plane of nutrition during gestation. Most of those experiments succeeded in demonstrating that birth weight differences could be obtained if the feeding levels differed sufficiently to produce highly significant live weight differences in the pregnant females between the groups of the order of 15 to 20 percent.

In the present study the heifers of the LP-HP group lost 5.6 percent of their autumn live weight and regained this loss by calving. There was no significant difference between the HP-HP and LP-HP groups with respect to birth weight thus indicating that most of the effect of the low plane of feeding had been offset by the high plane.

The HP-LP group showed a highly significant ($p < 0.01$) reduction of heifer live weight of 5.0 percent by calving time compared with the HP-HP group. The former group appeared to exhibit the greatest reduction in birth weight (7.6 percent) although again, the difference was not significant.

The live weight gain of the heifers after calving is important in terms of growth and also the rapidity of returning to a weight at which post-partum oestrus occurs. The HP-HP heifers exhibited a growth rate less than that of the heifers of the LP-HP group, indicating that the LP-HP heifers were better able to utilize the spring pasture, whether by satisfying their greater appetite, or by an improved efficiency of pasture utilization through the control of metabolism, or by a function of both.

The most important feature of this increased weight gain ability of the LP-HP group was that a large part of it occurred early in lactation when the demand of the calf through its milk consumption was small and the spring pasture growth was beginning. The superior ability to gain weight in the LP-HP heifers, however, was not at the expense of the weaning weight of the calf, since the difference between treatment groups for this trait was not significant. Hight (1968c) also found that the low plane of nutrition during early gestation did not significantly affect the weaning weight of the calf when it was offset by elevated feeding prior to parturition.

No measure of the rebreeding performance was possible because of the unrecognized infertility of one bull. The findings of Corah et al. (1975) and Turman et al. (1964) were included in the review of literature (Chapter Two, Section 1.3 xi). Based on their results it would appear that the HP-LP group could have been expected to return inferior rebreeding performance, especially with respect to the number of days to first oestrus. Morris (1976) found from a study of mature cows on the Massey property that the plane of nutrition during the immediate pre-partum period is of paramount importance to rebreeding performance. This implies that the LP-HP group should have performed satisfactorily in view of their elevated feeding for at least 3 weeks before calving began.

The effect of the plane of nutrition on the percentage of calves weaned should be measured as the proportion of the number of heifers mated in each nutritional group. This was not possible because of the removal of some heifers before the experiment began after being diagnosed barren. Nor would the percentage of calves weaned as a proportion of the heifers in the experiment at its start be meaningful since some reared foster calves after their own calves had died from disease and misadventure.

The value of the three pre-calving nutritional regimes attracts discussion with reference to pasture management and the periods of nutritional shortages during the winter.

The study involved the heifers of the LP-HP group on reduced intake for at least 45 days (26 May to 10 July) since the intended

restriction could not be implemented promptly enough to give a 70-day restriction. By way of contrast the HP-LP group was restricted for 34 days (26 June to 30 July) including the period of unintended depression due to climatic adversity.

No estimates of food intake were able to be made in the study, but it was observed that extreme pressure of numbers was required to achieve a live weight loss of the magnitude described. The heifers of the LP-HP group appeared to modify their grazing habit to include fibrous rushes and seed-head stalks. On the other hand, the high-plane groups were fed to the maximum levels available without the feeding of hay or expensive supplements.

The restriction of the LP-HP group early in the winter permitted the accumulation of pasture which was held over for feeding at a high plane to the heifers later in the winter. It is therefore suggested that this feeding regime was to be recommended for feeding a greater number of pregnant animals during the early winter without any detrimental effect being observed in the productivity of the heifer.

The heifers of the HP-LP group, on the other hand, required a lower stocking rate during the early winter in order to accommodate the level of intake at that time. As a consequence of the low plane at the end of gestation, the group appeared to experience a lower rate of post-calving live weight gain than the LP-HP or HP-HP groups, in spite of a failure to exhibit a significantly reduced calf birth weight, the trait which it was anticipated, would be most affected by this treatment.

2.   The Autumn Weight of the Dam

        The first order interaction between origin of dam and pre-
calving plane of nutrition was tested independently and found to be
non-significant.   Therefore it was not considered part of Model (3.1).

        The influence of autumn weight by origin of heifer is shown
in Tables 4.7 to 4.10 inclusively.   It is evident that the heifers
of the Hawke's Bay origin exhibited a marked superiority above the
performance of the Massey and Wairarapa heifers for productivity as
assessed by the weight of calf weaning.   It is appropriate to evaluate
the factors which may have contributed to the difference.

        There were three possible sources of variation in the autumn
live weight of the heifers of the three origins in the experiment.
These included the environment experienced before the time of purchase
(i.e., the first two-and-a-half-years-of-life), the amount of genetic
ability possessed conditioning the rapidity of growth at an early age,
and the age of the heifer.   No data were available concerning the
precise age of the Hawke's Bay or Wairarapa heifers.

        In the present study the heifers were run with two bulls
together during the mating season and it was therefore not possible to
record the sire of each calf.   Any variation in birth weight or weaning
weight due to the effect of the sire will have been accounted for by
the error term in Models (3.2 and 3.3).   The effect of the sire will
have been expressed in the birth weight and weaning weight of the calf
through the genetic ability for either pre- or post-natal growth passed
to the calf by the sire.   Theoretically half of the variation in birth
weight due to genetic effects will have been removed by the error term
in the above Models by accounting for the sire effect.   Thus it is assumed
that most of the variation which occurred in the live weight of the calf
was due to a difference in maternal ability between the heifers of the
different origins.

        The question arises as to how much of the superior ability for
maternal environment of the Hawke's Bay heifers was obtained from a
more favourable nutritional environment and how much was from a superior
inherent ability for growth to three-years-of-age.   In view of the
diminishing influence of origin of dam exhibited as the heifers became

older, as seen in Table 4.19, it is safe to assume that most of the advantage in maternal ability of this group was environmentally obtained. This distinction is necessary since it is the basis of a discussion of the importance of growing heifers to a large size before the autumn of their first pregnancy. If it was decided that the difference in the live weight of the heifers between origins was mostly genetically induced, then that discussion would have a dubious foundation.

(i)   The pre-calving live weight of the heifer

The least squares differences and least squares means for the weight of the heifer within origin are given for the six weighing days before calving in Table 4.7.

The heifers of Hawke's Bay origin were significantly (p < 0.01) heavier than the Massey or Wairarapa heifers at all weighing dates. The heifers of Wairarapa origin were heavier than the Massey heifers on all occasions although a significant difference was found only at days 42 (12 June; p < 0.05); 56 (26 June; p < 0.01) and 70 (10 July; p < 0.01).

The discussion of results of the influence of the pre-calving nutritional treatment on heifer live weight indicated a large depression of live weight in all treatment groups between days 56 and 85 of the trial, measured at day 70. The evidence indicated that the depression was probably climatically induced. This observation is strengthened by the fact that the analysis of heifer weight by origin classification also indicated a decline of the same magnitude as that measured in the HP-LP and HP-HP groups (up to 10kg). Apart from the common live weight decline at that time, the live weight of the heifer within origin remained remarkably stable and constant throughout gestation. The implication of this observation is that the weight loss in the low-plane treatment group was almost exactly matched by the amount of weight gain in the two high-plane groups at all stages of gestation.

After the experiment commenced, the weight of the heifer at each weighing day was corrected for her starting weight by applying a linear correction as a covariate to Model (3.1). This regression of weight at

Table 4.7

(a) Least squares differences, least squares means and standard errors for the effect of the autumn weight of the heifer on the winter weight changes before calving (kg)

(b) Regression coefficients within origin of heifer of heifer weight on autumn weight (kg/kg)

Origin:	No. of records	LSD Mean SE Start of experiment (1 May, 1975)	LSD Mean SE 25 days (26 May, 1975)	LSD Mean SE 42 days (12 June, 1975)
Massey	22	0.0 368.5 ± 5.1 ^{x}	0.0 369.6 ± 1.2 ^{x}	0.0 370.7 ± 1.1 $^{a\ x}$
Hawke's Bay	20	+37.2 405.7 ± 5.3 $^{x\ z}$	+39.6 409.2 ± 1.3 $^{x\ z}$	+41.0 411.7 ± 1.1 $^{x\ z}$
Wairarapa	12	+ 1.9 370.4 ± 7.2 ^{z}	+ 1.6 371.2 ± 1.7 ^{z}	+ 2.8 373.5 ± 1.5 $^{a\ z}$
b (Massey)			0.05 ± 0.06	0.11 ± 0.05 *
b (Hawke's Bay)			1.55 ± 0.05 ***	1.59 ± 0.05 ***
b (Wairarapa)			0.00 ± 0.10	0.04 ± 0.08

		56 days (26 June, 1975)	70 days (10 July, 1975)	85 days (25 July, 1975)
Massey		0.0 369.3 ± 0.8 ^{x}	0.0 359.0 ± 1.2 ^{x}	0.0 367.8 ± 3.9 ^{x}
Hawke's Bay		+39.3 408.6 ± 0.8	÷41.1 400.1 ± 1.2 ^{x}	+39.6 407.4 ± 4.0 $^{x\ z}$
Wairarapa		+ 6.9 376.2 ± 1.1 ^{x}	+ 7.5 366.5 ± 1.7 ^{x}	+ 3.9 371.7 ± 5.5 ^{z}
b (Massey)		0.10 ± 0.04 *	. 0.11 ± 0.05 *	0.04 ± 0.18
b (Hawke's Bay)		1.63 ± 0.03 ***	1.58 ± 0.05 ***	1.62 ± 0.16 ***
b (Wairarapa)		0.00 ± 0.06	-0.04 ± 0.09	-0.01 ± 0.31

Note: (i) Significance levels *** p < 0.001
        * p < 0.05

(ii) Values superscripted 'a' are significantly different at 5% level.
      Values superscripted 'x' or 'z' are significantly different at 1% level.

(iii) L S D = Least squares differences.

(iv) S E = Standard error of least squares mean.

each subsequent day on starting day weight was applied within origin
subgroup to increase the accuracy of the correction procedure and to
indicate from the regression coefficient the response of the heifers
to the winter environment at Tuapaka.

Among the heifers of Hawke's Bay origin the regression was
very highly significant (p < 0.01) and indicated that the heaviest
heifers on 1 May, 1975, continued to be the heaviest throughout the
pre-calving period. The size of the regression coefficient was
between 1.5 and 1.63 and indicated that a heifer having a 1kg live
weight advantage above another at the start of the experiment was
1.55 to 1.63kg heavier at a subsequent weighing day. The divergence
in body weight which resulted occurred largely in the first 56 days
of the experiment (b = 1.63; p < 0.001).

Among the heifers born at Massey the coefficient for the
regression of subsequent weight on starting weight was significant
(p < 0.05) at days 42, 56 and 70, and indicated that a 1kg live weight
advantage would promote a 0.1kg advantage at subsequent weighing days.

The coefficient for the regression of subsequent weight on
starting weight among the Wairarapa heifers indicated a non-significant
relationship which was consistently small (less than 0.05) and on two
occasions (days 70 and 85) was small and negative. Thus a weight
advantage at the start of the experiment was not associated with any
advantage at later weighing days.

The interpretation of the regression of weight on starting
weight for each origin subgroup is complicated by the absence of age
data for the heifers of the Hawke's Bay and Wairarapa origins. Among
the Hawke's Bay heifers it is suggested that the initial diversity of
weight change that occurred may be related to genetic differences
within this origin. Evidently the environment encountered by the heifers
in the Hawke's Bay favoured those of lesser genetic ability for rapid
growth to maturity. In a less favourable environment on the poorer
hill country at Tuapaka, the heaviest heifers increased their weight
advantage.

The independence of later weight from starting weight among
the Wairarapa heifers suggests that age differences may have been

great in this group. Younger heifers evidently continued their growth at a greater rate than older heifers which would have been closer to maturity.

The regression coefficient for the Massey heifers indicated that the relationship of live weight at a later time to the starting weight was more uniform than for the Wairarapa heifers. Although small and not always significant the coefficient was positive indicating that the ranking by weight at the start of the experiment did not change significantly. It is to be remembered that the Massey heifers grew on the property and hence would have been best adjusted to the conditions which prevailed.

(ii)   The birth weight of the calf

The birth weight of the calves from the heifers of the three origins is shown in Tables 4.2 and 4.10. The calves from the Massey heifers were lighter than those born of Hawke's Bay heifers by 1.3kg (4.7 percent) and heavier than the calves from the Wairarapa heifers by 1.6kg (6.4 percent). The difference between the Hawke's Bay and Wairarapa groups for calf birth weight (2.9kg) approached significance $(0.05 < p < 0.10)$.

Despite the highly significant difference that existed between the autumn weight of the heifers of Hawke's Bay origin and that of the Massey and Wairarapa heifers, the birth weights were not significantly different. The results indicate that growing heifers to a large body size by the autumn of their first pregnancy may be accomplished without significantly affecting the birth weight of the calf.

There was little in the literature on the effect of the autumn weight of the dam on the birth weight of the calf. However, the discussion of the weight of the dam at calving in the review of literature has indicated that its association with the birth weight of the calf is positive, but small. Alexander et al. (1960) found that approximately only 6 percent of the variation exhibited in birth weight was associated with the weight of the dam.

On the basis of the limited evidence available from the present

experiment dystocia was no more likely to occur in any one category of autumn weight than another. In the study, however, weight of the heifer was associated with size where the heaviest animals also tended to be the largest. Because of the manner of feeding after the start of the experiment, pelvic restriction due to fat deposition from over-conditioning was not considered to be likely.

(iii)   The post-calving live weight of the heifer

The influence of the autumn live weight of the heifer on her post-calving live weight is seen in Table 4.8.

Between the last weighing day before calving (25 July, 1975; Table 4.7) and the first day after calving (20 days post-partum; Table 4.8) there was a considerable change in the least squares differences between the origins of the heifers. The Wairarapa heifers, which before parturition were 3.9kg heavier than the Massey heifers, were 13.5kg heavier after calving. The Hawke's Bay heifers were 39.6kg heavier (p < 0.01) than the Massey heifers before parturition and were 28.8kg heavier afterwards - a reduction in their weight advantage of 10.8kg. Much of the change of these differences was due to variation in the ability to recover from parturition and the loss of live weight at that time.

The group which made the most live weight gain during the period from 6 days before the onset of calving to 20 days afterwards - a period of approximately 35 days for each post-calving herd - was that from the Wairarapa. The loss of weight by origin was, with the birth weight in parentheses: Massey 38.4kg (26.6kg); Hawke's Bay 49.2kg (27.9kg); Wairarapa 28.8kg (25.0kg).

If the foetus is assumed to comprise approximately 54 percent of the conceptus at parturition, all heifers should have lost about 50kg live weight, without accounting for the weight lost as part of the stress of parturition itself. The weight gain within 20 days of calving indicates quite clearly that the Wairarapa heifers rapidly gained much of the weight lost with the Hawke's Bay heifers gaining very little.

This weight change was very similar to the rapid growth made by the LP-HP treatment group between the last weighing day before calving

Table 4.8

The least squares differences, least squares means and standard errors for the
effect of the autumn weight of the heifer on post-calving heifer live weight (kg)

	No. of records	L S D 20 days post-partum	Mean	S E	L S D 40 days post-partum	Mean	S E	L S D 60 days post-partum	Mean	S E
Origin:										
Massey	19	0.0	329.4 ± 8.6 [x]		0.0	338.1 ± 8.9 [x]		0.0	349.2 ± 9.0 [x]	
Hawke's Bay	19	+28.8	358.2 ± 7.2 [x]		+25.5	363.6 ± 7.5 [x]		+29.4	378.6 ± 7.6 [x]	
Wairarapa	11	+13.5	342.9 ± 9.7		+ 8.0	346.1 ± 10.0		+11.1	360.3 ± 10.2	
		95 days post-partum			120 days post-partum			165 days post-partum		
Massey		0.0	370.2 ± 9.1 [x]		0.0	384.8 ± 9.4 [x]		0.0	397.3 ± 10.2	
Hawke's Bay		+27.0	397.2 ± 7.6 [x]		+29.3	414.1 ± 7.9 [x]		+24.2	421.5 ± 8.6	
Wairarapa		+ 7.2	377.4 ± 10.3		+ 9.6	394.4 ± 10.6		+ 6.9	404.2 ± 11.5	
		180 days post-partum			210 days post-partum (weaning)					
Massey		0.0	406.6 ± 10.1		0.0	406.7 ± 10.3				
Hawke's Bay		+25.5	432.1 ± 8.5		+25.1	431.8 ± 8.6				
Wairarapa		+ 9.3	415.9 ± 11.4		+13.0	419.7 ± 11.6				

Note: (i) Superscripted values are significantly different at 1% level.
       (ii) L S D = Least squares differences.
       (iii) S E = Standard error of least squares means.

and the first weighing day post-calving. It was suggested there
that the percentage of conceptus-not-foetus is able to be altered
by maternal control. Without live weight data from the heifers
at parturition the explanation is difficult. The most significant
finding is that the weight increase was made at a time of a low
demand from the calf, and at a stage most favourable to prepare the
heifer for rebreeding.

After calving the difference between the Wairarapa and Hawke's
Bay origin groups ceased to be significant, although care is required
in interpreting the least squares differences. It will be seen that
the difference between these groups ranged from 15.3kg at 20 days
post-partum to 12.1kg at weaning (210 days post-partum). It is likely
that if the variation indicated by the large standard errors was less,
the significance of the test of difference would have been greater.
Furthermore, the difference between the Wairarapa and Massey groups
was also non-significant mainly for the same reason of large standard
errors of the least squares means.

Thus clear weight differences continued to exist between origin
groups after calving although the advantage of the Hawke's Bay heifers
over the Wairarapa and Massey groups declined. Apart from the marked
gain of the Wairarapa heifers to 20 days post-partum, the weight change
between that time and weaning for the Massey and Wairarapa heifers was
comparable (77.3kg and 76.8kg, respectively). In the same period the
Hawke's Bay heifers gained 73.6kg.

(iv)   The milk consumption of the calf

The least squares means and least squares differences within
autumn live weight group for 20-, 40-, and 60-day milk yields are
presented in Table 4.9.

The WNW method of determining the milk yield of beef cows
contained certain flaws in this study, not the least of which were the
temperamental differences among the heifers and the length of the
period of isolation of the heifers from their calves.

Prior to their purchase for this study, the heifers from the
Hawke's Bay and Wairarapa had not been accustomed to regular human

contact of the intensity that the fully-recorded Massey heifers had experienced. Consequently these animals, especially the heifers of the Wairarapa origin, were more agitated during yarding for the WNW determinations.

The separation time for the cows and their calves was approximately 17 hours and may have caused some reduction of the milk yield of the heifers below the usual rate of secretion into the udder.

With due regard to these limitations, the estimation of the milk consumption of the calf was made in order to provide rankings of the groups in an attempt to explain the weight change patterns in the heifers and their calves, and to indicate the relative differences between the groups.

The Hawke's Bay heifers consistently produced more milk than the Massey heifers, and they in turn yielded more than the Wairarapa group at each of the three days of determination. None of the differences was significant.

The superiority of the milk yield of the Hawke's Bay heifers may be explained in terms of their having the least weight gain from calving to 20 days post-partum, and the heavier weight of their calves indicated a greater appetite.

Because of the small change in the milk yield of any origin group from 20 to 60 days post-partum, and because of the large standard errors associated with the least squares means, the basis for discussing the lactation curve over 60 days for any autumn live weight group appears weak. Only in the Wairarapa group did any noticeable depression of yield occur (0.3kg) and this did not appear to be related to the growth rate of the calf so much as to live weight change in the cow.

(v)   The weight of the calf during the pre-weaning
         period and at weaning

The influence of the autumn weight of the dam on the growth of the calf and its weaning weight is presented in Table 4.10.

The weight advantage obtained at birth by the calves of the

Table 4.9

The least squares differences, least squares means and standard errors for the effect of autumn weight of the heifer on the milk consumption of the calf (kg)

	No. of records	Milk consumption (kg)		
		L S D Mean S E 20 days post-partum	L S D Mean S E 40 days post-partum	L S D Mean S E 60 days post-partum
Origin:				
Massey	18	0.00 4.07 ± 0.21	0.00 3.91 ± 0.35	0.00 4.24 ± 0.59
Hawke's Bay	18	+0.19 4.26 ± 0.18	+0.38 4.29 ± 0.29	+0.14 4.38 ± 0.50
Wairarapa	9	-0.02 4.05 ± 0.28	-0.20 3.71 ± 0.46	-0.45 3.79 ± 0.79

Note: (i)   None of the differences between origin groups was statistically significant.
      (ii)   L S D = Least squares differences.
     (iii)   S E   = Standard error of least squares means.

heifers of the Hawke's Bay origin, which at that time was non-
significant, continued until weaning and became significant (p<0.05)
when the calves were 20-days-of-age. Between 20 days and 210 days
post-partum the superiority of the calves from the Hawke's Bay heifers
over the calves from the Massey heifers increased from 3.3kg to 18.4kg.

The difference between the calves of the Massey and Wairarapa
heifers was not significant at any part of the pre-weaning period
with the calves of the former heifers exhibiting a greater weight
through the pre-weaning period to 165 days post-partum. After this
age the calves from the Wairarapa heifers were marginally heavier (0.5kg
at weaning).

Thus, with respect to the autumn weight of the heifers on 1 May,
1975, and the influence of this upon the weaning weight of the calves,
there appeared to be a considerable difference between the groups.

The time elapsed between the start of the experiment (1 May,
1975) and weaning of the calves (11 March, 1976) was 315 days. In that
time the Massey heifers changed in live weight from 368.5 ± 5.1kg to
406.7 ± 10.3kg and weaned calves with a corrected mean weight of 174.3
± 5.9kg. The Hawke's Bay heifers were 37.2kg heavier (p<0.01) than
the Massey heifers at the start of the experiment and by weaning, 1976,
were 25.1kg heavier. The mean weaning weight of the calves from this
group was 18.4kg (p<0.05) superior to that of the calves from the
Massey heifers.

The Hawke's Bay heifers had accomplished much of their growth
before their first calving and were likely to be growing towards
maturity at a slower rate than the Massey heifers. Because of their
lesser need for nutrients for growth, the Hawke's Bay heifers could be
expected to provide a better maternal environment than the Massey heifers
through a different partitioning of a given amount of food consumed.

The mean live weight of the Wairarapa heifers at the start of
the experiment was 1.9kg greater than that for the Massey heifers, and
the difference was non-significant. There were fluctuations in the
degree of advantage of the Wairarapa group above the Massey group with
respect to the live weight of the heifers before calving (see Table 4.7).

Table 4.10

The least squares differences, least squares means and standard errors for the effect of the
autumn weight of the heifer on the pre-weaning and weaning weight of the calf (kg)

	No. of records	L S D	Mean S E Birth	L S D	Mean S E 20 days of age	L S D	Mean S E 40 days of age
Origin:	B W						
Massey	22 18	0.0	26.6 ± 0.7	0.0	47.8 ± 1.4 [b]	0.0	59.0 ± 1.9
Hawke's Bay	20 20	+ 1.3	27.9 ± 0.7 [a]	+ 3.3	51.1 ± 1.1 [b c]	+ 4.8	63.8 ± 1.5 [x]
Wairarapa	12 11	− 1.6	25.0 ± 0.9 [a]	− 2.5	45.3 ± 1.6 [c]	− 2.1	56.9 ± 2.3
			60 days of age		95 days of age		120 days of age
Massey		0.0	80.6 ± 2.3	0.0	105.6 ± 3.3	0.0	127.2 ± 4.2
Hawke's Bay		+ 4.9	85.5 ± 1.8	+ 9.8	115.4 ± 2.7 [x]	+11.4	138.6 ± 3.4 [x]
Wairarapa		− 0.7	79.9 ± 2.7	− 1.4	104.2 ± 4.0	− 1.3	125.9 ± 5.1
			165 days of age		180 days of age		210 days of age (weaning)
Massey		0.0	153.4 ± 4.6 [c]	0.0	168.8 ± 5.8	0.0	174.3 ± 5.9
Hawke's Bay		+15.2	168.6 ± 3.7 [b c]	+18.1	186.9 ± 4.7 [x]	+18.4	192.7 ± 4.7 [x]
Wairarapa		− 0.7	152.7 ± 5.6 [b]	+ 1.1	169.9 ± 7.0	+ 0.5	174.8 ± 7.1

Note: (i)   Number of records B = number of calves at birth; W = number present at all other weighing days.
         (ii) Values superscripted 'a' are significantly different at 10% level.
               Values superscripted 'b' are significantly different at 5% level.
               Values superscripted 'c' are significantly different at 1% level.
               Values superscripted 'x' are significantly different from unsuperscripted values at 5% level.
         (iii) L S D = Least squares differences.
         (iv) S E   = Standard error of least squares mean.

The difference that existed between the groups at weaning was 13.0kg, and was a continuation of the large advantage that came from the extremely rapid live weight recovery of the Wairarapa group in the first 20 days post-partum.

Because of the large standard errors of least squares means encountered, the difference between the heifers of the Wairarapa and Massey groups was not significant in the post-partum period. The least squares differences, nevertheless, serve to indicate the performance of these groups through the suckling period.

It has been indicated that the live weight change of the Massey and Wairarapa heifers during the pre-weaning period was similar, with the exception of the first 20 days. The growth rate of the calves to weaning was a reflection of this with the difference between the calves of these two groups at weaning being non-significant. This observation suggests that the inferior milk consumption figures for the calves of the Wairarapa heifers, compared to those of the Massey group were probably due to the temperamental nature of the Wairarapa heifers, and that in fact the maternal ability through milk production of these heifers was equal to that provided by the Massey heifers.

The published evidence (Table 2.8) indicated that there is a positive association of the weight of the dam, either immediately post-partum or at weaning, with the weaning weight of the calf. The data obtained from this study largely support the findings, although the disparity in the live weight of the heifers of Massey and Wairarapa origins are slightly at variance with this view. There appears, however, to be a minimal amount of information regarding the influence of the autumn weight of the dam on her subsequent productivity. Furthermore, most of the studies were made to evaluate the residual effect of previous calvings. The present experiment was conducted to evaluate the effect of obtaining high heifer weights prior to calving in their first pregnancy. The performance of the Hawke's Bay heifers indicated that the superior weight in the autumn was reflected in the pre-weaning growth of the calf.

(vi) Discussion

The analysis of the influence of the autumn live weight of the

heifer has added to the evidence obtained from the evaluation of pre-calving nutritional treatment of the extreme stability of the birth weight of the calf despite a large variation in the live weight of the dam.

In the present study, live weight differences in the autumn of the order of 37kg caused a difference in calf birth weight of 2.9kg. The experiment of Neel (1973) involving 45 first-calving Angus heifers showed a change of 3.3kg in birth weight per 100kg of initial live weight difference in the heifer, which largely supports the findings of this thesis. Neel found that initial cow weight did not have a significant effect on either the birth or weaning weight of the calf.

The small variation occurring in the pre-natal growth of the calf, irrespective of the initial weight of the dam, appears to substantiate the findings concerning the strength of the antagonism between maternal environment and the genotype of the calf for intra-uterine growth (Everett and Magee, 1965; Koch, 1972). Throughout the pre-partum period the balance between the reduction of labile body components of the dam and the growth of the conceptus appeared to influence all heifers similarly despite a difference in the initial weight of the heifers. Since the change in weight within origin, from the start of the trial to calving was no more than 1.7kg in any group, the conceptus evidently replaced the labile body reserves in a similar fashion in all heifers.

After parturition the influence of the autumn weight of the heifer changed considerably. It was found that the calves of the heaviest heifers (Hawke's Bay origin) consumed more milk (non-significant) than the calves of the other two groups and also exhibited superior average daily gain, to be significantly (p <0.01) heavier at weaning. Neel (1973) also found that daily milk production was positively, but non-significantly influenced by initial weight of the cow. Unlike the results of the present study, those of Neel showed weaning weight to be also non-significantly related to the initial weight of the dam. However, the rearing regimes differed considerably, from pasture and milk for the calves of the current study, to concentrate supplementation in the other.

The influence of the autumn weight of the dam on the weaning
weight of the calf may be explained in terms of the partitioning of
ingested nutrients to repair and maintenance (especially repair of
the reproductive organs), lactation and growth. It appears that the
heifers of Hawke's Bay origin had grown sufficiently to expend
considerably more energy on lactation than either of the other two
groups. The Wairarapa heifers appeared to give precedence to growth
immediately after parturition, whereafter, this and the Massey groups
proceeded to grow and nourish their calves at very similar rates.

In the absence of information regarding the rebreeding
performance of the females in this study, comment about the influence
of the autumn weight of the heifer on the time to conception and
calving interval is not possible.

3.   The Time of Calving and Post-partum Grazing Herd

    The analysis of the live weight of the heifer before calving
included the regression of her weight at each weighing date on the
date of calving. The regression coefficient was applied in the model
as a linear correction. At birth the weight of all calves was
corrected for the time of calving, once again by the linear regression
of weight on the date of birth.

    After calving the heifers and their calves were placed in one
of three herds, the calves born earliest being placed in Herd A and
the latest in Herd C. Each herd was closed when it was considered to
have sufficient numbers for pasture management during the pre-weaning
period and each included heifers from this study plus some mature cows.
The analysis of the results during the pre-weaning period when the
heifers and their calves were in herds, was made at a constant age of
calf between herds. For instance, the 20-days-of-age weighing was
made on 3 September, 1975 for Herd A, on 17 September for Herd B and
2 October for Herd C.

    Thus the analysis of the data obtained during the pre-weaning
period indicated the response of the calf and its dam to the prevailing
conditions at the specified age of the calf. The linear correction of
weight of calf (or weight of heifer) on the age of the calf in days,
was applied within herds, not across all calves (or heifers) at one
time, as was applied at birth and weaning.

    At weaning the linear correction was again applied to all animals
to adjust the weight of the calves to a 210-day basis.

    (i)   The live weight of the heifer before and after calving
    The linear regression coefficients for weight of heifer on time
of calving pertaining to both before and after calving are presented in
Table 4.12.

    Before calving the regression of weight of heifer on date of
calving was not statistically significant, except at day 56 of the
experiment, because of large variation as indicated by the standard
error values. The positive sign of the coefficients at all weighing

Table 4.11

The least squares differences, least squares means and standard errors for the effect of post-calving grazing herd on the live weight of the heifer (kg)

	No. of records	L S D Mean S E 20 days post-partum		L S D Mean S E 40 days post-partum		L S D Mean S E 60 days post-partum	
Herd:							
A	25	0.0	312.1 ± 8.8 [a x]	0.0	337.4 ± 9.1	0.0	340.8 ± 9.2
B	16	+37.6	349.7 ± 7.8 [x]	+ 5.2	342.6 ± 8.1	-13.1	353.9 ± 8.2
C	8	+56.5	368.6 ± 19.2 [a]	+30.4	367.8 ± 19.8	+52.5	393.3 ± 20.0
		95 days post-partum		120 days post-partum		165 days post-partum	
A		0.0	354.8 ± 9.3 [ns]	0.0	387.6 ± 9.6	0.0	390.8 ± 10.5
B		+20.6	375.4 ± 8.3	+ 8.2	395.8 ± 8.5	+11.2	402.0 ± 9.3
C		+59.8	414.6 ± 20.2	+22.2	409.8 ± 20.9	+39.3	430.1 ± 22.7 [ns]
		180 days post-partum		210 days (weaning)			
A		0.0	396.7 ± 10.3	0.0	396.9 ± 10.5		
B		+20.9	417.6 ± 9.2	+23.8	420.7 ± 9.4		
C		+43.7	440.4 ± 22.3 [ns]	+43.7	440.6 ± 22.9		

Note: (i) Values superscripted 'ns' are significantly different from unsuperscripted values at 10% level.
Values superscripted 'a' are significantly different at 5% level.
Values superscripted 'x' are significantly different at 1% level.
(ii) L S D = Least squares differences.
(iii) S E = Standard error of least squares mean.

Table 4.12

Regression coefficients of heifer weight on calving date
for six occasions before calving, and eight occasions
after calving (kg/day)

Pre-calving	Regression coefficient		Standard error
Start of experiment (1 May, 1975)	0.21	±	0.29
25 days (26 May, 1975)	-0.09	±	0.70
42 days (12 June, 1975)	0.08	±	0.06
56 days (26 June, 1975)	0.13	±	0.05 **
70 days (10 July, 1975)	0.09	±	0.07
85 days (25 July, 1975)	0.04	±	0.22
Post-calving			
20 days	0.40	±	0.77
40 days	0.16	±	0.80
60 days	0.15	±	0.81
95 days	0.11	±	0.82
120 days	0.39	±	0.84
165 days	0.36	±	0.92
180 days	0.09	±	0.90
210 days (weaning)	0.04	±	0.92

Note: Significance level ** $p < 0.01$

days indicated that those heifers calving later were gaining the most weight at that time. In view of the small size of the linear regression coefficient obtained, live weight change of the heifer as influenced by the time of calving, compared to the other factors affecting the pre-calving live weight of the cow, the stage of gestation at each weight was not considered an important source of variation.

After calving the regression of the weight of the heifer on calving date was used to correct for the effect on live weight of the spread of calving. The coefficient was not significant at any stage and indicated a declining influence of the date of birth as the lactation season progressed. As pasture conditions improved with the growing season, the disadvantage experienced by heifers calving early was reduced so that later in lactation, these heifers required less adjustment to correct them to the same basis as contemporaries calving later.

Because the post-calving herds were established on the basis of age of calf they are also discussed in the context of the time of calving. There were three herds, referred to as A, B and C. Herd A comprised heifers calving between 30 July and 14 August, a period of 15 days. Herd B was composed of heifers calving between 13 August and 24 August, a period of 11 days, while Herd C consisted of heifers calving between 21 August and 12 September, a period of 22 days. There was a small amount of overlap in the periods. The least squares means and least squares differences for the influence of the post-calving herd on the live weight of the heifers are presented in Table 4.11.

The least squares differences indicate that at all weighing days after calving, the heifers of Herd C were considerably heavier than those of Herd A. This difference was only significant at day 20 ($p < 0.05$). The large differences (between 30.4kg and 59.8kg) were not significant at all other days because of the large standard errors associated with the least squares means for Herd C. These were due to the small sub-class size (n = 8) which greatly reduced the confidence limits for the estimated mean (Sokal and Rohlf, 1969).

At weaning, when all heifers were adjusted to a common length

of lactation period, the heifers in Herd C were 43.7kg heavier than
the heifers of Herd A. Similarly the heifers of Herd B were 23.8kg
heavier than those of Herd A. This weight advantage on a time
corrected basis, indicated that heifers calving later in 1975
experienced a more favourable environment for growth than heifers
calving earlier. The 1975-76 summer was cooler and wetter than the
previous six summer seasons and to recommend that calving should have
been delayed to more closely equate pasture growth with lactation
would be to seriously overlook the previous history of the Manawatu
summer rainfall distribution (see Pleasants, 1974).

(ii)   The birth weight of the calf

The regression of the birth weight of the calf on the date of
birth was small and non-significant (Table 4.13). The regression
coefficient indicated that for each 10 days later that calving occurred,
birth weight increased by only 0.4kg, and over the entire spread of
calving this would have amounted to an upper limit of approximately
1.8kg.

A conclusion of the study of Hight (1966) was that birth date
did not influence birth weight. This was considered to be important
because it meant that birth weight was not related to the length of the
pre-calving treatment period. The non-significant regression of birth
weight on time of calving in the present study also indicates that the
interaction of treatment with the pre-calving period could be safely
considered to be non-significant.

(iii)   The milk consumption of the calf

The least squares regression coefficients for the effect of the
time of calving on the milk consumption of the calf are presented in
Table 4.13.

The estimates were not significant at any part of the 60-day
test period. They were low (+0.01) and positive for the 20-day and
40-day estimations indicating that the younger calves obtained slightly
more than the older calves. At the 60-day milk determination, the
regression coefficient was small and negative indicating an increase of
0.05kg of extra milk consumed from an increase of 1 day of age of the
calf.

Table 4,13

The least squares regression coefficients for the effect of time of calving on the growth of the calf and on its milk consumption (kg/day)

Post-partum period (days)	Regression coefficient	
	Calf live weight (kg/day)	Milk consumption (kg/day)
0 (birth)	0.04 ± 0.04	
20	-0.53 ± 0.12 **	0.01 ± 0.02
40	-0.42 ± 0.17 *	0.01 ± 0.32
60	-0.65 ± 0.20 **	-0.05 ± 0.06
95	-0.58 ± 0.30 ns	
120	-0.67 ± 0.38 ns	
165	-0.79 ± 0.41 ns	
180	-0.78 ± 0.52	
210 (weaning)	-0.89 ± 0.53 ns	

Note: Significance levels ns $0.05 < p < 0.10$

                        * $p < 0.05$

                        ** $p < 0.01$

It appears that at the first two determinations very young calves may have taken an excessively long time to complete suckling and this may have allowed the older calves which had completed their suckling to defaecate or urinate before the second weighing. At the last determination (60 days) all calves probably showed sufficient rapidity of suckling to reduce the error from excretory losses. Pleasants (1974) has discussed errors arising from this source.

The least squares differences and least squares means for the milk consumption of the calves of the three post-calving herds are presented in Table 4.14.

The differences were not statistically significantly mainly due to large within herd variation. However, the differences appeared to follow the climate and pasture changes quite closely and indicated the flexibility of lactational performance with time that appears to exist in beef cattle (Klett et al., 1965).

In the case of Herd A, 20 days post-partum occurred in blustery winds, up to gale force, accompanied by rain (New Zealand Gazette, 1975). In Herds B and C the 20 days post-partum fell in mid-September and early October, respectively. Both of these months had climates with warm temperatures and favourable conditions for pasture growth. At 40 days post-partum, the favourable conditions experienced by Herds B and C were encountered by Herd A, and it is seen from Table 4.14 that this herd produced its most milk at this time. Herds B and C were still experiencing favourable conditions at 40 days post-partum, although the milk consumption of the calves fell slightly from the 20-day determination for no obvious reason.

By 60 days post-partum Herd A calves were almost certainly able to take advantage of the favourable pasture conditions in mid-October and were likely to be less dependent on milk. The milk consumption estimates declined markedly between 40 and 60 days for this group. The climate of November, when 60-day determinations were made for Herds B and C, was remarkable for the high frequency of wintry southerly conditions which retarded pasture growth. Snow fell to low levels and the sunshine hours were below normal. Thus the dependence of the calf on its dam's milk supply was illustrated by a resurgence of the yield

Table 4.14

The least squares differences, least squares means and standard errors for the effect of
post-calving grazing herd on the milk consumption of the calf (kg)

Herd:	No. of records	Milk consumption (kg)					
		L S D 20 days post-partum	Mean S E	L S D 40 days post-partum	Mean S E	L S D 60 days post-partum	Mean S E
A	22	0.00	3.73 ± 0.24	0.00	4.01 ± 0.40	0.00	3.30 ± 0.68
B	13	+0.51	4.24 ± 0.23	0.00	4.01 ± 0.37	+1.07	4.37 ± 0.64
C	10	+0.69	4.42 ± 0.42	-0.11	3.90 ± 0.68	+1.44	4.74 ± 1.17

Note: (i) None of the differences between herds was statistically significant.
     (ii) L S D = Least squares differences.
    (iii) S E   = Standard error of least squares mean.

of these two groups from 40 to 60 days of the order of 0.36kg and
0.84kg, respectively.

(iv)   The weight of the calf during the pre-weaning
        period and at weaning

The least squares regression coefficients for the weight of the
calf at the time of birth are shown in Table 4.13.

There was a highly significant and negative effect of the time
of calving on the pre-weaning weight of the calf up to 60-days-of-age.
It meant that, within herd, at 20 days post-partum, the older calves
were 0.53kg per day heavier for every day earlier that they were born.
There was a small reduction in the advantage of age at 40 days post-
partum when the regression coefficient was -0.42 (p < 0.05). At 60 days
post-partum the advantage of older calves was again highly significant
(b = -0.65; p < 0.01). From 95-days until 180-days-of-age the
advantage of the older calves increased per day of age from 0.58kg per
day (p < 0.10) to 0.78kg per day (p < 0.10).

Much of the superiority of the older calves through the pre-
weaning period is directly attributable to the favourable climate for
pasture growth that prevailed, especially from November to early March
(New Zealand Gazette, 1976; see Appendix 1). The ambient temperatures
were reduced by southerly airstreams that also brought rain during
periods normally experiencing dry to drought conditions. Not only were
the older calves able to benefit from readily digestible pasture, but
it was also likely that the lactation of the dam was persistent under
such conditions.

The least squares differences and least squares means for the
effect of post-calving grazing herd on the pre-weaning and weaning
weight of the calf are shown in Table 4.15.

For 95 days after calving the calves of Herd C exhibited a
significantly superior (p < 0.01) live weight at the ages of 20-, 40-,
60-, and 95-days than the calves of Herd A. At the same ages of calf
the calves of Herd A were lighter than those of Herd B, although the
difference was statistically significant only at the ages of 20-days
(p < 0.05) and 60-days (p < 0.01).

Table 4.15

The least squares differences, least squares means and standard errors for the effect of
post-calving grazing herd on the pre-weaning and weaning weight of the calf (kg)

Herd:	No. of records	L S D Mean S E 20 days of age	L S D Mean S E 40 days of age	L S D Mean S E 60 days of age
A	24	0.0 41.7 ± 1.5 [a x]	0.0 52.7 ± 2.1 [x]	0.0 61.7 ± 2.5 [x z]
B	15	+ 5.4 47.1 ± 1.4 [a z]	+ 5.0 57.7 ± 1.9 [z]	+31.7 93.4 ± 2.3 [x]
C	10	+13.7 55.4 ± 2.6 [x z]	+16.6 69.3 ± 3.7 [x z]	+29.2 90.9 ± 4.4 [z]
		95 days of age	120 days of age	165 days of age
A		0.0 97.1 ± 3.7 [x]	0.0 122.3 ± 4.7 [a]	0.0 153.3 ± 5.1 [x]
B		+ 8.5 105.6 ± 3.4 [z]	− 3.7 118.6 ± 4.3 [x]	− 5.4 147.9 ± 4.7 [z]
C		+25.5 122.6 ± 6.4 [x z]	+28.6 150.9 ± 8.1 [a x]	+20.1 173.4 ± 8.9 [x z]
		180 days of age	210 days of age (weaning)	
A		0.0 172.4 ± 6.4	0.0 178.5 ± 6.5	
B		− 2.5 169.9 ± 5.9	− 1.2 177.3 ± 6.0	
C		+10.9 183.3 ± 11.2	+ 7.4 185.9 ± 11.4	

Note: (i)   Values superscripted 'a' are significantly different at 5% level.
              Values superscripted 'x' or 'z' are significantly different at 1% level.
        (ii) L S D = Least squares differences.
        (iii) S E = Standard error of least squares mean.

It is likely that the superiority of the calves of Herd B above those of Herd A at 60 days (31.7kg; p<0.01) was due to contrasting pasture conditions at this age for these calves. At 60-days-of-age the calves and their dams of Herd A were experiencing a dry period with reduced ambient temperatures. Later when calves of Herd B were 60-days-of-age the climate of October was favourable for pasture growth.

The superiority of the calves of Herd B above those of Herd A was reversed from 120-days-of-age to weaning (at 210-days-of-age) although the difference was not significant. It is suspected that the milk supply of the heifers of Herd B may have decreased from 60 days post-partum to the extent that live weight gain of the heifer was made at the expense of the nourishment of the calf (Table 4.11). If pasture conditions were less favourable for the calves of Herd B than Herd A at a comparable age, the diminished milk supply would have aggravated the reduced live weight gain of the calves.

The calves of Herd C continued their superiority of live weight above the calves of Herd A, although this advantage was reduced from 29.2kg (p<0.01) at 60-days-of-age to 10.9kg (non-significant) at 180-days-of-age.

Most of the reduction in weight advantage of the calves born later (Herds B and C) over the calves of Herd A at a comparable age may be explained in terms of the change of pasture quality with time, and the prevailing climatic conditions. When Herd A calves were needing pasture in addition to milk for live weight growth, the pasture would have been palatable and more easily digested than later when the calves of Herd B and more especially Herd C, were also becoming dependent on pasture intake for most of their growth.

The regression of the weight of the calf on its age at weaning for all calves is seen in Table 4.13 and was used to correct all calves to a 210-day basis. The magnitude and sign of the covariate (-0.89 ± 0.53; p<0.10) indicated that for every day earlier that the calf was born it was 0.89 ± 0.53kg heavier than one born a day later.

At weaning the calves of Herd C were heavier than the calves of

Herd A which in turn were marginally heavier than those of Herd B.

The heifers of Herd C exhibited a superior live weight to those of Herd A at weaning on a linearly-corrected basis and weaned calves 7.4kg heavier. Apparently the later calving enabled weight gain in the dam in addition to lactational persistency giving heavier calves at weaning.

The heifers of Herd B appeared to exhibit live weight gain in favour of lactational performance, since the corrected weaning weight of their calves was below that of Herd A while their own live weight was appreciably greater (23.8kg). The alteration of the balance of the allocation of ingested nutrients to body weight gain and lactation in the heifer appeared to occur as early as 60 to 95 days post-partum, when for Herd B, this period coincided with a fall of snow to low levels and cold wintry conditions. It appears that the flexibility of lactation normally associated with beef cows was either insufficient in this group to compensate for the reduced live weight gain of the calf encountered during the period or did not occur at all.

(v)   Discussion

The main trait under consideration, namely the birth weight of the calf, was not influenced by the time at which calving occurred. Hence any recommendation to change the calving date with respect to other productive characters may be made without incurring a significantly altered birth weight.

The results of this study suggest that calving among the three-year-old heifers yielded a better live weight gain of the calf and a heavier weaning weight if the calf was born in late August and early September than if it was born in the early part of August.

The methods of correcting the weight of a population to a constant age basis have been reviewed by Nicoll (1975). The method used in the present study is that designated Method II by Nicoll, or the estimated linear regression coefficient. That author considered that the method has an advantage over a method which corrects for the elapsed time between birth and weaning (Method I) since ".....the estimated regression coefficient is indicative of the weight-age relationship of the

population over a smaller portion of the growth curve.". This method
corrects on a rate of gain basis, and has been criticized in the
case of a small population, or if the correlation between weight and
age are low (Creek, 1964). If live weight gain within a population
differs because of wide age distribution or if seasonal variation
causes differential growth within the group, the correction procedure
may be biased (Pleasants, 1974). In the present experiment, with
consideration of the climate during the summer and the confining of
the age distribution of the calf within a 44-day calving season, the
method of linear correction of weight for time (in days) from
parturition was considered to be satisfactory (for the major traits
including the live weight of the heifer, and the milk consumption and
live weight of the calf).

Published estimates of the regression coefficient for weaning
weight on age in beef cattle were collated by Nicoll (1975). The
majority of estimates he presented appeared to fall within the range of
0.40 to 0.85. In the current study the regression coefficient was
(-) 0.89 $\pm$ 0.53.

The time to first oestrus was not measured in this experiment.
The recent study of Morris (1976), using mixed-age Angus cows indicated
that, in the same season of lactation as the current study (1975-1976),
calving date significantly ($p < 0.01$) influenced the subsequent post-
partum oestrus interval. The regression coefficient reported by him
was -1.05, indicating that a shorter post-partum oestrus interval was
attributed to a later calving date.

4.   The Sex of the Calf

(i)   The live weight of the heifer before and after calving
        The least squares differences for the effect of the sex of the
calf on the live weight of the heifer before and after calving are
presented in Table 4.16.

        At all weighing dates throughout the experimental period leading
up to calving, those heifers carrying male calves had a lighter live
weight than those carrying female calves. (At day 42, 65 days before
calving the ranking of the live weight of the heifers by sex of calf
was reversed). The difference in favour of heifers carrying female
calves was significant (p 0.05) at 75 days before the onset of calving
and was strongly significant 51 days before.

        The birth weight of the calf was not significantly affected by
sex in this experiment although male calves were 1.0kg heavier (see
Table 4.17). This suggests that the early influence of the sex of the
calf on the live weight of the heifer was unlikely to be through the
weight of the foetus per se, but rather through the size of the remaining
products of the conception.

        On those weighing dates that had statistically significant effect
of sex upon the liveweight of the heifer, the magnitude of the differ-
ence between the sex subclasses was never greater than 3.18kg (less
than 1 percent of heifer body weight at the time). The test of
significance indicated that the reliability of finding such a difference
was high although the amount of emphasis which can be placed on the
effect due to sex is low, both with respect to the objective of the
experiment, and with respect to the size of the other factors which
affected the weight of the heifer.

        The least squares differences presented in Table 4.16 indicated
that after calving, those heifers nursing male calves were always
(although not significantly) lighter than those nursing female calves.
The difference was not consistent and fluctuated considerably with time
post-partum.

        The difference between sex of calf subclasses for heifer live
weight was not related to the differences between the sexes for the

Table 4.16

<u>The least squares differences for the effect of</u>

<u>the sex of the calf on the live weight of the heifer</u>

<u>before and after calving</u>

Time before calving (days)[a]	No. of records	Differences between sexes (kg) (male minus female)
106 (0)	54	− 5.7
82 (25)		− 3.2 [*]
65 (42)		+ 0.3
51 (56)		− 3.0 [**]
37 (70)		− 2.5
22 (85)		− 3.6
Time after calving (days)		
20	49	− 1.5
40		− 6.0
60		− 0.7
95		− 6.8
120		−10.0
165		− 1.6
180		− 9.7
210		−15.3

Note: (i) Significance levels ** $p < 0.01$

                                * $p < 0.05$

      (ii) Superscript 'a': figures in parentheses correspond to
                               elapsed time of experiment.

estimates of milk consumption since the female calves removed more
than the males on each of the three days of determination. It is
likely that on pasture, the total amount of milk consumed is related
to the frequency of suckling whereby male calves suckle their dams
more frequently than female calves. It was evident that a negative
association which existed between the weight change of the dam and
the increase in live weight of the calf was influenced by the sex of
the calf. Thus, when male calves showed their greatest live weight
advantage over female calves, their dams tended to show their
greatest deficit from the heifers suckling female calves. This
applied mostly in the period from 60-days post-partum to weaning at
210-days post-partum.

(ii)   The birth weight of the calf

The least squares difference for the influence of the sex of
calf on birth weight is seen in Table 4.17. The difference of 1.0kg
in favour of male calves was not significant.

Previously at Massey, Pleasants (1974) found that sex
differences in birth weight were least among first-calving cows and
that bull calves were significantly heavier at birth from cows in
their second or subsequent calvings. Data were available from the
second calves of the heifers in the present experiment and the males
in that year (1976) were significantly (p <0.05) heavier at birth
than female calves (difference = 3.1kg).

No data were available on the gestation length of the calf in
either year, hence the association of longer gestation period with
the higher birth weight of male calves is beyond comment with respect
to the present results. The superiority of the birth weight of male
calves is in agreement with the majority of published findings.

(iii)   The milk consumption of the calf

The least squares differences for the influence of the sex of
the calf on milk consumption are shown in Table 4.17. The difference
between sexes was not significant, but female calves consumed margin-
ally more milk at all three dates of determination. The size of the
difference increased with the age of the calf until at 60 days, female
calves consumed 1.09kg more than males.

Table 4.17

The least squares differences for the effect of the sex of
the calf on milk consumption, birth weight, pre-weaning
weight and weaning weight (kg)

Time after calving (days)	No. of records	Milk consumption (male minus female)	No. of records	Pre-weaning weight (male minus female)
0 (birth)			54	+ 1.0
20	45	-0.05		+ 0.7
40		-0.33		+ 1.0
60		-1.09		+ 3.7
95			49	+ 3.1
120				+ 1.4
165				+ 4.8
180				+ 5.2
210 (weaning)				+ 3.6

Note: (i) None of the differences between the sexes was
statistically significant.

The literature is not unanimous on the superiority of either sex for the amount of milk consumed. Under similar conditions at Massey, Pleasants (1974) found a year by sex interaction where female calves tended to obtain the most milk at determinations when the climatic conditions of the season had been favourable. The climate of the spring and early summer when determinations were made were certainly considered favourable in the year of the present investigation.

Most of the studies which found a significant advantage for one sex for milk consumption have placed males above females because of the positive association of higher birth weight with increased capacity for milk (see Chapter Two, Section 3.4 iv). It will be recalled that the difference between the sexes for birth weight in the present study was not significant.

(iv)   The weight of the calf during the pre-weaning
        period and at weaning

The influence of the sex of the calf on its pre-weaning growth and weaning weight is presented in Table 4.17. Male calves were heavier then female contemporaries at all stages of the pre-weaning period although the differences were not significant.

It would appear from the estimation of milk consumption that male calves did not remove more milk at a suckling than females. It has already been suggested that more frequent suckling by males may have occurred in the field leading to improved pre-weaning performance. Jeffery et al. (1971a) found higher milk yield to be associated with male calves in one season and lesser production in the next. Despite the lower milk yield of the dams with male calves in the second year, male calves had a greater average daily gain to weaning than did the females.

Most studies which have measured the intake of calves have found superior efficiency of utilization of feed by bull and steer calves. Oltjen et al. (1969) and Zinn et al. (1970) were among those to compare male and female calves. The former authors recorded the feed conversion of females to be 85 percent of that of the males.

In the present study the least squares difference between male

and female calves at weaning was 3.6kg. In the second year of the
study the difference was 12.0kg (p<0.10). Harwin et al. (1966)
found a sex by age of dam interaction among Herefords of two-year and
mature age groups. The depression in the weaning weight of the
female calves as a consequence of being reared by immature dams was
10.5kg less than the depression experienced by male calves.

Castration of bull calves was carried out in December with
elastrator rubber rings. Since the main effects were analysed at a
particular age of calf because of the herd grouping, any immediate
effects of castration on male calves would have influenced the differ-
ence between the sexes in the three herds at different weighing dates.
For Herds A and B this would have occurred at the 165-day weighing
and for Herd C, at the 120-day weighing. Consequently the effect of
castration on the weight of the male calves could not be isolated.

(v)   Discussion

In the first season of this experiment (1975-1976), the sex of
the calf did not have a significant effect on any productive trait
that was measured. Male calves were heavier at birth and at weaning
although they consumed slightly less milk on the days of estimation
of milk consumption. The difference between the sexes at birth and
at weaning was 1.0kg and 3.6kg, respectively. The greater live weight
increase of the male calves appeared to be inversely related to the
difference in live weight between the dams of the male and female
calves of 15.2kg (non-significant) at weaning.

The general non-significance of the differences appears to be
a result of the immaturity of the heifers, because the influence of
sex of calf was greater in the second season (1976-1977).

Table 4.18

The least squares differences, least squares means and standard errors for the effect of pre-calving plane of nutrition, 1975, on the birth and weaning weight of calves born in 1975 and 1976

| | Birth weight | | | | | |
| | 1975 | | | 1976 | | |
	N R	L S D	Mean S E	N R	L S D	Mean S E
Treatment:						
HP–LP	18	−2.1	25.7 ± 0.8	11	+1.7	30.4 ± 1.1
LP–HP	17	−1.9	25.9 ± 0.8	13	+4.2	32.9 ± 1.1 [a]
HP–HP	19	0.0	27.8 ± 0.7 ns	12	0.0	28.7 ± 1.1 [a]

| | Weaning weight | | | | | |
| | 1976 | | | 1977 | | |
	N R	L S D	Mean S E	N R	L S D	Mean S E
Treatment:						
HP–LP	16	−4.6	178.8 ± 5.6	11	+2.7	163.5 ± 5.5
LP–HP	16	−3.8	179.6 ± 5.9	12	+1.2	162.0 ± 5.4
HP–HP	17	0.0	183.4 ± 6.0	12	0.0	160.8 ± 5.3

Note: (i)   Significance levels: ns $0.05 < p < 0.10$
                                      Values superscripted 'a' are
                                      significantly different at 5% level
        (ii)   N R   = Number of records
       (iii)   L S D = Least squares difference
        (iv)   S E   = Standard error of least squares mean

5.   Year Two, 1976-1977:   The Influence of Main Effects From 1975

The study was continued to evaluate residual effects, especially those caused by the pre-calving nutritional treatment imposed in the first year of the study, and the difference in live weight which arose from the three origins of the heifers comprising the experimental group.

Holloway et al. (1975) reported on an investigation of three-year-old Hereford, Hereford-Holstein cross and Holstein heifers on range and in drylot. Two levels of winter feeding produced a live weight loss in both groups among breeds, but no difference in the birth weight between treatments. Despite a supplemental level effect (p<0.05) on rebreeding performance, the supplemental level of the dam did not affect the birth weight of the second calf of these heifers.

Hight (1968c) found evidence among mature Angus cows of residual effects of the post-calving plane of nutrition in the previous year on the live weight change of the cows over the pre-calving period, the calving date and the birth weight of the calf.

(i)   The plane of nutrition before the first calf

Table 4.18 presents the least squares differences and least squares means for the effect of the plane of nutrition of the heifers before their first calf on the birth weight of their second calf. There was a residual effect of the plane of nutrition in the winter of the first gestation. The birth weight of the calves from the heifers on the LP-HP treatment was the heaviest and was significantly greater (p<0.05) than that of the calves of the HP-HP treatment group. It is seen that the birth weight of the calves from the heifers of the HP-LP regime was slightly (1.7kg; non-significant) heavier than that of the HP-HP group.

The least squares means and least squares differences for the weight of the heifers during the gestation period following the weaning of their first calf are seen in Table 4.18. The reduction in the number of animals eligible for inclusion in the experiment in the second year from a failure to rebreed meant that inclusion of the effect of the weaning weight of the previous calf would have created instability in the model. However, there appeared to be a residual effect of the weight change of the heifer during lactation on the live weight during the

following gestation.

Table 4.20 indicates that the HP-LP group of heifers gained the most live weight during the second pregnancy, the least squares difference between this group and both of the others being 24.5kg by the last weighing day before second calving. This group had, however, gained the least amount of weight during the previous lactation and weaned the lightest calves. In spite of the live weight advantage in the HP-LP group, they did not give birth to the heaviest calves, the group which did so was the LP-HP (p < 0.05).

The heifers which gave birth to the lightest calves were those which had formerly been in the HP-HP group. It is not clear whether the cause of the reduction was the superior performance of this group for the weaning weight of their first calf, or whether there was a negative relationship between the nutritional plane in the first year and the plane in the second year.

The live weight of the HP-HP and LP-HP groups during the second gestation period and at calving is presented in Table 4.20. The two groups followed a very similar growth pattern throughout pregnancy. The birth weight of the calves from the two groups is seen in Table 4.18. It appears that the difference between the two groups for the birth weight of the second calf, in favour of the LP-HP group, was largely a result of the live weight change of the heifers during the previous pre-weaning period because of the similarity of live weight change within the two groups after that time. During the first lactation the HP-HP heifers gained less weight than did the LP-HP heifers and weaned heavier calves, but neither difference was significant.

The point may also be made that the feeding regime in the second gestation was similar to that offered to the LP-HP group in the first. The consequence of this appears to have been a different partitioning of nutrients to the foetus and the dam in the LP-HP heifers than in either of the other two groups during the second gestation. The weight during gestation of the HP-HP group was the same as the LP-HP group while the weight of the HP-LP group was greater. However, the birth weight of the calves from the LP-HP group was the greatest. If the weight of the calf at birth comprises 54 percent of the products of conception, this indicates that the conceptus weighed approximately 8kg more in the LP-HP heifers than in the HP-HP heifers and 4.5kg more than

in the HP-LP heifers.

This investigation has shown that, when the mechanism for the control of calf birth weight in the dam was affected by nutrition, and was manifested in a residual manner at the second calving, then restricting the intake of the heifer early in her first gestation period favoured the growth of the calf ahead of live weight gain in the dam, while feeding to a high level for all, or the latter part of gestation, reduced the birth weight of the calf relative to the former programme.

At the weaning of the second calf, the analysis of variance indicated that a minimal amount of variation was due to the treatment imposed before the birth of the first calf. The least squares differences and least squares means are presented in Table 4.18.

(ii)   The autumn weight of the heifer before the first calf
The least squares differences and least squares means for the effect of the weight of the dam as at 1 May,1975, on the birth and weaning weights of the calves born after 27 July, 1976 are presented in Table 4.19.

The autumn live weight differences which existed in 1975 from environmental differences between the heifers from the different origins were found to affect the birth weight of the calves in that year by 2.9kg (Hawke's Bay group minus Wairarapa group). In the second year the birth weight of the calves of the Hawke's Bay heifers was 1.8kg heavier than the birth weight of the calves of the heifers from the other two origins. This difference was not significant and reflected the decline in the effect of the difference in autumn weight of the heifer that existed 15 months previously.

The live weight of the heifer within origin, for the second gestation period, is shown in Table 4.20. It is seen that the superiority of the Hawke's Bay heifers was greatly reduced in the pre-calving period and that the Wairarapa heifers continued the growth, comparative to all other heifers, that had commenced after the first calving. By the second calving, the Hawke's Bay and Wairarapa heifers weighed the same and the Massey heifers weighed approximately 9kg less. This difference was non-significant.

Table 4.19

The least squares differences, least squares means and

standard errors for the effect of autumn live weight

of the dam, 1975, the sex of the calf and the time of

calving on the birth and weaning weight of calves

born in 1975 and 1976

	Birth weight							
	1975				1976			
	N R	L S D	Mean	S E	N R	L S D	Mean	S E
Origin:								
Massey	22	0.0	26.6 ± 0.7		13	0.0	30.1 ± 1.1	
Hawke's Bay	20	+ 1.3	27.9 ± 0.7 [a]		15	+ 1.8	31.9 ± 1.0	
Wairarapa	12	- 1.6	25.0 ± 0.9		8	- 0.1	30.0 ± 1.3	
Sex:								
Male	23	+ 1.0	27.0 ± 0.7		16	+ 3.1	32.2 ± 1.0 [*]	
Female	31	0.0	26.0 ± 0.6		20	0.0	29.1 ± 0.9	
Covariate: weight on day of birth (kg/day)	54		0.04 ± 0.04		36		+0.07 ± 0.04	

	Weaning weight							
	1976				1977			
	N R	L S D	Mean	S E	N R	L S D	Mean	S E
Origin:								
Massey	18	0.0	174.3 ± 5.9		13	0.0	163.4 ± 5.2	
Hawke's Bay	20	+18.4	192.7 ± 4.7 [b]		14	+ 0.4	163.8 ± 4.9	
Wairarapa	11	+ 0.5	174.8 ± 7.1		8	- 4.2	159.2 ± 6.5	
Sex:								
Male	20	+ 3.6	182.4 ± 5.3		15	+12.3	168.3 ± 5.0 [ns]	
Female	29	0.0	178.8 ± 4.5		20	0.0	156.0 ± 4.3	
Covariate: weight on day of birth (kg/day)	49		-0.89 ± 0.53 [ns]		35		-0.93 ± 0.23 [**]	

Note: (i) Values superscripted 'a' are significantly different (p<0.10) from unsuperscripted values

Values superscripted 'b' are significantly different (p<0.05) from unsuperscripted values

ns 0.05 < p<0.10   * p<0.05   ** p<0.01

(ii) N R = Number of records

(iii) L S D = Least squares differences

(iv) S E = Standard error of least squares mean

The reduction of the size of the residual effect of the autumn weight of the heifer on the birth weight of the second calf contrasts with the significant residual effect on birth weight that existed for the influence of pre-calving plane of nutrition in the first year which was previously discussed. The explanation for the dissimilarity of the influence of these two main effects appears to rest in the conclusion that the autumn live weight of the dam influenced the birth weight of the calf through the size of the dam. The treatment effect was a function of induced live weight change in the heifer and the short-term effect (one to two years) this had on the efficiency of the metabolism of the dam, including the partitioning of ingested nutrients to the conceptus and to her own body.

The results of the investigation of the effect of the autumn weight of the heifers, indicate that any advantage of a high live weight is gained mostly in the weaning weight of the first calf. The birth weight of the calves from the heifers was stable in both the first and second years despite a highly significant live weight difference between the heifers in the autumn of their first pregnancy caused by their having different origins.

(iii) The sex of the calf

The effect of sex of calf on birth weight and weaning weight is presented in Table 4.19. It is seen that in 1976 male calves were significantly heavier at birth (3.1kg; $p < 0.05$) than females. At weaning, at 164-days-of-age, males were 12.3kg heavier ($p < 0.10$).

The non-significance of the sex difference in the first year of calving when the heifers were three-years-old, and the significant difference when they were four-years-old, confirms the findings of Pleasants (1974) of a sex by age of dam interaction where the calves of first calving heifers did not show a significant difference due to sex. Koch and Clark (1955a); Harwin et al. (1966); and Pahnish (1958) were among those who published evidence of a sex by age of dam interaction at weaning.

The discussion of the influence of sex of unborn calf on the weight of the heifer during gestation indicated that heifers carrying female calves had a heavier live weight than those carrying male calves. The phenomenon recurred in the second year of the study with the magnitude of the difference greatly increased (Tables 4.16 and 4.20).

Table 4.20

The least squares differences and least squares means for the effect of treatment (1975),
weight of the dam in the autumn of first pregnancy, and the sex of the unborn calf
on the weight of the cow before the second calving (1976)

| | N R | Pre-calving cow weight (kg) | | | | | |
| | | 1 April, 1976 | | 12 June, 1976 | | 27 July, 1976 | |
		L S D	Mean	L S D	Mean	L S D	Mean
Treatment:							
HP-LP	11	+23.6	431.8	+13.4	391.5	+24.5	434.8 ns
LP-HP	13	- 1.4	406.8	+ 2.6	380.7	0.0	410.3
HP-HP	12	0.0	408.2	0.0	378.1	0.0	410.3
Origin:							
Massey	13	0.0	410.1	0.0	376.7	0.0	412.8
Hawke's Bay	15	+11.3	421.4	+ 4.6	381.3	+ 9.0	421.8
Wairarapa	8	+ 5.2	415.3	+15.7	392.4	+ 8.4	421.2
Sex:							
Male	16	-19.0	406.1	-12.1	377.4	-15.0	411.0
Female	20	0.0	425.1	0.0	389.5	0.0	426.0
Covariate (weight of cow on date of calving: kg/day)			-0.25		-0.46		-0.12

Note: (i)   ns $0.05 < p < 0.10$
       (ii)   N R = Number of records
      (iii)   L S D = Least squares differences

158

(iv)   The time of calving

The linear regression of pre-calving weight of the heifer on
the day of birth is presented in Table 4.20. The regression coefficient
was not significant in either year of the experiment indicating that
there was little advantage obtained by the heifers before parturition
by calving in any particular part of the calving season. A seasonal
effect operated where the heifers calving latest in 1975 were marginally
heavier throughout the gestation period. In 1976 those calving earliest
were the heaviest.

During the second pregnancy there appeared to be a relationship
between the time of calving and the live weight of the heifer as
affected by the level of nutrition. At the start of the winter in 1976,
the regression coefficient for cow live weight on time of calving was
-0.25kg per day (non-significant), the negative sign indicating an
advantage of early-calving heifers over those calving later. In mid-
winter when the plane of nutrition was most depressed the regression
coefficient was -0.46kg per day (non-significant), and indicated that
those heifers nearest to calving were best able to maintain their live
weight at that time. By the last weighing day before calving, the
regression coefficient had diminished to a non-significant -0.12kg per
day.

The regression coefficients for the effect of the time of birth
on birth weight and weaning weight of the calves born in 1975 and 1976
are compared in Table 4.19. The time of calving did not significantly
influence the birth weight of the calf in either year.

At weaning, however, from the 1976-1977 season, the advantage
obtained by older calves over their younger contemporaries was 0.93kg
per day and was highly significant ($p < 0.01$). The linear regression of
calf weight on the age (in days) indicated that calving early in the
season gave an advantage which in the second year was significant.

The explanation for the lower weaning weight in the second season
compared with the first (see Tables 4.18 and 4.19), lies in the average
age at weaning. In the 1975-1976 season the average age was 210 days;
in 1976-1977 it was 163 days.

(v)   Discussion

In the current study the difference in the weaning weight of
the calves from the heifers of the different origins was reduced from
18.4kg (Hawke's Bay origin minus Massey origin; p <0.05) to 0.4kg
(non-significant), suggesting that the residual effect of the size of
the heifers during their first pregnancy was insignificant by the
second lactation. The results obtained by Cowan et al. (1974) from
Friesian heifers indicated that the superiority of the lactational
performance of the animals with the highest live weight in the first
lactation was reduced in the subsequent lactation. It was also seen
that the difference in birth weight between origin groups, which was
not significant (difference ≤ 2.9kg; 0.05 <p<0.10), was reduced at
the second calving (difference ≤ 1.9kg; non-significant).

The residual effect of the pre-calving plane of nutrition
offered the heifers in their first gestation period on the live weight
change of the heifer during the second pregnancy, and the birth weight
of the calf, was much more pronounced than was the influence of the
autumn weight of the heifer. The HP-LP heifers, being those which
were restricted in nutrition in the last 3 to 5 weeks of pregnancy
gained the most live weight between the weaning of the first calf and
the second calving. They had previously gained the least amount of
weight during the first lactation and weaned the lightest calves,
neither difference, however, was significant.

Hight (1968c) found that Angus cows previously subjected to a
low plane of nutrition after calving, thereby gaining less weight than
their well-fed contemporaries, exhibited increased weight gain in the
subsequent pregnancy, this characteristic being similar to that shown
by the heifers of the HP-LP group in the present work. The cows
restricted after calving in the experiment of Hight differed from the
heifers of the current study, in that the birth weight of the
subsequent calves of the cows was heavier, supposedly as part of the
compensatory mechanism induced by the low plane of nutrition offered
after calving. The heifers of the present experiment showed a residual
effect of plane of nutrition on the birth weight of the calf, not from
the heifers which made the greatest live weight gain in the second
pregnancy, but from the heifers which had been offered a low plane of
nutrition in their first pregnancy then a high plane four weeks before
calving (LP-HP).

It thus appears that the immaturity of the heifers influenced the amount of residual effect from the plane of nutrition before the first calf, compared to the effect exhibited by the mature cows in the study of Hight (1968c). While the mature cows showed an ability for greater live weight growth during pregnancy as well as for greater birth weight of the next calf, the heifers of the present experiment either used the ingested nutrients for increased body weight during the second pregnancy (HP-LP) or for an increased birth weight of the second calf (LP-HP).

C H A P T E R   F I V E

CONCLUDING DISCUSSION

This study has been successful in enabling an examination to be
made of the influence of short- and long-term objectives of beef cow
management on the birth weight of the calf, and other productive
characters.

The short-term objective was to examine the influence on the
heifer and her offspring of the winter nutrition offered to her over a
period of three months. The experiment was particularly topical
because it involved maiden, three-year-old heifers. This age group has
attracted much discussion among cattlemen as to the possibility of
manipulation of the pregnant animal by management of nutrition in order
to alter the birth weight of the calf and therefore reduce the risk of
dystocia. It was also possible to examine the live weight change of
the heifer after calving, and the influence of this live weight change
of the dam on the growth of its calf, as a consequence of the managerial
manipulation of the pre-calving live weight of the heifer.

The second objective, which is longer term with respect to the
time taken to implement a change in managerial policy, involved the
importance of the live weight of the heifer during her first pregnancy,
especially in the autumn, three months before calving. This aspect was
facilitated by procuring heifers raised in three environments and
having different live weights. The traits studied in connection with
this second objective included the live weight change of the dam, and
the birth, pre-weaning and weaning weights of the calf.

The most important finding has been the stability of the birth
weight of the calf in terms of both of the objectives mentioned in the
foregoing. It was found that the plane of nutrition offered the heifers
before calving, which produced a highly significant live weight differ-
ence ($p < 0.01$) between the treatment groups, did not cause a significant
difference in the birth weight of the calves (difference $\leqslant 2.1$kg;
$0.05 < p < 0.10$).

The influence of induced live weight loss in the pregnant bovine on the total amount of conceptus at parturition has also been studied elsewhere (Ewing et al., 1966; Joubert, 1954; Ryley, 1961). The experiments of these workers estimated and showed an ability of the maternal organism to alter the amount of supportive tissue (conceptus-not-foetus) in an attempt to shelter the foetus from nutrient stress and also to partially reduce the body weight loss that the dam was experiencing in a situation of restricted intake. In the present study it was not possible to weigh the heifers at parturition and hence the influence of the mechanism referred to above was not able to be assessed. This phenomenon of the ability of the cow to alter the relative proportions of the components of the reproductive tract during pregnancy has not been investigated closely in New Zealand and it is suggested that it may provide a partial explanation of the success of the pregnant bovine in growing a calf to a normal birth weight under conditions of restricted nutrition. Whether or not altering the size of the uterus and its contents other than the foetus per se influences the subsequent reproductive performance of the cow remains to be investigated.

After calving the manner in which the live weight differences between treatment groups were induced became important in connection with the performance of both the heifer and her calf.

From the discussion in Chapter Four, Section 1 (vi), of the effect of the plane of nutrition offered the pregnant heifers in the first year of the experiment, it may be concluded that the HP-HP nutritional level returned the best gross productivity in terms of the weight of calf weaned. These heifers were not the heaviest at weaning (difference non-significant) and it is suggested that the slight disparity of live weight was a result of their superior lactational performance which was reflected in the weaning weight of the calf.

The LP-HP group had a calf birth weight slightly depressed in relation to the HP-HP group, and weaned calves 3.8kg (non-significant) lighter than the HP-HP group. The live weight at weaning of the LP-HP heifers was marginally greater than the HP-HP group indicating that the LP-HP heifers gave a slightly greater preference to live weight growth than did the HP-HP heifers.

The HP-LP group of heifers was that which attracted the greatest attention of any of the three treatments in view of the belief among cattlemen that this treatment affords the best opportunity to reduce the birth weight of the calf. The restriction of intake of the heifers in this group in the last trimester of pregnancy, from approximately 50 days before the onset of calving, produced a live weight reduction of 16.0kg (4.1 percent) in that time. Compared to the HP-HP group, which was 5.5 percent heavier at calving, the HP-LP group gave birth to calves 2.1kg lighter ($0.05 < p < 0.10$).

The heifers of this latter group did not show the same ability to regain the weight lost in the pre-partum period as did the other two treatment groups and were 16.2kg lighter than the heifers of the HP-HP group at weaning. In spite of the lesser live weight gain in the HP-LP heifers, neither the weaning weight of the calf nor the estimated milk consumption of the calf were superior to those in the other two groups, which if they had been, would have been a partial explanation for the inferior post-calving live weight growth of these heifers.

The consideration of the influence of the plane of nutrition during the winter, in Chapter Four, Section 1 (vi) indicated that a 45-day period of restriction of intake followed by an elevated plane for a further 20 days resulted in a minimally reduced post-calving performance of the LP-HP heifers in comparison to the HP-HP group. It was suggested that the 45-day restriction during the early winter period enabled a greater stocking rate than the high planes at the same time, in order to allow the accumulation of pasture for feeding the heifers at a high plane when the demand of increasing foetal weight became accentuated in the last month of gestation.

The HP-LP and HP-HP groups required a higher level of feeding during that period of the winter having minimal pasture growth. The expense of maintaining a high plane of nutrition at that time compared with a low plane was discussed by Hight (1968c). The advantage of imposing a restricted intake on pregnant cows during the early winter period was considered by that author to include a reduction in the cost of supplementation at the time of restriction and also an improved efficiency and appetite in the restricted animals, making them

more capable of utilizing the increased growth of the pasture that is characteristic of the spring season. The LP-HP heifers of the present study did not show a significantly improved efficiency of pasture utilization in terms of calf weight at weaning, or lactation. They did, however, show superior live weight gain immediately after calving, before the demand of the suckling calf became large.

Much of the discussion has centred upon the effect of the plane of nutrition on the live weight change of the heifer, before and after calving, the birth weight of her calf, and the pre-weaning and weaning weight of the calf. It is appropriate to consider as well the influence that the three nutritional planes are likely to have had upon pasture growth.

It should be noted that no measure of the intensity of grazing was made, nor was a measure of the period of spelling of the pasture pertinent because the heifers were integrated into a stocking policy with other cattle and with sheep. The three regimes, HP-LP, LP-HP and HP-HP, must be considered in a comparison of their likely influence on pasture rather than in terms of what actually happened since it was not feasible to make this measurement.

Smetham (1973) has discussed the work of Blackman (1933) in connection with the association of pasture yield with grazing patterns. Many of the conclusions of the latter author were confirmed by Brougham (1959, 1960).

The dominant grass species of the Tuapaka pasture are perennial rye grass (<u>Lolium perenne</u>) and browntop (<u>Agrostis tenuis</u>) with white clover (<u>Trifolium repens</u>) as the major legume. Changes in the proportion of the grasses in the sward are important because they constitute the bulk of the yield.

The results of Brougham (1960) indicate that the least damage is done to pasture yield in spring and summer if close grazing occurred in the winter. Because the pasture species exhibit their lowest activity at that time, removal of the leaf to 2.5 to 5.0cm has been found to be beneficial to subsequent productivity. Brougham (1960) found that yields were increased by 75 to 85 percent by severe grazing in winter, but that at all other seasons severe grazing reduced subsequent yield.

Smetham (1973) considered that the so-called slow rotation over the autumn and winter, which is facilitated by intensive grazing, is the technique which makes all-grass wintering possible. More grass is grown since the pasture is allowed to grow during longer spelling periods at a higher leaf area index than would be attained with set stocking, or mob grazing at a lax stocking rate. Furthermore, the method of a slow rotation and increased intensity of grazing requires a higher stocking rate than does a rapid rotation with low intensity of grazing. This means that higher numbers can be supported on a given area which then more adequately control pasture length and pasture quality in the spring and early summer.

The regime which was best suited to optimum pasture management of the three was the LP-HP group. These heifers were grazed intensively in the early part of the winter and more laxly as pasture recovery began in the late winter and early spring. It is not considered likely that the growing season would have been sufficiently advanced for pasture yields to have been inhibited, in the manner described by Brougham (1960), by the intensive grazing imposed on the HP-LP group from 10 July, 1975 to 30 July, 1975. However, the number of animals which could be wintered per hectare in this or the HP-HP group would not have been as high as for the LP-HP group because of their respective stocking rates for the bulk of the winter.

Hence, while the HP-LP heifers returned a marginally greater weaning weight of the calf than the LP-HP group, and therefore produced more saleable product on a per heifer basis, it is believed that the LP-HP heifers would have produced more on a per hectare basis without apparent detriment to their subsequent productivity. The absence of data on stocking rate, amount of pasture eaten, and the rebreeding performance prevent a more definite conclusion. The discussion of Smetham (1973) suggests that the LP-HP regime would also have contributed best to the improvement of the hill pastures for spring growth and summer grazing.

The interaction between the autumn live weight of the heifer and the effect of the pre-calving plane of nutrition was not significant and hence the response of a heifer of any particular origin to any one of the treatments was not affected by her autumn live weight.

The discussion of the effect of managerial manipulation of the live weight of the heifers during the winter of their first pregnancy applies equally to all categories of autumn live weight.

The second major consideration of the study was the live weight of the heifers in the autumn of their first pregnancy. The results showed that there was a significant ($p < 0.01$) live weight difference between the heifers of Hawke's Bay origin and those of the other two origins, namely Massey and Wairarapa. In spite of the disparity of the live weight of the heifers, its influence on the birth weight of the calves was not significant (difference ≤ 2.9kg; $0.05 < p < 0.10$).

The most important factor which emerged was the influence of the autumn live weight of the heifer through its persistence to the post-partum period, on the live weight growth of the calf before weaning. Those heifers which had grown to the heaviest live weight by the autumn of first pregnancy produced the heaviest calves at weaning (difference ≤ 18.0kg; $p < 0.05$) and yielded the most milk to the calf at each of three determinations. The difference, however, was non-significant.

The experiment demonstrated that the heifers which had grown to the largest size by the autumn of their first pregnancy made the least live weight gain after the calves were born, and produced the heaviest calves at weaning. Those which had made the least live weight gain before the first calf was conceived, continued to make live weight growth after parturition at the expense of lactation and subsequent live weight growth in the calf.

Most of the studies included in the review of literature (Chapter Two) in which the weight of the dam was related to the weaning weight of the calf and to milk production, indicated that heavier dams at, or immediately after calving reared heavier calves largely through the production of more milk. Reported regression coefficients of weight of calf on live weight of dam were 0.07kg/kg (Jeffery and Berg, 1972b) and 0.085kg/kg (Tanner et al., 1965). It emerged, however, that the relationship between the live weight of the dam and the live weight of the calf at weaning was small in comparison to the size of the

inverse relationship between the weight change of the cow in the
lactational period and the weaning weight of the calf. The results
of Singh et al. (1970) suggest that the inverse relationship
between the live weight change of the dam and the weaning weight of
the calf could be expected to be smallest in primiparous heifers and
to increase in size with increased age of dam.

In the present work, all heifers gained in live weight after
calving. It is believed that the superior maternal ability of the
Hawke's Bay heifers over the heifers of the Wairarapa and Massey
origins for pre-weaning growth of the calf, was not so much a result
of a greater live weight of the heifer in the autumn, or at calving,
as it was a result of the pattern of post-partum live weight growth.
In exhibiting the slowest live weight gain after calving the Hawke's
Bay heifers evidently partitioned more of their ingested nutrients to
lactation than to the body than did the heifers of the other two
origins. The conclusion from this part of the study was the positive
advantage of an optimum live weight of the heifer in the autumn of her
first pregnancy.

Swanson (1967) has discussed the relationship between the size
of the cow and the lactational performance. He drew attention to the
care which must be given to the manner in which animals are grown to
approximately the sixth month of gestation. It has been well established
that excessive fatness of the heifer can obstruct normal mammary
development and lead to reduced milk yield. Hence the objective of
obtaining a heavy live weight three to four months before calving must
be adopted bearing in mind the possible consequences of over-feeding
maiden females including reduced lactational performance and long-term
damage to the udder.

In the present case neither the lactational performance of the
heifers nor the weaning weight of the calf indicated that any of the
groups had impaired milk yield caused by over-fatness during the develop-
ment of the udder. None of the heifers, however, would have been
considered to be other than in good store condition during their first
pregnancy.

The evaluation of the longer-term effect of the plane of
nutrition of the heifer during the winter of her first pregnancy

indicated that residual effects persisted to the second calving.
Those heifers fed well until three to five weeks before first
calving then restricted to lose approximately 4 percent of the live
weight at that time,before calving (HP-LP) showed the greatest
ability to achieve live weight growth during their second pregnancy.
This did not, however, result in an increased birth weight of the
second calf in this group.

The regime of feeding at a low plane of nutrition during the
winter until three to five weeks before calving to induce a 5 percent
live weight loss, followed by an elevated plane to regain the weight
lost (LP-HP), resulted in an increased birth weight at the second
calving.

Feeding at a high plane of nutrition continuously in the winter
of first pregnancy (HP-HP) produced the lightest calves at second
calving of any of the three nutritional regimes.

The influence of the live weight of the heifer in the autumn of
her first pregnancy on the birth weight or weaning weight of the
second calf was small and non-significant.

In both years (1975-76 and 1976-77) it was found from the linear
regression of weight of calf on its age in days, that those calves born
earliest had a weight advantage at weaning over the calves born later
(b (1975-76) = -0.89; b (1976-77) = -0.93). It was noted, however,
that the live weight growth of the calves was greater for those born
later in the 1975 calving season than those born earlier, because of
the more favourable climate during the 1975-76 summer for pasture growth
than had been usual before that year. The effects of the mild summer
climate and prolonged pasture growth were shown in the persistency of
lactation in the late-calving heifers which, it was expected, would
otherwise have shown an early reduction of milk yield, reflected
ultimately in the growth of the progeny.

This experiment has provided valuable information about the
manner of the preparation of maiden heifers for first calving. Its
most important finding was the stability of the birth weight of the
calf under normal management practises. Furthermore, the advantage of

growing heifers to a large body size before first calving was shown
to result in an optimization of the weaning weight of the calf,

The planes of nutrition imposed revealed that satisfactory
nutrition of the pregnant heifer does not imply high plane feeding
until a month before calving, followed by a restrictive period to
eliminate dystocia due to large calves at birth. The most satisfactory
system of beef heifer wintering was one of mild live weight loss to the
last three to five weeks of pregnancy, thereafter the growth of the
foetus and the preparation of the heifer for rebreeding and lactation
was allowed for by elevated feeding from then to calving. This latter
system is recommended for its economical use of pasture in the critical
winter period and the improved metabolic efficiency of the heifers
managed in this manner, appeared to persist through to the second
calving.

The outcome of this work has wide application to the New Zealand
beef cattle industry in that the principles derived pertain both to the
breeder feeding heifers intensively, and to enterprises involving
breeding cattle on hill country, for which the experiment was primarily
intended.

REFERENCES

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

Absher, C.W. and Hobbs, C.S. (1968). Pre-calving level of energy in
    first calf heifers. J.Anim. Sci., 27: 1130 Abstr.

Agricultural Research Council, London (1965). The Nutrient Require-
    ments of Farm Livestock. No. 2. Ruminants. 264pp.

Alexander, M.H. (1950). Length of gestation in the five major breeds
    of dairy cattle. J. Dairy Sci., 33: 377 Abstr.

Alexander, G.I. (1964). Lamb survival: physiological considerations.
    Proc. Aust. Soc. Anim. Prod., 5: 113-122.

Alexander, G.I., Sutherland, D.N., Davey, G.P. and Burns, M.A. (1960).
    Studies on factors in beef cattle production in a subtropical
    environment. 1. Birth weight. Queensland J. Agric. Sci., 17:
    123-134.

Al-Mallah, M.Y. (1965). A study of sex differences in various
    statistics calculated from data on growing Angus bulls and
    heifers fed at different levels. Diss. Abstr., 36 (3): 985B -
    986B.

Andersen, H. (1962). Relationship between the length of gestation and
    birth weight of the calf. Aarsberetn. Inst. Sterilitetsforskn.
    K. Vet. -og. Landbokojsh. 115.

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

Anderson, D.C. and Bellows, R.A. (1967). Some causes of neonatal and
    post-natal calf losses. J. Anim. Sci., 26: 941 Abstr.

Arnett, D.W., Holland, G.L. and Totusek, R. (1971). Some effects of
    obesity in beef females. J. Anim. Sci., 33: 1129-1136.

Baharin, K. and Beilharz, R.G. (1975). Estimation of genetic parameters
    in beef cattle from records of performance. Aust. J. Exp. Agric.
    and Anim. Husb., 15: 731-739.

Baker, R.L. (1975). Progeny testing of Angus bulls. N.Z. Ministry of
    Agriculture and Fisheries, Ann. Rep. Res. Div., 1974-1975 p.244
    A.B.A., 45: No. 548.

Baker, R.D. and Barker, J.M. (1975). Winter nutrition and grazing
    management of suckler cows and calves. Ann. Rep. Grassld. Res.
    Inst., Hurley, (1975): 100.

Bar-Anan, R., Soller, M. and Bowman, J.C. (1976). Genetic and environ-
    mental factors affecting the incidence of difficult calving and
    perinatal calf mortality in Israeli-Friesian dairy herds.
    Anim. Prod., 22: 299-310.

Barton, R.A. (1970). The yield and composition of milk of suckled beef cows, and their relation to calf liveweight gains. In: New Zealand Beef Production, Processing and Marketing. Ed. A.C. Campbell. Publ. N.Z. Inst. Agric. Sci. Wellington, pp.130-140.

Batra, T.R. and Touchberry, R.W. (1974). Birth weight and gestation period in purebred and crossbred dairy cattle. J. Dairy Sci., 57: 323-327.

Bellows, R.A., Anderson, D.C. and Short, R.E. (1969). Some factors associated with calving difficulty. J. Anim. Sci., 29: 184 Abstr.

Bellows, R.A., Gibson, R.B., Anderson, D.C. and Short, R.E. (1971). Precalving body size and pelvic area relationships in Hereford heifers. J. Anim. Sci., 33: 455-457.

Bellows, R.A., Short, R.E., Anderson, D.C., Knapp, B.W. and Pahnish, O.F. (1971). Cause and effect relationship associated with calving difficulty and calf birth weight. J. Anim. Sci., 33: 407-415.

Bellows, R.A., Varner, L.W., Short, R.E. and Pahnish, O.F. (1972). Gestation feed level, calf birth weight and calving difficulty. J. Anim. Sci., 35: 185 Abstr.

Benyshek, L.L. and Marlowe, T.J. (1973). Relationship between Hereford cow weight and progeny performance. J. Anim. Sci., 37: 406-409.

Berg, R.T. (1961). Factors influencing calf weaned weights in a commercial Aberdeen Angus herd. J. Anim. Sci., 20: 670 Abstr.

Bernard, C.S., Fahmy, M.H. and Lalande, G. (1973). The influence of age at first calving and winter feeding management as yearlings on calf production from Beef Shorthorn cows. Anim. Prod., 17: 53-58.

Berruecos, J.M. and Robison, O.W. (1968). Preweaning growth in Brahmans. J. Anim. Sci., 27: 1124 Abstr.

Bewg, W.P., Plasto, A.W. and Daly, J.J. (1969). Studies on reproductive performance of beef cattle in a subtropical environment. 1. Conception rate, length of oestrous cycle and length of gestation. Qd. J. Agric. Anim. Sci., 26: 629-637.

Bishop, A.H., Cummins, L.J. and Morgan, J.H.L. (1975). Objectives for the genetic improvement of beef cattle. J. Aust. Inst. Agric. Sci., 41: 178-191.

Blackman, G.E. (1933). Investigations on the intensive system of grazing management. XII. The influence of the grazing factor on the botanical composition of intensively managed pastures. Emp. J. exp. Agric., 1: 253-269.

Blackwell, R.L. and Henderson, C.R. (1955). Variation in fleece weight, weaning weight and birth weight of sheep under farm conditions. J. Anim. Sci., 14: 831-843.

Blanchard, R.P., Freeman, A.E. and Spike, P.W. (1966). Variations in lactation yield of milk constituents. J. Dairy Sci., 49: 953-956.

Blaxter, K.L. (1957). The effects of defective nutrition during pregnancy in farm livestock. Proc. Nutr. Soc., 16: 52-58.

Bodisco, V. and Cevallos, E. (1971). Birth weight of Brown Swiss calves. Agronomia trop., 21: 159-170. A.B.A., 40: No. 1646.

Bogart, R. (1959). Improvement of Livestock. Publ. The Macmillan Company, New York. 436pp.

Bond, J. and Wiltbank, J.N. (1970). Effect of energy and protein on estrus, conception rate, growth and milk production of beef females. J. Anim. Sci., 30: 438-444.

Bosman, D.J. and Harwin, G.O. (1966). Genetic and environmental factors affecting pre-weaning traits in beef cattle under extensive ranching conditions. Proc. S. Afr. Soc. Anim. Prod., 5: 153-159.

Boston, A.C., Whiteman, J.V. and Frahm, R.R. (1975). Phenotypic relationships within Angus and Hereford females. II. Repeatabilities of progeny weaning weights. J. Anim. Sci., 41: 23-32.

Botkin, M.P. and Whatley, J.A. (1953). Repeatability of production in range beef cows. J. Anim. Sci., 12: 552-560.

Brandt, G.W. (1958). Heterosis in dairy cattle as measured by birth weights, gestation lengths, certain body weights, and measurements, and mammary gland grades. Diss. Abstr., 19: 643B.

Brännäng, E., Lindkvist, G., Magnusson, B. and Froger, J.L. (1975). Konsulentavd. Stenc. Serie. Allm. 2, 6: 1-7. cited by Philipsson, J. (1976b).

Braude, R. and Walker, D.M. (1949). Mortality, weight and body measurements at birth of Dairy Shorthorn calves. J. Agric. Sci., Camb., 39: 156-163.

Brinkman, W.L. and Zemmelnik, G. (1975). The effect of inbreeding on birth weight, six weeks weight and twelve weeks weight of White Fuloni calves at Shika. Sumaru Agricultural Newsletter, 17: 51-55. A.B.A., 44: No. 2083.

Brinks, J.S., Clark, R.T., Kieffer, N.M. and Quesenberry, J.R. (1962). Mature weight in Hereford range cows - heritability, repeatability, and relationship to calf performance. J. Anim. Sci., 21: 501-504.

Brinks, J.S., Clark, R.T., Kieffer, N.M. and Urick, J.J. (1964). Estimates of genetic, environmental and phenotypic parameters in range Hereford females. J. Anim. Sci., 23: 711-716.

Brinks, J.S., Clark, R.T., Rice, F.J. and Kieffer, N.M. (1961). Adjusting birth weight, weaning weight, and preweaning gain for sex of calf in range Hereford cattle. J. Anim. Sci., 20: 363-367.

Brinks, J.S. Urick, J.J., Pahnish, O.F., Knapp, B.W. and Riley, T.J.
(1967). Heterosis in preweaning and weaning traits among
lines of Hereford cattle. J. Anim. Sci., 26: 278-284.

Brito, R. (1973). Gestation length of zebu cows in Cuba. Effect of
bull. Revista Cubana de Ciencias Veterinarias, 4: 83-86.
A.B.A., 44: No. 4718.

Brody, S. and Cunningham, R. (1936). Growth and development. XXXIX.
Relation between monetary profit and energy efficiency of milk
production with special reference to the influence of live
weight thereon. Mo. Ari. Exp. Sta. Res. Bul. 239.

Broster, W.H. (1971). The effect on milk yield of the cow of the
level of feeding before calving. Dairy Sci. Abstr., 33:
253-270.

Broster, W.H. (1972). The effect on milk yield of the cow of the level
of feeding during lactation. Dairy Sci. Abstr., 34: 265-288.

Brougham, R.W. (1959). The effects of season and weather on the growth
rate of a ryegrass and clover pasture. N.Z. J. agric. Res., 2:
283-296.

Brougham, R.W. (1960). The effects of frequent hard grazings at
different times of the year on the productivity and species
yields of a grass-clover pasture. N.Z. J. agric. Res., 3:
125-136.

Brown, C.J. (1960). Influence of year and season of birth, sex, sire
and age of dam on weights of beef calves at 60, 120, 180 and
240 days of age. J. Anim. Sci., 19: 1062-1070.

Brown, C.J. and Galvez, M. (1969). Maternal and other effects on
birth weight of beef calves. J. Anim. Sci., 28: 162-167.

Brownson, R.M. (1974). Beef cattle enterprise management strategies.
Diss. Abstr., 35 (7): 3119B-3120B. A.B.A., 43: No. 2752.

Brumby, P.J., Walker, D.K. and Gallagher, R.M. (1963). Factors assoc-
iated with growth in beef cattle. N.Z. J. agric. Res., 6:

Burris, M.J. and Blunn, C.T. (1952). Some factors affecting gestation
length and birth weight of beef cattle. J. Anim. Sci., 11:
34-41.

Burris, M.J., Blunn, C.T. and Baker, M.L. (1964). Some factors affect-
ing birth weights of beef calves. J. Anim. Sci., 9: 635 Abstr.

Campbell, A.G. and Clayton, D.G. (1966). Increasing stocking rate and
butterfat production by redistribution of available feed supply.
Proc. Ruakura Farmers' Conference, 1966. pp.181-193.

Carpenter, J.A., Fitzhugh, H.A., Cartwright, T.C. and Thomas, R.C.
(1973). Relationships between calf performance and mature size
of beef cows. J. Anim. Sci., 37: 231 Abstr.

Carter, A.H., Muller, J.P.E. and Baker, R.L. (1975). Exotic breeds
     for beef herds: preliminary results. Proc. Ruakura Farmers'
     Conf., 27: 19-24. A.B.A., 44: No. 4085.

Cartwright, T.C. and Warwick, B.L. (1955). Heritability of rate of
     gain in young growing beef cattle. J. Anim. Sci., 14:
     363-371.

Christensen, K. (1968). Relationships between milk composition, and
     yield of milk, fat, and protein in Red Danish cattle. Anim.
     Prod., 10: 445-450.

Christenson, R.K., Zimmerman, D.R., Clanton, D.C., Jones, L.E.,
     Tribble, R.L. and Sotomayor, R. (1967). Effect of pre-calving
     energy levels on performance of beef heifers. J. Anim. Sci.,
     26: 916 Abstr.

Christian, L.L., Hauser, E.R. and Chapman, A.B. (1965). Association
     of preweaning and postweaning traits with weaning weight in
     cattle. J. Anim. Sci., 24: 652-659.

Clark, R.T., Shelby, C.E., Quesenberry, J.R., Woodward, R.R. and
     Willson, F.S. (1958). Production factors in range cattle under
     Northern Great Planes conditions. USDA Tech. Bull. No. 1181.

Cole, L.J. and Johansson, I. (1933). The yield and composition of milk
     from Aberdeen Angus cows. J. Dairy Sci., 16: 565-580.

Cooper, C.R., Sutherland, T.M., Pattengale, P.S. and Williams, J.S.
     (1965). Effects of environmental factors and their two way
     interactions on weaning traits in Colorado beef herds. J. Anim.
     Sci., 24: 847 Abstr.

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

Cowan, R.T., O'Grady, P. and Moss, R.J. (1974). Relationship of age
     and liveweight at first calving to subsequent lactation yields
     of Friesian heifers grazing tropical pastures. Qd. J. agric.
     Anim. Sci., 31: 367-370.

Creek, M.J. (1964). Animal production studies in Jamaica. II. The
     development and evaluationof a field programme of calf weighing.
     J. agric. Sci., Camb., 62: 157-164.

Cundiff, L.V. (1970). Experimental results on crossbreeding cattle for
     beef production. J. Anim. Sci., 30: 694-705.

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

Cundiff, L.V., Gregory, K.E. and Long, C.R. (1975). Genetic variation
     among and within herds of Angus and Hereford cattle. J. Anim.
     Sci., 41: 1270-1280.

Cundiff, L.V., Willham, R.L. and Pratt, C.A. (1966a). Effects of
     certain factors and their two-way interactions on weaning
     weight in beef cattle. J. Anim. Sci., 25: 972-982.

Cundiff, L.V., Willham, R.L. and Pratt, C.A. (1966b). Additive
     versus multiplicative correction factors for weaning weight
     in beef cattle. J. Anim. Sci., 25: 983-987.

Cunningham, E.P. and Henderson, C.R. (1965a). Estimation of genetic
     and phenotypic parameters of weaning traits in beef cattle.
     J. Anim. Sci., 24: 182-187.

Cunningham, E.P. and Henderson, C.R. (1965b). Repeatability of
     weaning traits in beef cattle. J. Anim. Sci., 24: 188-191.

Dawson, W.M., Cook, A.C. and Knapp, B. (1960). Milk production of
     Beef Shorthorn cows. J. Anim. Sci., 19: 502-508.

Dawson, W.M., Phillips, R.W. and Black, W.H. (1947). Birth weight
     as a criterion of selection in beef cattle. J. Anim. Sci., 6:
     247-257.

Dawson, W.M., Vernon, E.H., Baker, A.H. and Warwick, E.J. (1954).
     Selection for increased weights of six-month-old beef calves
     in a Brahman-Angus population. J. Anim. Sci., 13: 557-562.

Dearbourn, D.D., Koch, R.M., Cundiff, L.V., Gregory, K.E. and
     Dickerson, G.E. (1973). An analysis of reproductive traits
     in beef cattle. J. Anim. Sci., 36: 1032-1040.

Deese, R.E. and Koger, M. (1967). Maternal effects on preweaning
     growth rate in cattle. J. Anim. Sci., 26: 250-253.

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

Dickey, J.R., Koger, M., Franke, D.E. and Burns, W.C. (1970). Milk
     production in beef cattle. J. Anim. Sci., 30: 317 Abstr.

Dickey, J.R., Koger, M., Franke, D.E. and Burns, W.C. (1971).
     Nursing period effect on beef cow milk yield. J. Anim. Sci.,
     32: 378 Abstr.

Dietz, W. and Young, B.A. (1972). Effects of body condition on
     winter energy requirements of beef cows. Can. J. Anim. Sci.,
     52: 588 Abstr.

Drennan, M.J. (1971a). Single suckled beef production. 1. Influence
     of stocking rate during the grazing season, creep grazing of
     the calf and double suckling on live-weight changes and milk
     production of the cows. Irish J. agric. Res., 10: 287-295.

Drennan, M.J. (1971b). Single suckled beef production. 2. Influence
     of stocking rate during the grazing season, creep grazing of
     the calf and double-suckling on calf performance. Irish J.
     agric. Res., 10: 297-305.

Drennan, M.J. and Bath, I.H. (1976a). Single suckled beef
    production. 3. Effect of plane of nutrition during late
    pregnancy on cow performance. Irish J. agric. Res., 15: 157-158.

Drennan, M.J. and Bath, I.H. (1976b). Single suckled beef
    production. 4. Effect of plane of nutrition during late
    pregnancy on subsequent calf performance. Irish J. agric.
    Res., 15: 169-176.

Drewry, K.J., Brown, C.J. and Honea, R.S. (1959). Relationships
    among factors associated with mothering ability in beef cattle.
    J. Anim. Sci., 18: 938-946.

Dreyer, D. (1965). Tierzüchter, 25: 58-61. cited by Philipsson, J.
    (1976a).

Dunn, R.J., Magee, W.T., Gregory, K.E., Cundiff, L.V. and Koch, R.M.
    (1970). Genetic parameters in straightbred and crossbred beef
    cattle. J. Anim. Sci., 31: 656-663.

Dunn, T.G., Wiltbank, J.N., Zimmerman, D.R. and Ingalls, J.E. (1965).
    Dam's energy intake on milk production and calf gains.
    J. Anim. Sci., 24: 586 Abstr.

Edwards, J. and Bailey, C.M. (1975). Relation of dam and calf weights
    in diverse environments. J. Anim. Sci., 41: 248 Abstr.

England, N., Brinks, J.S., Bogart, R., England, D.C. and Clark, R.T.
    (1961). Factors affecting calf weight gains during the
    suckling period. J. Anim. Sci., 20: 672 Abstr.

Everett, R.W. and Magee, W.T. (1965). Maternal ability and genetic
    ability of birth weight and gestation length. J. Dairy Sci.,
    48: 957-961.

Ewing, S.A., Smithson, L. and Stephens, D. (1967). Mature size and
    energy requirements of producing beef cows. J. Anim. Sci.,
    26: 918 Abstr.

Ewing, S.A., Stephens, D. and Smithson, L. (1966). Weight loss
    pattern of beef cows at calving. J. Anim. Sci., 25: 922 Abstr.

Fagg, B.W., Singleton, W.L., Nelson, L.A. and Huber, D.A. (1975).
    Dystocia in crossbred heifers. J. Anim. Sci., 41: 266 Abstr.

Fahmy, M.H. and Lalande, G. (1972). Trends in preweaning performance
    of Beef Shorthorn calves. Can. J. Anim. Sci., 52: 575 Abstr.

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

Fitzhugh, H.A. (1965). A biometrical evaluation of weight of beef
    cows and the performance of their progeny. Ph.D. Thesis,
    Texas A. and M. University. cited by Jeffery et al. (1971b).

Foot, A.S., Line, C. and Rowland, S.J. (1963). The effect of pre-
    partum feeding of heifers on milk composition. J. Dairy Res.,
    30: 403-409.

Foote, W.C., Pope, A.L., Chapman, A.B. and Casida, L.E. (1959).
Reproduction in the yearling ewe as affected by breed and
sequence of feeding levels. II Effects on fetal development.
J. Anim. Sci., 18: 463-474.

Frahm, R., Gould, M., Stanforth, T., Cobb, B. and Mizell, B. (1975).
How rapidly can growth rate be increased in beef cattle by
selection? Research Report, Agric. Exp. Stn. Okla. State Univ.,
P -725: 20-30. A.B.A., 45: No. 682.

Franke, D.E., England, N.C. and Hendry, J.E. (1965). Effect of breed
of dam and breed of sire on birth weight of beef calves.
J. Anim. Sci., 24: 281 Abstr.

Freeman, A.E. (1975). Management traits in dairy cattle. Dystocia,
udder characteristics related to production, and a review of
other traits. 26th Ann. Meet. of the European Ass. for Anim.
Prod., Warsaw. cited by Philipsson, J. (1976a).

Furr, R.D. (1962). Effect of different levels of supplemental winter
feed upon the production of fall-calving beef cows. Ph.D. Thesis,
Okla. State Univ., Stillwater. cited by Totusek et al. (1973).

Gaines, J.A., McClure, W.H., Vogt, D.W., Carter, R.C. and Kincaid, C.M.
(1966). Heterosis from crosses among British breeds of beef
cattle: Fertility and calf performance to weaning. J. Anim.
Sci., 25: 5-13.

Gerlaugh, P., Kunkle, L.K. and Rife, D.C. (1951). Crossbreeding beef
cattle: A comparison of the Hereford and Aberdeen-Angus breeds
and their reciprocal crosses. Ohio Agric. Exp. Stn. Res. Bull.
703.

Gianola, D. and Tyler, W.J. (1974). Influences on birth weight and
gestation period of Holstein-Friesian cattle. J. Dairy Sci.,
57 (part 1): 235-240.

Gifford, W. (1953). Records of performance tests for beef cattle in
breeding herds. Milk production of dams and growth of calves.
Ark. Agric. Exp. Stn. Bull. 531.

Gleddie, V.M. and Berg, R.T. (1968). Milk production in range beef
cows and its relationship to calf gains. Can. J. Admin. Sci.,
48: 323-333.

Godley, W.C. and Tennant, G.O. (1969). The influence of dam's weight
on calf performance. J. Anim. Sci., 28: 129 Abstr.

Gregory, K.E., Blunn, C.T. and Baker, M.L. (1950). A study of some of
the factors influencing the birth and weaning weights of beef
calves. J. Anim. Sci., 9: 338-346.

Gregory, K.E., Swiger, L.A., Koch, R.M., Sumption, L.J., Rowden, W.W.
and Ingalls, J.E. (1965). Heterosis in pre-weaning traits of
beef cattle. J. Anim. Sci., 24: 21-28.

Hammond, J. (1935). The inheritance of productivity in farm animals.
Emp. J. Exp. Agric., 3: 1-12.

Harricharan, H., Mahadevan, P. and Springer, B.G.F. (1976). The performance of Santa Gertrudis, Sahiwal, Brahman and crossbred animals in the intermediate savannahs of Guyana. J. agric. Sci., Camb., 87: 269-276.

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

Harris, R.R., Brown, V.L. and Anthony, W.B. (1965). Effect of winter nutrition upon performance of beef cows and their calves. J. Anim. Sci., 24: 280 Abstr.

Harwin, G.O., Brinks, J.S. and Stonaker, H.H. (1966). Genetic and environmental interactions affecting weaning weights of Hereford calves. J. Anim. Sci., 25: 779-782.

Haycock, R.E. (1973). A comparison of the Charolais, British Friesian and Hereford breeds as sires of crossbred single-suckled calves for beef production. Anim. Prod., 17: 267-273.

Heyns, H. (1960). The growth of the Afrikaner calf in relation to the production and composition of the milk of its dam. II. The milk production of the dam and growth of its calf. Sth. African J. Agric. Sci., 3: 517-530.

Hickman, C.G., Lee, A.J., Sfen, S.B. and Kozub, G.C. (1971). Influence of body size during lactation on level of milk production. Can. J. Anim. Sci., 51: 317-325.

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

Hight, G.K. (1968a). Nutrition and management of the beef breeding herd. Sheepfarming Annual 1968. pp.113-130.

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

Hight, G.K. (1968c). A comparison of the effects of three nutritional levels in late pregnancy on beef cows and their calves. N.Z. J. agric. Res., 11: 477-486.

Hight, G.K. (1969). Friesians on hill country. Sheepfarming Annual 1969. pp.127-146.

Hight, G.K., Everitt, G.C. and Jury, K.E. (1971). Reciprocal crossbreeding of Friesian and Angus cattle. Proc. N.Z. Soc. Anim. Prod., 31: 43-50.

Hight, G.K., Everitt, G.C. and Jury, K.E. (1973). Reciprocal crossbreeding of Friesian and Angus cattle. N.Z. J. agric. Res., 16: 519-528.

Hironaka, R. and Peters, H.F. (1969). Energy requirements for wintering mature pregnant beef cows. Can. J. Anim. Sci., 49: 323-330.

Hodge, P.B., Beasley, R.C. and Stokoe, J. (1976). Effect of three levels of grazing nutrition upon calving and subsequent performance in Hereford heifers. Proc.Aust. Soc. Anim. Prod., 11: 245-248.

Hodge, P.B. and Rowan, K.J. (1970). Effect of varying the plane of nutrition on the calving performance of Hereford heifers. Proc. Aust. Soc. Anim. Prod., 8: 410-414.

Hohenboken, W.D. and Brinks, J.S. (1969). Effect of environmental corrections on repeatability of weaning weight in Angus. J. Anim. Sci., 29: 534-540.

Holloway, J.W., Stephens, D.F., Whiteman, J.V. and Totusek, R. (1975). Performance of 3-year-old Hereford, Hereford × Holstein and Holstein cows on range and in drylot. J. Anim. Sci., 40: 114-125.

Hughes, J.H. (1972). The influence of winter nutrition on the growth and milk production of Hereford females, and the birth date and growth of their calves. Diss. Abstr., 33: 507B.

Humes, P.E., Moin, S.b. and Idris, I.b. (1975). Birth and preweaning traits of exotic cross calves. J. Anim. Sci., 41: 250 Abstr.

Hutton, J.B. and Parker, D.F. (1973). The significance of differences in levels of feeding, before and after calving, on milk yield under intensive grazing. N.Z. J. agric. Res., 16: 95-104.

Jafar, S.M., Chapman, A.B. and Casida, L.E. (1950). Causes of variation in length of gestation in dairy cattle. J. Anim. Sci., 9: 593-601.

Jeffery, H.B. and Berg, R.T. (1971). Evaluation of milk variables as measures of milk effect on preweaning performance of beef cattle. Can. J. Anim. Sci., 51: 21-30.

Jeffery, H.B. and Berg, R.T. (1972a). Influence of cow size and other factors on weight gain of beef calves to 365 days of age. Can. J. Anim. Sci., 52: 11-21.

Jeffery, H.B. and Berg, R.T. (1972b). An evaluation of several measurements of beef cow size as related to progeny performance. Can. J. Anim. Sci., 52: 23-37.

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

Jeffery, H.B., Berg, R.T. and Hardin, R.T. (1971b). Factors affecting preweaning performance in beef cattle. Can. J. Anim. Sci., 51: 561-577.

Johnson, L.E. and Dinkel, C.A. (1951). Correction factors for adjusting weaning weights of range calves to the constant age of 190 days. J. Anim. Sci., 10: 371.

Jordan, W.A., Lister, E.E., Wauthy, J.M. and Comeau, J.E. (1973). Voluntary roughage intake by nonpregnant and pregnant or lactating beef cows. Can. J. Anim. Sci., 53: 733-738.

Jordan, W.A., Lister, E.E., and Rowlands, G.T. (1968). Effect of varying planes of winter nutrition of beef cows on calf performance to weaning. Can. J. Anim. Sci., 48: 155-161.

Joubert, D.M. (1954). The influence of winter nutritional depressions on the growth, reproduction and production of cattle. J. agric. Sci., Camb., 44: 5-66.

Klett, R.H., Mason, T.R. and Riggs, J.K. (1965). Milk production of beef cows and its relationship to the weaning weight of their calves. J. Anim. Sci., 24: 586 Abstr.

Klosterman, E.W., Parker, C.F., Bishop, R.R., Cahill, V.R. and Ruland, F.S. (1972). Effect of cow size and breed on net efficiency. J. Anim. Sci., 35: 177 Abstr.

Knapp, B., Baker, H.L., Quesenberry, J.R. and Clark, R.T. (1942). Growth and production factors in range cattle. Mont. Agric. Exp. Stn. Bull., 400.

Knapp, B. and Clark, R.T. (1947). Genetic and environmental correlations between growth rates of beef cattle at different ages. J. Anim. Sci., 6: 174-181.

Knapp, B., Lambert, W.V. and Black, W.H. (1940). Factors influencing length of gestation and birth weight in cattle. J. agric. Res., 61: 277-285.

Knapp, B. and Nordskog, A.W. (1946). Heritability of growth and efficiency of beef cattle. J. Anim. Sci., 5: 62-70.

Knox, J.H. and Koger, M.L. (1945). Effect of age on the weight and production of range cows. N. Mex. Agr. Exp. Stn. Res. Bull., 1004.

Koch, R.M. (1951). Size of calves at weaning as a permanent characteristic of range Hereford cows. J. Anim. Sci., 10: 768-775.

Koch, R.M. (1972). The role of maternal effects in animal breeding: VI. Maternal effects in beef cattle. J. Anim. Sci., 35: 1316-1323.

Koch, R.M. and Clark, R.T. (1955a). Influence of sex, season of birth and age of dam on economic traits in range beef cattle. J. Anim. Sci., 14: 386-397.

Koch, R.M. and Clark, R.T. (1955b). Genetic and environmental relationships among economic characters in beef cattle. I. Correlations among paternal and maternal half-sibs. J. Anim. Sci., 14: 775-785.

Koch, R.M. and Clark, R.T. (1955c). Genetic and environmental relationships among economic characters in beef cattle. III. Evaluating maternal environment. J. Anim. Sci., 14: 979-996.

Koch, R.M., Gregory, K.E., Ingalls, J.E. and Arthaud, R.L. (1959). Evaluating the influence of sex on birth weight and preweaning gain in beef cattle. J. Anim. Sci., 18: 738-744.

Koger, M., Jilek, A.F., Burns, W.C. and Crockett, J.R. (1975). Sire effects for specific combining ability in purebred and crossbred cattle. J. Anim. Sci., 40: 230-234.

Koger, M., Cunha, T.J. and Warnick, A.C. Ed.(1973). Crossbreeding Beef Cattle. Series 2. Publ. University of Florida Press, Gainesville, 459 pp.

Koger, M., Mitchell, J.S., Kidder, R.W., Burns, W.C., Hentges, J.F. and Warnick, A.C. (1967). Factors influencing survival in beef calves. J. Anim. Sci., 26: 205 Abstr.

Kress, D.D., Hauser, E.R. and Chapman, A.B. (1969). Efficiency of production and cow size in beef cattle. J. Anim. Sci., 29: 373-383.

Kress, D.D. and Webb, R.P. (1972). Sex x sire interactions in beef cattle. J. Anim. Sci., 34: 885 Abstr.

Kropp, J.R., Atephens, D.F., Holloway, J.W., Whiteman, J.V., Knori, L. and Totusek, R. (1972). Performance of Hereford, Holstein and Hereford x Holstein females as influenced by level of winter supplement. J. Anim. Sci., 35: 191 Abstr.

Laird, R. and Hunter, E.A. (1977). The length of gestation period of Ayrshire cows when mated with bulls of other breeds. Anim. Prod., 24: 63-67.

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

Lamond, D.R., Holmes, J.H.G. and Haydock, K.P. (1969). Estimation of yield and composition of milk produced by grazing beef cows. J. Anim. Sci., 29: 606-611.

Lampkin, K. and Lampkin, G.H. (1960). Studies on the production of beef from Zebu cattle in East Africa. II. Milk production in suckled cows and its effect on calf growth. J. agric. Sci., Camb., 55: 233-239.

Lampo, P. and Willems, A. (1965). Causes in variation in birth weight of calves. Tijdschr., 34: 79-84. A.B.A., 33: No. 3164.

Lasley, J.F., Day, B.N. and Comfort, J.E. (1961). Some genetic aspects of gestation length and the birth and weaning weights in Hereford cattle. J. Anim. Sci., 20: 737-741.

Laster, D.B. (1973). Factors affecting calving difficulty. In: U.S. Meat Animal Research Center. 1973. Beef Cattle Research Progress Report. pp.36-40. A.B.A., 42: No. 2633.

Laster, D.B., Glimp, H.A., Cundiff, L.V. and Gregory, K.E. (1973). Factors affecting dystocia, and the effects of dystocia on subsequent reproduction in beef cattle. J. Anim. Sci., 36: 695-705.

Laster, D.B. and Gregory, K.E. (1973). Factors influencing peri- and early postnatal calf mortality. J. Anim. Sci., 37: 1092-1097.

Lehmann, R.P., Gaines, J.A., Carter, R.C., Bovard, K.P. and Kincaid, C.M. (1961). Selection indexes for weaning traits in beef calves. J. Anim. Sci., 20: 53-57.

Lindsey, T.L., Wilson, G.R., Cahill, V.R. and Swiger, L.A. (1970).
Measurements related to cow productivity. J. Anim. Sci.,
31: 175 Abstr.

Linton, A.C., Brinks, J.S., Stonaker, H.H., Sutherland, T.M. and
Faulkner, L.C. (1968). Factors affecting weaning weights
of cattle. J. Anim. Sci., 28: 1104 Abstr.

Loganathan, S., Cooper, R.J. and Hobbs, C.S. (1965). Factors
affecting preweaning performance of Hereford calves.
J. Anim. Sci., 24: 849 Abstr.

Long, C.R. and Gregory, K.E. (1974). Heterosis and breed effects
in preweaning traits of Angus, Hereford and reciprocal
cross calves. J. Anim. Sci., 39: 11-17. A.B.A., 43, No. 24.

Lush, J.L. (1945). Animal Breeding Plans. 3rd ed. Publ. Iowa State
College Press, Ames. 443pp.

McDonald, P., Edwards, R.A. and Greenhalgh, J.F.D. (1973). Animal
Nutrition. 2nd ed. Publ. Longman Inc., New York. 479pp.

McDonald, R.P. and Turner, J.W. (1969). Parental breed and weight
effect on beef calves. J. Anim. Sci., 28: 130 Abstr.

Mangus, W.L. and Brinks, J.S. (1971). Relationships between direct
and maternal effects on growth in Herefords. 1. Environ-
mental factors during preweaning growth. J. Anim. Sci., 32:
17-25.

Marlowe, T.J. and Gaines, J.A. (1958). The influence of age, sex,
and season of birth of calf and age of dam on preweaning
growth rate and type score of beef calves. J. Anim. Sci., 17:
706-713.

Marlowe, T.J., Mast, C.C. and Schalles, R.R. (1965). Some non-
genetic influences on calf performance. J. Anim. Sci., 24:
494-501.

Mason, I.L. (1951). Performance recording in beef cattle. Anim.
Breed. Abstr., 19: 1-24.

Meade, J.H., Dollahon, J.C., Taylor, J.C. and Lindley, C.E. (1959).
Factors influencing weaning weights of Hereford and Angus
cattle in Mississippi. J. Anim. Sci., 18: 1149 Abstr.

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

Meyer, U. (1972). Some results of the crossbreeding experiment
between Simmental and Red Holstein cattle. Mitt. Schweiz.
verb. K.B.S. Arb. K. Besam, 10: 21-23. A.B.A., 40: No. 2751.

Milk Marketing Board (1966). The Charolais Report. Milk Marketing
Board., Thames Ditton, Surrey. 47pp.

Miller, R.H., Hooven, N.W. and Creegan, M.E. (1973). Usefulness of periodic body weights to predict yield, intake and feed efficiency of lactating cows. J. Dairy Sci., 56: 1540-1544.

Minyard, J.A. and Dinkel, C.A. (1965). Weaning weight of beef calves as affected by age and sex of calf and age of dam. J. Anim. Sci., 24: 1067-1071.

Moin, S.,Humes, P.E. and Schiling, P.E. (1975). Cow weight effects on calf birth and weaning weight. J. Anim. Sci., 40: 174 Abstr.

Molineuvo, H.A. (1971). Effect of heterosis on birth and weaning weights in the Charolais x Aberdeen-Angus cross. Annls. Genet. Sel. anim., 2: 75-84. A.B.A., 39: No. 333.

Morris, S.T. (1976). A study of some factors affecting the post-partum oestrus interval in suckled Angus cows. Master of Agricultural Science Thesis, Massey University, 133pp.

Munford, R.E., Campbell, I.L., McDowall, F.H. and Davey, A.W.F. (1964). The effect of restricted grazing during a single day upon milk yield, milk composition, and butterfat characteristics of Jersey cows. J. Dairy Res., 31: 59-69.

National Academy of Sciences. National Research Council (U.S.) (1970). Nutrient requirements of domestic animals. 4. Nutrient requirements of beef cattle. National Research Council Publication 1137. Washington, D.C.

Neel, J.B. (1973). The influence of initial cow weight on progeny performance and TDN efficiency in production of slaughter cattle. Diss. Abstr. 34 (3): 937B-938B.

Neel, J.B., Anderson, J.M., Hobbs, C.S., Odom, J.A. and Corrick, J.A. (1972). Effect of winter feeding on beef cow performance. J. Anim. Sci., 34: 345 Abstr.

Neville, W.E. (1962). Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J. Anim. Sci., 21: 315-320.

Neville, W.E., Baird, D.M., McCampbell, H.C. and Sell, O.E. (1962). Influence of dam's milk production and other factors on post-weaning performance and carcass characteristics of Hereford cattle. J. Anim. Sci., 21: 943-949.

Neville, W.E., Baird, D.M. and Sell, O.E. (1960). Influence of sire, dam's milk production, three levels of nutrition and other factors on 120, and 240 day weights of Hereford calves. J. Anim. Sci., 19: 1223 Abstr.

Nicoll, G.B. (1975). A study of adjustment factors for the weaning weights of Hereford and Angus calves. Master of Agricultural Science Thesis, Massey University. 121pp.

Omar, M.A. (1974). Estimate of daily milk yield in Hereford and Angus dams. Master of Science Thesis, Okla. State Univ. Stillwater. cited by Boston et al. (1975).

O'Mary, C.C. and Coonrad, D.J. (1972). Effect of sire on calving
    difficulty. J. Anim. Sci., 35: 1089 Abstr.

O'Mary, C.C. and Hillers, J.K. (1976). Factors affecting time
    intervals in parturition in beef cattle. J. Anim. Sci.,
    42: 1118-1123.

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

Pahnish, O.F. (1958). Some genetic and environmental factors
    influencing the weaning weights of southwestern range cattle.
    Diss. Abstr., 19: 648B.

Pahnish, O.F., Brinks, J.S., Urick, J.J., Knapp, B.W. and Riley, T.M.
    (1969). Results from crossing beef x beef and beef x dairy
    breeds: Calf performance to weaning. J. Anim. Sci., 28:
    291-299.

Pahnish, O.F., Roberson, R.L., Taylor, R.L., Brinks, J.S., Clark, R.T.
    and Roubicek, C.B. (1964). Genetic analyses of economic traits
    measured in range-raised Herefords at preweaning and weaning
    ages. J. Anim. Sci., 23: 562-568.

Parker, E.E., Waldrip, W.J. and Marion, P.T. (1966). Effects of
    grazing rates and levels of winter supplements on cow-calf
    performance. J. Anim. Sci., 25: 599 Abstr.

Patchell, M.R. (1957). The influence of undernutrition of dairy cows
    on the yield and composition of milk. N.Z. J. Sci. and Tech.,
    38A: 682-688.

Petty, R.R. and Cartwright, T.C. (1966). A summary of genetic and
    environmental statistics for growth and conformation traits
    of young beef cattle. Texas Agr. Exp. Stn. Dept. Anim. Sci.
    Tech. Rep. 5.

Philipsson, J. (1976a). Studies on calving difficulty, stillbirth and
    associated factors in Swedish cattle breeds. I. General
    introduction and breed averages. Acta Agriculturae Scandinavica,
    26: 151-164.

Philipsson, J. (1976b). Studies on calving difficulty, stillbirth and
    associated factors in Swedish cattle breeds. II. Effects of
    non-genetic factors. Acta Agriculturae Scandinavica. 26:
    165-174.

Philipsson, J. (1976c). Studies on calving difficulty, stillbirth and
    associated factors in Swedish cattle breeds. III. Genetic
    parameters. Acta Agriculturae Scandinavica, 26: 211-220.

Philipsson, J. (1976d). Studies on calving difficulty, stillbirth and
    associated factors in Swedish cattle breeds. IV. Relationships
    between calving performance, precalving body measurements and
    size of pelvic opening in Friesian heifers. Acta Agriculturae
    Scandinavica, 26: 221-229.

Philipsson, J. (1976e). Studies on calving difficulty, stillbirth and associated factors in Swedish cattle breeds. V. Effects of calving performance and stillbirth in Swedish Freisian heifers on productivity in the subsequent lactation. Acta Agriculturae Scandinavica, 26: 230-234.

Pinney, D., Pope, S.L., Cotthem, C.V. and Urban, K. (1962). Effect of winter plane of nutrition on the performance of three- and four-year-old beef cows. Okla. Agr. Exp. Stn. Publ. 67.

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

Plasse, D., Koger, M. and Verde, O.G. (1968). Estimation of genetic parameters for prenatal and postnatal growth in the Santa Gertrudis. Mems. Assoc. lat-am. Prod. Anim., 3: 103-114, cited by Willis and Wilson (1974).

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

Pope, L.S. (1967). Winter feeding and reproduction in cows. pp.32-43. In: Factors Affecting Calf Crop. Ed. T.J. Cunha, A.C. Warnick, M. Koger. Publ. Univ. of Florida Press, Gainesville. 376pp.

Powell, T.L. (1972). Intensification of the spring-calving single-suckler herd. Anim. Prod., 14: 77-84.

Powell, T.L. and Matravers, C. (1975). Feeding levels in late pregnancy and early lactation for spring calving single suckler cows. Exp. Husb., 29: 29-37.

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

Quesenberry, J.R. (1950). Livestock breeding research at the U.S. Range Livestock Experimental Station. U.S.D.A. Information Bull. 18.

Remmen, J.W.A. (1975). Calving performance and calf mortality. 26th Ann. Meet. of the European Ass. for Anim. Prod., Warsaw. 23rd-27th June, 1975. cited by Philipsson, J. (1976a).

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

Reynolds, W.L., De Rouen, T.M. and Meyerhoeffer, D.G. (1967). Milk production of Angus, Brahman and Zebu-cross cows. J. Anim. Sci., 26: 206 Abstr.

Reynolds, W.L., De Rouen, T.M., Meyerhoeffer, D.G., Wiltbank, J.N. and Temple, R.S. (1965). Birth weight and gestation length of beef cattle. J. Anim. Sci., 24: 851 Abstr.

Rhodes, R.F., Scarth, R.D. and Cook, M.K. (1970). The effect of certain biological and environmental factors on weaning weight of beef calves. J. Anim. Sci., 31: 168 Abstr.

Rice, F.J., Kelly, A.M. and Lasley, J.F. (1954). Length of gestation in Hereford cows and its relation to performance. J. Anim. Sci., 13: 961 Abstr.

Rice., L.E. and Wiltbank, J.N. (1970). Dystocia in beef heifers. J. Anim. Sci., 30: 1043 Abstr.

Reid, J.T. (1960). Effect of energy intake upon reproduction in farm animals. J. Dairy Sci., 43 (Suppl.): 103-122. A.B.A. 28: No. 2341.

Rife, D.C. (1948). Variations in the length of gestation in Aberdeen-Angus and Hereford cows carrying purebred and crossbred calves. Abs. Book, 8th International Gen. Congress, pp. 112-113.

Rife, D.C., Gerlaugh, P., Kunkle, L., Brandt, G.W. and Snyder, L.H. (1943). Comparative lengths of the gestation periods of Aberdeen-Angus and Hereford cows carrying purebred and crossbred calves. J. Anim. Sci., 2: 50-52.

Rollins, W.C. and Guilbert, H.R. (1954). Factors affecting the growth of beef calves during the suckling period. J. Anim. Sci., 13: 517-527.

Rollins, W.C. and Wagnon, K.A. (1956). A genetic analysis of weaning weights in a range beef herd operated under optimum and suboptimum nutritional regimes. J. Anim. Sci., 15: 125-133.

Roman, J., Wilcox, C.J., Martin, F.G., Becker, R.B. and Koger, M. (1970). Maternal effects on birth weights of Jersey calves. J. Dairy Sci., 53: 655 Abstr.

Rutledge, J.J., Robison, O.W., Ahlschwede, W.T. and Legates, J.E. (1971). Milk yields and its influence on 205-day weight of beef calves. J. Anim. Sci., 33: 563-567.

Rutledge, J.J., Robison, O.W., Ahlschwede, W.T., and Legates, J.E. (1972). Estimating milk yield of beef cows. J. Anim. Sci., 34: 9-13.

Rutledge, J.J., Robison, O.W. and Legates, J.E. (1970). Factors affecting estimates of milk yield of beef cows. J. Anim. Sci., 31: 167 Abstr.

Ryley, J.W. (1961). Drought feeding studies with cattle. 6. Sorghum silage, with and without urea, as a drought fodder for cattle in late pregnancy and early lactation. Qld. J. agr. Sci., 18: 409-424.

Sagebiel, J.A. (1968). A biometrical analysis of dystocia and heterosis for gestation length and birth weight in beef cattle. Ph.D. Dissertation, Univ. Mo., Columbia. cited by Sagebiel et al. (1973).

Sagebiel, J.A., Krause, G.F., Sibbit, R., Langford, L., Comfort, J.E., Dyer, A.J. and Lasley, J.F. (1969). Dystocia in reciprocally crossed Angus, Hereford and Charolais cattle. J. Anim. Sci., 29: 245-250.

Sagebiel, J.A., Krause, G.F., Sibbit, R., Langford, L., Dyer, A.J. and Lasley, J.F. (1973). Effect of heterosis and maternal influence on gestation length and birth weight in reciprocal crosses among Angus, Charolais, and Hereford cattle. J. Anim. Sci., 37: 1273-1278.

Sagebiel, J.A., Krause, G.F., Sibbit, B., Langford, L., Dyer, A.J. and Lasley, J.F. (1974). Effect of heterosis and maternal influence on weaning traits in reciprocal crosses among Angus, Charolais and Hereford cattle. J. Anim. Sci., 39: 471-479.

Sagebiel, J.A., Lasley, J.F., Krause, G.F., Sibbit, B., Langford, L. and Dyer, A.J. (1972). Heterosis for gestational traits in beef cattle. J. Anim. Sci., 35: 182 Abstr.

Saul, G.R. and Morgan, J.H.L. (1976). The milk production of two year old Hereford and Friesian cows. Proc. Aust. Soc. Anim. Prod., 11: 30p.

Schlote, W., Buchsteiner, R. and Wortmann, H. (1975). Calving performance in cattle (Heritability estimates). 26th Ann. Meet. of the European Ass. of Anim. Prod., Warsaw, 23-27 June, 1975. cited by Philipsson, J. (1976a).

Schwark, H.J. and Oehler, H. (1973). Calf birth weight as a result of intra-uterine growth and the causes of its variability. 3. Parental effects on birth weight, its heritability and the effect of season of the year and of different years on birth weight. Tierzucht., 16: 72-82. A.B.A., 42: No. 3043.

Schwulst, F.J. (1969). Heterosis effects on milk production of beef cows. Diss. Abstr., 30: 7-B. A.B.A., 38: No. 1186.

Schwulst, F.J., Sumption, L.J., Swiger, L.A. and Arthaud, V.H. (1966). Use of oxytocin for estimating milk production of beef cows. J. Anim. Sci., 25: 1045-1047.

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

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

Sellers, H.I., Willham, R.L. and De Baca, R.C. (1970). Effect of certain factors on weaning weight of beef calves. J. Anim. Sci., 31: 5-12.

Serwanja, J.C., Welch, J.A. and Kidder, H.E. (1969). Dam's milk yield and composition on growth of Angus calves. J. Anim. Sci., 29: 198 Abstr.

Shelby, C.E., Clark, R.T., Quesenberry, J.R. and Woodward, R.R. (1960). Heritability of some economic characteristics in record of performance bulls. J. Anim. Sci., 19: 450-457.

Shelby, C.E., Clark, R.T. and Woodward, R.R. (1955). The heritability of some economic characteristics of beef cattle. J. Anim. Sci., 14: 372-385.

Shelby, C.E., Harvey, W.R., Clark, R.T., Quesenberry, J.R. and Woodward, R.R. (1963). Estimates of phenotypic and genetic parameters in ten years of Miles City ROP steer data. J. Anim. Sci., 22: 346-353.

Singh, A.R., Schalles, R.R., Smith, W.H. and Kessler, F.B. (1970). Cow weight and preweaning performance ofcalves. J. Anim. Sci., 31: 27-30.

Singh, B.B. and Tyagi, J.C. (1970). Magnitude of effects of factors affecting birth weights of Hariana calves. Indian vet. J., 47: 851-854. A.B.A., 39: No. 1447.

Singleton, W.L., Nelson, L.A. and Huber, D.A. (1973). Factors influencing dystocia of two year old heifers. J. Anim. Sci., 37: 251 Abstr.

Smetham, M.L. (1973). Grazing management. pp179-228. In Pastures and Pasture Plants. Ed. R.H.M. Langer. Publ. A.H. and A.W. Reed, Wellington.

Smith, G.M., Laster, D.B. and Gregory, K.E. (1976). Characterisation of biological types of cattle. 1. Dystocia and preweaning growth. J. Anim. Sci., 43: 27-36.

Smithson, L., Ewing, S.A. and Renbarger, R.E. (1966). Influence of level of nutrition of the dam on birth weight of beef calves. J. Anim. Sci., 25: 909 Abstr.

Sokal, R.R. and Rohlf, F.J. (1969). Biometry. Publ. W.H. Freeman and Company, San Francisco, 776 pp.

Srinivasan, G. and Martin, T.G. (1970). Environmental effects on pre-weaning performance of calves. J. Anim. Sci., 31: 168 Abstr.

Stubbs, T.H. and Brett, D.J. (1976). Short term effects of level of dry matter intake upon milk yield, fatty acid composition of milk fat, and some blood constituents of Hereford cows. Aust. J. agric. Res., 27: 175-182.

Sutherland, T.M. and Lush, J.L. (1962). Effects of inbreeding on size and type in Holstein-Friesian cattle. J. Dairy Sci., 45: 390-395.

Swanson, E.W. (1967). Level of feeding and mammary development. pp.122-138. In: Factors Affecting Calf Crop. Ed. T. Cunha, A. Warwick, M. Koger. Publ. Univ. of Florida Press, Gainesville. 376pp.

Swiger, L.A. (1961). Genetic and environmental influences on gain of beef cattle during various periods of life. J. Anim. Sci., 20: 183-188.

Swiger, L.A., Koch, R.M., Gregory, K.E., Arthaud, V.H., Rowden, W.W. and Ingalls, J.E. (1962). Evaluating pre-weaning growth of beef calves. J. Anim. Sci., 21: 781-786.

Tanner, J.E., Cooper, R.J. and Kruse, W.E. (1965). Relationships between weaning weights of calves and weights and measurement of their dams. J. Anim. Sci., 24: 280 Abstr.

Tanner, J.E., Frahm, R.R., Willham, R.L. and Whiteman, J.V. (1970). Sire × sex interactions and sex differences in growth and carcass traits of Angus bulls, steers and heifers. J. Anim. Sci., 31: 1058-1064.

Taylor, B.R. (1967). The Hereford cattle recording scheme. Beef Rec. Assoc. Tech. Rep. 6.

Taylor, J.C., Carter, R.C., Kincaid, C.M., Priode, B.M. and Gaines, J.A. (1960). Estimates of genetic and phenotypic parameters in beef cattle. IV. Repeatability of cow performance. J. Anim. Sci., 19: 700-708.

Tewolde, A., Franke, D.E., Burns, W.C. and Koger, M. (1976). Factors influencing Angus and Hereford cow traits. J. Anim. Sci., 43: 223 Abstr.

Tonn, R. (1975). Selection criteria in extensive breeding of beef cattle with examples from Kenya. Tierzüchter, 27: 425-428. A.B.A., 44: No. 1126.

Totusek, R. (1968). Early weaning vs. normal weaning vs. creep feeding of heifer calves. Okla. Agr. Exp. Stn. Pub. No. MP-80, p.72.

Totusek, R., Arnett, D.W., Holland, G.L. and Whiteman, J.V. (1973). Relation of estimation method, sampling interval and milk composition to milk yield of beef cows and calf gain. J. Anim. Sci., 37: 153-158.

Touchberry, R.W. and Bereskin, B. (1966). Crossbreeding dairy cattle. 1. Some effects of crossbreeding on the birth weight and gestation period of dairy cattle. J. Dairy Sci., 49: 287-300.

Tudor, G.D. (1972). The effect of pre- and post-natal nutrition on the growth of beef cattle. I. The effect of nutrition and parity of the dam on calf birthweight. Aust. J. agric. Res., 23: 389-395.

Turman, E.J., Smithson, L., Pope, L.S., Renbarger, R.E. and Stephens, D.F. (1964). Effects of feed level before and after calving on the performance of two-year-old heifers. Okla. Agr. Exp. Stn. Misc. Publ. No. 74. pp.10-17.

Urick. J.J., Knapp, B.W., Brinks, J.S., Pahnish, O.F. and Riley, T.M. (1971). Relationship between cow weights and calf weaning weights in Angus, Charolais and Hereford breeds. J. Anim. Sci., 33: 343-348.

Verde, O. and Bodisco, V. (1974). Body weight at birth and at first calving in Criollo cattle in Venezuela. Mems. Assoc. lat-am. Prod. Anim., 9: 45-46. A.B.A., 43: No. 959.

Vernon, E.H., Harvey, W.R. and Warwick, E.J. (1964). Factors
       affecting weight and score of crossbred-type calves.
       J. Anim. Sci., 23: 21-27.

Veseley, J.A. and Robison, O.W. (1971). Genetic and maternal effects
       on preweaning growth and type score in beef calves. J. Anim.
       Sci., 32: 825-831.

Wagnon, K.A. and Carroll, F.D. (1966). Reproduction difficulties
       in range beef cattle. Bull. Calif. Agric. Exp. Stn., No. 822:
       28pp. A.B.A., 35: No. 2462.

Walker, D.E. (1962). Suckling and grazing behaviour of beef heifers
       and calves. N.Z. J. agric. Res., 5: 331-338.

Walker, D.E. (1963). Milk production of beef heifers. Proc.Ruakura
       Farmers' Conference, 1963. pp.53-62.

Warwick, E.J. (1958). Fifty years of progress in breeding beef
       cattle. J. Anim. Sci., 17: 922-943.

Willham, R.L. (1963). The covariance between relatives for
       characters composed of components contributed by related
       individuals. Biometrics, 19: 18-27.

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

Willis. M.B. and Wilson, A. (1974). Factors affecting birth weight
       of Santa Gertrudis calves. Anim. Prod., 18: 231-236.

Wiltbank, J.N., Gregory, K.E., Rothlisberger, J.A., Ingalls, J.E. and
       Kasson, C.W. (1967). Fertility in beef cows bred to produce
       straightbred or crossbred calves. J. Anim. Sci., 26: 1005-
       1010.

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

Wilson, L.L., Gillooly, J.E., Ruch, M.C., Thompson, C.E. and Purdy, H.R.
       (1969). Effects of energy intake, cow body size and calf sex
       on composition and yield of milk by Angus-Holstein cows and
       preweaning growth rate of progeny. J. Anim. Sci., 28: 789-795.

Woodward, R.R. and Clark, R.T. (1959). A study of stillbirths in a
       herd of range cattle. J. Anim. Sci., 18: 85-90.

APPENDIX 1

Climatological Data

New Zealand Gazette
Monthly May 1975 - March 1976

Year 1975 - 1976

Month and Year		Mean Air Temp. °C	Total Rainfall (mm)	Total Sunshine (hrs)	Comments
May	1975	12.3	130 (63)	78	Warm month, marked by a high frequency of westerly wind. Rain welcome.
June	1975	8.2	67 (172)	125	Winds South-easterly; frosts made month coldest since August, 1974. Pasture growth reduced. Rainfall 25 percent down.
July	1975	7.7	128 (139)	118	High frequency of winds West to South-west. Two cold spells, one in third week bringing snow to low levels. Coldest days of winter to date - 21 and 23. Final week very warm.
August	1975	9.7	161 (161)	96	Wet. Gale force winds early part of month.
September	1975	10.7	56 (65)	130	Comparatively dry month.
October	1975	13.2	83 (107)	197	Favourable month for pasture growth.
November	1975	13.0	54 (110)	176	Cool. Usual westerly weather absent. Unusually high frequency of wintry southerly conditions. 20 - 23, cold and wintry, snow to low levels.
December	1975	15.0	102 (114)	189	Cool. Dry first 3 weeks. Gusty westerlies.
January	1976	17.2	90 (116)	139	Cloudy and unusually wet. Pasture growth above normal.
February	1976	14.5	60 (100)	168	Coldest February for 39 years. Gale force South-easterly winds; dry and cold.
March	1976	16.3	85 (65)		Warm. Rainfall in Manawatu well above national average.

Note: Total rainfall figures represent precipitation at Massey University, 61 metres above sea level. Numbers in parentheses represent rainfall at Ballantrae No. 1 station on the Southern Ruahine range, 347 metres above sea level.