THE INFLUENCE OF BODY WEIGHT AND CHANGES IN BODY WEIGHT OF THE COW DURING THE PREVIOUS YEAR AND DURING THE SUCKLING PERIOD ON PREWEANING TRAITS IN THE CALF

by

SOMCHIT YODSERANEE

AN ABSTRACT OF A THESIS

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ABSTRACT

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This study was to estimate and evaluate the environmental factors affecting birth weight, preweaning average daily gain and weaning weight of calves from the control herd of a selection experiment. Environmental factors studied were sex of the calf, age of cow, cow weight at parturition, sire, and year of record of the calf. In addition, cow weight in the previous June, October and December and changes in cow weight from these three different times until parturition were studied for their effects on birth weight of the calf. Cow weight in the previous October, in the June and October following parturition, and changes in body weight from the previous

October until parturition, from parturition to the October following parturition and from June to October following parturition were included to study their effects on preweaning average daily gain and weaning weight of the calf. The effects of birth weight of the calf on preweaning average daily gain and weaning weight of the calf were also examined.

The data, collected from 1961 through 1969, consisted of 456 records of birth weight and 429 records of weaning weight of purebred Shorthorn calves. The calves were the progeny of 129 cows bred repeatedly to six sires over the period of the experiment. Least squares analyses were employed to estimate and evaluate the environmental factors affecting the preweaning traits. In the models, age of cow was divided into five classes (3, 4, 5 to 7, 8 to 10 and 11 to 13 years old). Weights of the cow were classified into six classes (≤899, 900 to 1,009, 1,010 to 1,119, 1,120 to 1,229, 1,230 to 1,339, ≥1,340 pounds). Changes in body weight were also broken into six groups as follows: ≤-50, -49 to 0, 1 to 50, 51 to 100, 101 to 150, ≥151 pounds. Birth weight of the calf was broken into six classes (≤49, 50 to 59, 60 to 69, 70 to 79, 80 to 89, ≥90 pounds). All effects except the effects of sire were considered as fixed variables.

The data were adjusted for sex of calf, age of cow, and year of record and estimates of paternal half-sib heritability and repeatability of the preweaning traits were calculated from the adjusted data. The corrected records were further adjusted for the effects of sires and these adjusted data were used to calculate correlation coefficients among the preweaning traits and between each of these traits and the cow weight at parturition. Coefficients of the regression of preweaning average daily gain and weaning weight on birth weight were also computed from these adjusted data.

Least squares analyses of variance revealed that sex of the calf was the most important source of variation in birth weight, preweaning average daily gain and weaning weight. Males averaged 5 pounds heavier at birth, grew 0.2 pounds more per day from birth to weaning and were 35.10 pounds heavier at weaning than females. The effects of age of cow on preweaning traits of the calf were not significant although the heaviest calves at birth were produced by 5- to 7-year old cows. Their calves also grew most rapidly from birth to weaning and were the heaviest at weaning. Although weights of cow did not influence birth weight, preweaning average daily gain or weaning weight of calves significantly, heavier cows tended to produce heavier calves; the calves grew faster from birth to weaning and were heavier at weaning. Only the cow weight change from the previous June until parturition influenced birth weight significantly ($p<0.01$). Cows losing weight produced heavier calves at birth than did cows which gained weight during the same period. The estimates of paternal half-sib heritability of birth weight, preweaning average daily gain and weaning weight were 0.25 ±0.17, 0.38 ±0.26 and 0.31 ±0.22, respectively. Repeatability estimates of birth weight, preweaning average daily gain and weaning weight were 0.11 ±0.05, 0.27 ±0.05 and 0.27 ±0.05, respectively. Correlation coefficients between birth weight and weaning weight, preweaning average daily gain and cow weight at parturition were 0.47 ±0.04, 0.22 ±0.05 and 0.26 ±0.05, respectively. The correlation coefficient between weaning weight and preweaning average daily gain was 0.83 ±0.03 while that between weaning weight and cow weight at parturition was 0.32 ±0.04 and that between preweaning average daily gain and cow weight at parturition was 0.29 ±0.05. The coeffccients of regression of preweaning average daily gain and of weaning weight on birth weight were 0.006 pounds per day and 2.42 pounds, respectively.

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

Estimation and evaluation of identifiable sources of environmental variation permits the animal breeder to accurately appraise genetic parameters and to formulate optimum breeding plans. The success of these breeding plans depends upon the accuracy with which the data can be adjusted for as many environmental factors as possible.

In beef production, the performance traits which are of greatest importance are reproductive performance, cow productivity, post weaning performance, and carcass merit. Of these traits, cow productivity plays a major role in production efficiency. Preweaning traits which influence cow productivity are birth weight, preweaning average daily gain, and weaning weight of the calf. Preweaning traits are also related to traits associated with post weaning performance such as efficiency of gain, yearling weight and 18 month weight as well as the mature weight of the cow. Superior performance in these preweaning traits is therefore of economic importance to the commercial beef producer. Consequently, it is important to be able to accurately predict the breeding value of heifers to permit selection of superior herd replacements.

Factors which influence preweaning traits in beef cattle are sex of calf, age of cow, birth weight of calf, sire of calf and year of record. There have also been a few reports describing the relationship between preweaning traits and the weight or size of the cow shortly before or immediately after parturition. Most studies have also investigated the influence of cow weight changes during the period from parturition until the calf is weaned, upon preweaning growth rate and weaning weight of the calf. However, there have been no reports on the effects of cow weight changes from one parturition until the next upon the subsequent calf's performance in terms of birth weight, preweaning average daily gain, and weaning weight. Knowledge of these effects on the subsequent calf's performance would help predict the cow's potential productivity earlier and permit earlier and more accurate culling and selection.

The purpose of this thesis is to estimate and evaluate the following:

(1) The effects of sex of calf, age of cow, sire of calf, and year of record on birth weight, preweaning average daily gain, and weaning weight of the calf.

(2) The effects of the weight of the cow at parturition and in the previous June, October, and December on the birth weight of the calf.

(3) The effects of cow weight changes from the previous June until parturition, from the previous

October until parturition and from the previous December until parturition on the birth weight of the calf.

(4) The effects of the weight of the cow in the previous October, at parturition, and in June and October following parturition on preweaning average daily gain and weaning weight of the calf.

(5) The effects of cow weight changes from the previous October until parturition, from parturition until the following October, and from June until October following parturition on preweaning average daily gain and weaning weight of the calf.

(6) The effects of birth weight of the calf on preweaning average daily gain and weaning weight.

(7) The heritability and repeatability of birth weight, preweaning average daily gain, and weaning weight of the calf.

REVIEW OF LITERATURE

Previous studies have shown that birth weight, weaning weight and average daily gain from birth to weaning are related to such post-weaning performance traits as efficiency of gain, yearling weight and 18 months weight (Cartwright and Warwick, 1955; Bogart *et al.*, 1956; Christian *et al.*, 1965; Bogart and Frischnecht, 1967). An increase in birth weight, preweaning gain and weaning weight resulted in an increase in post-weaning performance. Reducing the environmental variation, and adjusting for known environmental effects of preweaning traits should make selection for overall productivity more effective and permit increased genetic improvement.

Factors Influencing Birth Weight

Sex of Calf

Dawson *et al.* (1947) observed a sex difference in birth weight of beef Shorthorns. Male calves were, on the average 4.2 pounds heavier than female calves at birth when birth weights of all calves were corrected to a mature dam basis. Gregory *et al.* (1950) found male calves to be

5.0 and 4.0 pounds heavier than female calves at two different field stations in Nebraska. Botkin and Whatley (1953) reported that bulls were 4.4 pounds heavier than heifers at birth. Koch and Clark (1955) showed a sex difference in birth weight of Hereford calves. Bulls averaged 5.6 pounds more than heifers at birth. Brinks *et al.* (1961) indicated that sex differences in birth weight of grade and purebred Hereford calves were highly significant ($p<0.01$). Males were 5.4 and 5.2 pounds heavier at birth than females of grade and purebred Herefords, respectively. Although the variation in birth weights among bulls was greater ($p<0.05$) than among heifers, birth weights of female calves were 7 percent less than those of males in both grade and purebred herds. Koch *et al.* (1959) evaluated the influence of sex on birth weight and compared two methods of data adjustment (additive vs. multiplicative). They reported that male calves averaged 5.2 pounds or 1.076 times heavier than female calves at birth. The difference in results from using the two methods of adjustment was considered too small to be of practical significance.

As reported by Lasley *et al.* (1961) the average birth weight of 414 Hereford calves was 71.9 pounds with a standard deviation of 8.3 pounds. On the average, bulls weighed 2.5 pounds more than heifers. Kumazaki and Mutsuo (1969a) reported a significant difference in birth weight of Japanese Black calves. On the average, bull calves were 4.26 pounds heavier than heifer calves at birth. Singh *et al.* (1970) reported a highly significant sex ($p<0.01$) difference in birth weight of grade Hereford calves; bulls averaged 4.26 pounds more than heifers. Based on the proportion of total sum of squares, Vesely and Robison (1971) found sex to be the most important source of variation for birth weight of Hereford calves at four North Calorina locations. Males were 4.5 pounds heavier than females.

Age of Cow

Venge (1949) found that age of cow affected birth weight of the calf with the heaviest calves being born to cows from 4 to 6 years of age. In range Hereford cattle birth weight increased with increasing age of cow as reported by Koch and Clark (1955). Maximum production was reached at six years of age and the largest difference in birth weight was between calves from three and four year old cows. The use of appropriate correction factors for cow age 3, 4, and 10 years or older helped to remove most of the variation in birth weight due to the age of cow. Lasley *et al.* (1961) adjusted birth weight of calves to a 6 year old cow basis after finding that age of cow significantly ($p<0.01$) influenced birth weight of calves. Vaccaro and Dillard (1966) reported that older cows were heavier and produced heavier calves at birth than young cows. Calves from 3 year old heifers were on the average ten pounds lighter than those from cows 6 years of age.

The influence of age of cow on birth weight of Japanese calves was significant, as reported by Kumazaki and Mutsuo (1969a). Birth weight of calves increased with cows' age until they were 7 to 10 years of age and thereafter declined slightly. In another study it was found that peak calf weight was reached when the cows were from 6 to 9 years of age and thereafter declined (Kumazaki and Mutsuo, 1969b). Although the effect of age of cow on birth weight of calf was not significant, Singh *et al.* (1970) observed that cows 8 to 11 years old tended to produce the heaviest calves at birth. The lightest calves at birth were produced by 3 year old cows. Ray *et al.* (1970) reported that the cow's age significantly ($p<0.05$) influences birth weight of her calf. Birth weight increased with increasing age of cow with the heaviest calves being produced by cows 5 to 8 years old. Birth weight decreased slightly after that age. Vesely and Robison (1971) indicated that age of cow significantly ($p<0.01$) influenced the birth weight of her calf. Increasing age of cow resulted in increasing birth weight of calf until about the eighth year, thereafter birth weight decreased slightly as the cow aged.

Weight (Size) of Cow and Cow Weight Change

Dawson *et al.* (1947) reported that heavier cows produced heavier calves at birth. The correlation coefficient between the calf's birth weight and the weight of cow at calving was 0.49. Gregory *et al.* (1950) reported that cows heavier than the mean weight at calving tended to give birth to calves that were also heavier than the mean birth weight of all other calves. The correlation coefficient between birth weight of the calf and weight of the cow immediately after calving was 0.21 compared to 0.32 for the correlation coefficient between birth weight of the calf and weight of the cow prior to parturition. Brinks *et al.* (1962) also indicated that heavier cows tended to produce heavier calves at birth. Spring weight of the cows was highly correlated with calf's birth weight. Vaccaro and Dillard (1966) reported a high correlation between birth weight of the calf and the cow's weight 90 days before calving. On the average, each pound increase in the cow's weight resulted in an increase of 0.025 pounds in birth weight of the calf. The effect of both cow's weight 90 days before parturition and her weight change during this period accounted for 8 to 23 percent of the variation in birth weight of the calf. However, most of this effect was due to cow's weight 90 days prepartum. The correlation coefficient between cow's 90 day prepartum weight and the calf's birth weight was 0.32. Singh *et al.*

(1970) found a highly significant ($p<0.01$) effect of cow's weight at parturition on birth weight of the calf. Cows weighing 862 to 963 pounds produced the lightest calves at birth; those weighing 1319 to 1366 pounds at parturition produced the heaviest calves at birth. The correlation coefficient between cow's weight at parturition and birth weight of the calf was 0.26, which was highly significant ($p<0.01$).

Sire of the Calf

Birth weights of calves sired by different bulls were found to be significantly different by Gregory *et al.* (1950). According to Rice *et al.* (1954), the average birth weight of calves sired by eight different bulls varied from 70.0 pounds to 78.3 pounds which was highly significant ($p<0.01$).

After records were adjusted for sex, season and age of dam, Brown and Galvez M. (1969) showed that the sire effect on birth weight of the calf was highly significant ($p<0.01$) and accounted for 20.0 and 9.5 percent of the total variation of birth weight for Hereford and Angus cattle, respectively. Singh *et al.* (1970) reported that the variation due to sire, in birth weight of 619 calves from 13 sires was highly significant ($p<0.01$). Vesely and Robison (1971) analysed data from 1962 Hereford calves, collected from four North Carolina locations and reported that birth weights of calves were significantly different ($p<0.01$) among 49 sire groups.

Year of Record

Dawson *et al.* (1947) corrected birth weight of calves for age of cow and sex of calf and observed no significant difference among birth weights of calves born in different years to the same sires. Burris and Blunn (1952) reported that year of record had no significant effect on birth weight. Year effects did not have any influence on birth weights as indicated by Pahnish *et al.* (1964). Brown and Galvez M. (1969) reported that year effects account for 0.1 and 3.4 percent of the total variation in corrected birth weights for Hereford and Angus, respectively, and were highly significant ($p<0.01$). Singh *et al.* (1970) estimated the effect of year of record on birth weight of calf by least squares procedures and concluded that the year of record had a highly significant ($p<0.01$) effect on birth weight of calf. Vesely and Robison (1971) also reported that year effects on birth weight of calf were highly significant ($p<0.01$), as revealed by the least squares analysis of variance.

Factors Influencing Preweaning Average Daily Gain and Weaning Weight

Sex of Calf

As reported by Rollins and Guilbert (1954) bull calves on the average gained 0.13 pounds per day more than heifer calves from birth to four months of age. However, this difference was not statistically significant. For 240 days weaning weight, bull calves were 68 pounds heavier than heifer calves. The upper and lower limits of the 95 percent confidence interval were 149 and 17 pounds. Marlowe and Gaines (1958) observed that sex of calf influenced preweaning growth rate in both creepfed and non-creepfed groups. Bulls grew faster than heifers. The differences were slightly larger in the creepfed groups. Adjusting to a weaning age of 210 days, bulls were 46 pounds heavier than heifers. Minyard and Dinkel (1960) indicated that sex of calf had a highly significant ($p<0.01$) influence on weaning weight. Males were 34 pounds heavier than females at weaning. Brinks *et al.* (1961) found sex differences in the weaning weight of Hereford calves to be 24.1 pounds in favor of males.

Brown (1960) determined the weights of calves at 60, 120, 180 and 240 days of age by interpolation, using monthly weight and average daily gain during the 30-day interval and reported that at 180 days of age, male calves were 30 ±6 pounds heavier than female calves. Swiger (1961) found that bulls and heifers, respectively grew at different rates up to weaning. The average daily gain from birth to weaning was 1.61 pounds for bulls and 1.46 pounds for heifers. He also observed the regression of weight on age computed from the least squares analysis to be 2.0 pounds per day for the bulls and 1.4 pounds per day for the heifers. He concluded from this study that the bulls grew at a much faster rate immediately prior to weaning than they did earlier. Pahnish *et al.* (1961) adjusted weaning weight of calves to a standard weaning age of 270 days and to a constant age of dam basis and found that bulls were significantly heavier than heifers ($p<0.01$). The sex differences in weaning weight ranged from 44 to 99 pounds.

Studying some nongenetic influences on calf performance in Angus and Hereford cattle, Marlowe *et al.* (1965) reported that non-creepfed bull calves grew 12.6 percent faster than non-creepfed heifer calves. The difference was 15.7 percent in favor of the bulls for the creepfed group. Adjusting to a 210 days weaning weight, non-creepfed bulls were 50 pounds heavier than heifers in the same group. Among the creepfed calves, males were 62 pounds heavier than females at weaning. Cunningham and Henderson (1965) have also stated that bull calves grow faster than heifer calves. The weighted mean for preweaning average daily gain of the males was 0.158 pounds per day higher in Angus and 0.160 pounds per day higher in Hereford than the means for female calves. Cundiff *et al.* (1966) found sex difference in weaning weight of calves. The bulls were 56 pounds heavier than heifers at weaning.

Harwin *et al.* (1966) studied the effect of genetic and environmental interactions on weaning weight of Hereford calves. They reported that during the five most favorable years bull calves averaged 33.6 pounds heavier than heifers, but only 11.2 pounds heavier during the five least favorable years, although the sex x year interaction was not significant.

Recent studies by most researchers reveal that sex of the calf significantly influences preweaning performance. Bulls generally grew faster from birth to weaning and were heavier at weaning than heifers. Kumazaki and Mutsuo (1969a) reported the sex difference in weaning weight of Japanese Black calves. Bulls were 41.34 pounds heavier than heifers at weaning. Ray *et al.* (1970) also found a sex difference in weaning weight of Hereford calves. Bulls were 27.26 pounds heavier than heifers at weaning. Singh *et al.* (1970) reported that sex of the calf significantly influenced preweaning performance of calves in grade Herefords ($p<0.01$). Steers gained 0.105 pounds per day more and were 23.88 pounds heavier at weaning than heifers. Tanner *et al.* (1970) observed significant differences due to sex of the calf for gain from birth to weaning and for 205-day weaning weight. The advantage of bulls over heifers in preweaning average daily gain was 0.16 pounds. The bulls averaged 36.6 pounds heavier than heifers at weaning.

From the study on preweaning traits of 1962 Hereford calves in North Carolina, Vesely and Robison (1971) showed that the effect of sex on weaning weight of calves was highly significant ($p<0.01$). Bull calves averaged 40.3 pounds heavier than heifers at weaning.

Age of Cow

Rollins and Guilbert (1954) observed that young cows and old cows produced calves that grew more slowly to four months of age and were lighter in weight at weaning than calves produced by cows of intermediate ages. On the average, calves from cows 7 to 10 years old exceeded calves from 3, 4 and 12 to 14 year old cows by 21, 13 and 18 pounds, respectively, in weaning weight. Koch and Clark (1955) found differences in weaning weight of range Hereford calves produced by cows of different age groups. The largest change in weaning weight of calves were those produced by cows between the ages of 3 and 4 years. Maximum production of these cows, as expressed by weaning weight, was reached at 6 years of age. After that age weaning weight declined.

Marlowe and Gaines (1958) reported from their study of preweaning growth rate of calves that the most important source of variation in growth rate was attributed to differences in age of cows. The estimates of this effect indicated that maximum production was obtained from cows 6 to 10 years old. The largest difference was between the 2- and 3-year old females. However, these differences decreased with each successive age group until maximum production was reached. Minyard and Dinkel (1960) stated that the influence of age of cow on calf weaning weight was highly significant ($p<0.01$). Eight-year old cows produced the heaviest calves at weaning. Using weight and average daily gain during the 30-day interval from 60 to 240 days of age of calves, Brown (1960) reported that 180-day weight increased with increasing age of cow. The peak production was reached when the cow was 6 years old.

Koger *et al.* (1962) reported the significant effect of age of cow on weaning weight of calf. Calves from cows between 5 and 11 years of age exceeded, in weaning weight, calves from cows 2, 3, 4, and 12 years old and older by 45 to 108, 21 to 567, 7 to 387 and 15 pounds, respectively. Sewall *et al.* (1964) analysed 1066 records of weaning weight of grade Hereford calves and found that age of cow significantly influenced weaning weight. The heaviest calves were weaned from 6 to 10-year old cows. Calves of 8-year old cows averaged 83.1 pounds more when weaned than did those from 2 year old cows. Jamison *et al.* (1965) indicated that calves out of 2, 3 and 4 year old cows showed significantly lower preweaning average daily gain than did those from older females.

As reported by Minyard (1965) differences in weaning weight of the two sexes were slightly greater for 8- to 11-year old cows. Production as expressed by calf weaning weight reached a peak at 8 years of age. Weaning weights were lowest among calves from 2-year old cows and showed the largest change between the ages of 2 and 3 years. Marlowe *et al.* (1965) observed an increase of preweaning calf gain with age of cow from 2 to 7 years. There was no significant difference in gains of calves from 7 through 11-year old cows. Calf gains decreased slightly as cows' age increased beyond 11 years.

Burgess and Bowman (1965) reported that weaning weight of calves from 2-year old and 3-year old cows weighed 34.3 and 13.5 pounds below the overall average, respectively. Weaning weights differed slightly and varied from 2.3 to 5.9 pounds above the population mean as cows varied from 4 years to 8 years of age. Calves from cows 9 years of age and older were the heaviest group and were 14 pounds above the overall average. Cundiff *et al.* (1966) found a difference of 45 pounds in weaning weight of calves produced by 2-year and 3-year old cows in favor of the calves from the latter group. They also pointed out that the effect of age of cow was slightly more curvilinear in males than in females, however, it was essentially the same regardless of sex.

Although the variation of 165 day weaning weight due to different age groups of cows was less than those reported in earlier literature, Hohenboken and Brinks (1969) observed that weaning weight increased with cow's age up to 6 to 8 years old. However, the production of cows 9 years and older did not decline. Kumazaki and Mutsuo (1969a) reported the significant effect of age of cow on weaning weight of Japanese Black calves. Weaning weight increased with age of dam up to 7 to 10 years of age, after which weaning weight of calves slightly declined. From another study (Kumazaki and Mutsuo, 1969b) they reported that maximum production was reached when the cow was 6 to 7 years old. Rhodes *et al.* (1970) stressed the importance of age of cow for its influence on variation in weaning weight of calves. Calves produced by 8- and 9-year old cows were the heaviest. Sellers *et al.* (1970) indicated that within each sex the effect of age of the cow was highly significant ($p<0.005$). Weaning weight increased with increasing age of cows and peak production of cows was estimated to be from 6 to 12 years of age. Singh *et al.* (1970) reported the influence of age of cow on weaning weight and preweaning average daily gain of grade Hereford calves. Both growth rate and weaning weight of calves increased as the age of their dams increased up to 7 years. Thereafter, growth rate and weaning weight decreased slightly. Calves from 5-to 7-year old cows were

22 pounds heavier while those produced by cows 12 years old or more were 37 pounds lighter than the overall average.

Vesely and Robison (1971) reported an increase in weaning weight of calves as the cows' age increased up to and including the eighth year of life. After that age weaning weight declined. Mangus and Brinks (1971) reported that heifers from 2, 3, 4 and 12-year old and older cows had lower weaning weight averages than those from 5 through 11-year old cows.

Weight (Size) of Cow and Cow Weight Change

Gregory *et al.* (1950) reported correlation coefficients for calf gains from birth to weaning with cow gains from calving to weaning to be -0.12 and -0.32 for two experimental stations in Nebraska. The negative correlation between gain of calf from birth to weaning and gain of cow from calving to weaning indicated that cows making smallest gains during the nursing period tended to produce calves that made higher gains. They also observed that the correlation coefficient for weight of the calves at weaning and weight of the cows at weaning was 0.20 for one station and -0.11 for another station.

Brinks *et al.* (1962) observed that cow weight changes over the winter months and during the summer grazing season were correlated more highly with the calf's preweaning gain than with either birth weight or weaning weight. Cows that gained the most (for young cows, 3 to 5 years of age) or lost the least (for older cows, 6 years and older) during the winter months tended to produce faster gaining calves. Conversely, cows that gained the most during the grazing season tended to produce slower gaining calves. Cows gaining the most during the suckling period weaned the lighter calves. However, they noted that heavier cows generally produced heavier calves at weaning. Vaccaro and Dillard (1966) reported the relationship of cow's weight and weight changes to calf's growth rate in Hereford cattle. Heavier cows at 90 days before calving produced the faster gaining calves. They were also heavier at 180 days of age. Among the young cows, those which produced faster gaining calves lost less weight during the period 90 days prepartum and the first 60 days of lactation, but gained weight during the later part of the nursing period. Conversely, older cows which lost less weight during the period 90 days before calving and the first 60 days of the suckling period produced slower gaining calves. Generally, older cows which lost weight during the whole suckling period produced calves which grew faster and were heavier at 180 days of age than comparable young cows.

Nelson and Cartwright (1967) reported that Angus calves from cows averaging 1,276 pounds gained most rapidly whereas, Hereford calves showed highest daily gain from dams averaging 1,344 pounds. They also observed that the relationship between preweaning daily gain and cow weight was more curvilinear among Hereford than among Angus. Godley *et al.* (1970) also found a significant effect of weight of cow at the beginning of the breeding season on preweaning weight per day of age. The weight of Hereford cows was positively correlated with calf weight per day of age at 90, 120, 180 and 210 days. This same relationship was not significant in Angus cattle. Singh *et al*, (1970) reported that the influence of weight of cow at parturition on preweaning daily gain or weaning weight of calf was not significant. However, they stated that calves from cows weighing 1,012 pounds through 1,214 pounds at parturition grew faster than calves from heavier or lighter cows. Weight changes of cows during the nursing period significantly ($p<0.01$) influenced preweaning daily gain and weaning weight of calves. Calves from cows that lost weight during the suckling period grew faster than calves from cows that gained weight during this period. Urick *et al.* (1971) reported that the correlation coefficient between the previous fall weight of cows and 205 days weaning weight of calves was 0.21. This relationship was positive and linear. Weaning weight increased 4.3 pounds for every 102 pounds increase in weight of cows.

Birth Weight of Calf

Gregory *et al.* (1950) reporting work from two

Nebraska stations on birth weight of calves, found simple correlation coefficients of 0.07 and 0.44 for weight gains from birth to weaning. Martin *et al.* (1954) observed within classification correlation coefficient of birth weight with eight week gain to be 0.159 ±0.46. Cartwright and Warwick (1955) reported a value of 0.31 for the correlation coefficient between birth weight and 180-day adjusted weaning weight of calves.

Bogart *et al.* (1956) and Nelms and Bogart (1956) reported that birth weight was related to suckling gain of calf. The correlation coefficient between birth weight and suckling gain was 0.35. They concluded that the difference in suckling gains exhibited by bull and heifer calves was largely due to a difference in birth weight. The males were heavier at birth and maintained this advantage throughout the suckling period. Larger calves at birth gained more rapidly during the nursing period. The regression coefficient for rate of suckling gain on birth weight was 0.0115 pounds per day. Gottlieb *et al.* (1962) found the value of 0.33 and 0.51 for the within year correlation coefficients between birth weight and preweaning average daily gain and birth weight and weaning weight of calves.

Christian *et al.* (1965) found a correlation coefficient of 0.62 between birth weight and weaning weight of calf on a within sex basis. The partial regression of weaning weight on birth weight was highly significant. They concluded that the correlation between birth weight and weaning weight was more than a part-whole relationship. Vaccaro and Dillard (1966) indicated that birth weight had a significant effect on calf's gain during the first 60 days of suckling period. On the average, each pound of weight at birth accounted for 1.9 pounds of total gain from birth to 180 days of age at one station and 0.8 pounds at another station.

Singh *et al.* (1970) reported that birth weight significantly ($p<0.01$) influenced preweaning average daily gain and weaning weight of calves. The regression coefficient of preweaning average daily gain and weaning weight on birth weight were 0.004 pounds per day and 2.01 pounds, respectively. The correlation coefficient between birth weight and weaning weight was 0.12, non-significant. Vesely and Robison (1971) reported the value of 0.42 for the correlation coefficient between birth weight and weaning weight of Hereford calves.

<u>Sire of the Calf</u>

Gregory *et al.* (1950) and Neville (1962) indicated that differences among sires were not significant ($p>0.05$) for gain from birth to weaning. Rice *et al.* (1954) found that sires had a significant effect ($p<0.01$) on weaning weight of calves. The highest difference in weaning weight between sire groups was 42.8 pounds. Shelby *et al.* (1960) reported significant differences for preweaning gain and 180-day weaning weight of calves from sires within lines.

Pahnish *et al.* (1961) observed that sires had a significant effect on weaning weight of both bulls and heifers. However, Pahnish *et al.* (1964) reported that sire effect on weaning weight of bull calves was not significant ($p>0.05$). Minyard and Dinkel (1965) reported a highly significant ($p<0.01$) influence of sire on weaning weight of both Hereford and Angus calves. Bradley *et al.* (1966) indicated that calves sired by a high-gaining sire gained significantly faster during the preweaning period and exhibited significantly heavier weaning weights than calves sired by a low-gaining sire. Analysing the data from calves sired by eight males in a commercial herd, Thrift *et al.* (1970) reported that the sire was a significant source of variation for weaning weight and preweaning gain of calves ($p<0.05$). Tanner *et al.* (1970) stressed the significant effect of sire on preweaning traits of calves. The magnitude of within year sire differences ranged from 29.57 to 47.49 pounds for 205-day weaning weight. Singh *et al.* (1970) also reported a significant ($p<0.01$) effect of sire on preweaning average daily gain and weaning weight of grade Hereford calves.

Year of Record

Shelby *et al.* (1955) discussed the variation of weaning weight of calves caused by year of birth. The differences among years were highly significant ($p<0.01$). Highly significant ($p<0.01$) effects of years on weaning weight have also been reported by Pahnish *et al.* (1964). Sellers *et al.* (1970) studied the environmental effects on weaning weight of Angus and Hereford calves recorded in the Iowa Beef Improvement Association program from 1956 through 1967. They reported that year effects were highly significant ($p<0.005$) within each sex. Also bulls and steers showed much larger variation in the early years than in the later years whereas heifers did not show such difference. Vesely and Robison (1971) pointed out that year was an important source of variation in preweaning growth of calf. They also stressed that this factor was impossible to control and the constant estimate determined in one experiment was irrelevant to another experiment.

Summary

From a review of the literature there is ample evidence showing the effects of various factors upon birth weight, preweaning average daily gain and weaning weight of the calf. The factors which have received most attention have been the sex and sire of the calf, the age of the dam and her body weight and changes in body weight before and after parturition, and the year in which the calf was born. In general, most results are in agreement although some effects such as sire of calf, age of cow, and year of record have not been entirely consistent. In all of the studies reported above the data have been gathered from populations which were under some form of selection. As far as the author is aware, no results have been reported from data obtained from a control or random mating population, free from selection pressure. Such data might be expected to be less biased than data obtained from populations under selection.

The sex of the calf has been shown to be the most important factor affecting the variation in preweaning traits. Bull calves are heavier at birth than heifers, grow more rapidly from birth to weaning, and are heavier at weaning.

Birth weight, preweaning average daily gain, and weaning weight of the calf have been shown to increase with increasing age of the dam until the dam reached 6 to 9 years of age after which there is a decline in all three traits. In some cases, however, there was no apparent decline even after the dams reached 11 years of age.

The body weight of the cow a few months before calving and subsequent changes in her weight have been shown to affect birth weight, preweaning average daily gain, and weaning weight of the calf. In general, the cows which were heavier shortly before or immediately after calving produced heavier calves. Young cows which were still growing lost less weight before calving, whereas, mature cows lost more weight particularly during the first few months of lactation. The effects of the cow's weight change until next parturition upon calf performance in the following preweaning period have not been studied. Only the effects of the cow's weight change during the suckling period on the preweaning average daily gain and weaning weight of the current offspring have been reported.

The influence of the cow's weight change from one parturition until the next upon the performance of the subsequent calf in terms of birth weight, preweaning average daily gain, and weaning weight is worthy of investigation.

MATERIAL AND METHODS

Source of Data

In 1956 the Research Branch of the Canada Department of Agriculture initiated an experiment to explore the rate and duration of response to single trait selection. The project began in the 1957 breeding season on a cooperative basis using straight bred beef Shorthorn cattle at five locations (Brandon and Melita in Manitoba; Indian Head and Scott in Saskatchewan; and Lacombe, Alberta). These herds were related with some degree of inbreeding, particularly at Lacombe. Wide outcrosses using a total of 22 bulls were practiced for two years (calf crops of 1958 and 1959) in an attempt to secure a reasonably broad sampling of the genetic material within the breed. Subsequently the herds were closed in two breeding "units", one comprising Brandon, Melita and Indian Head, the other comprising Scott and Lacombe. In 1960 the Scott herd was transferred to Lacombe and the Melita and Indian Head herds were transferred to Brandon in 1961 and 1965, respectively.

For the 1959 breeding season, the breeding females in each herd were assigned at random within age class to a control or a select line and these lines have been kept distinct since that time.

The data used in this study were obtained over a period of nine years (1961 to 1969, inclusive) from the control line of a selection experiment initiated in 1956. The control line used in conjunction with the selection experiment enables correction for environmental fluctuation or trend so that generic change in the selected population can be estimated.

Data taken from the records of the control line each year were as follows:

(1) birth weight of calf

(2) weaning weight of calf

(3) weight of cow at parturition

(4) weight of cow in June

(5) weight of cow in October

(6) weight of cow in December

A. *Control Line*

This line is composed of six breeding groups each consisting of one sire and 12 to 18 females. The initial control breeding groups established in 1959 are still being maintained and the same sires are still in service so that there were many repeat matings in the line over the years. Every effort has been made to minimize genetic change in this line by the following procedures:

(a) The calf crop of each year was produced by repeat matings and therefore did not change in terms of genetic expectation.

(b) Control females remained in their breeding herds and were bred to the same mates until barren for two consecutive years or culled for pronounced physical unsoundness.

(c) Semen was collected from the control bulls and placed in storage to permit their continued use after the individuals were no longer serviceable.

B. *Select Line*

This line is composed of eleven breeding groups each consisting of one sire and 12 to 18 females. In the select line maximum selection pressure is exerted by the following procedures:

(a) Bulls are replaced annually as yearlings and no mating is made between animals having more than one common grandparent.

(b) Calves chosen for select line replacements are those that obtain the highest yearling weight (unadjusted for age of dam) on a performance test, provided they are considered to be sufficiently sound for breeding use.

(c) Twenty-five percent of cows were replaced annually for the following reasons:

(1) Death or marked physical unsoundness.

(2) Failure to calve in any one year.

(3) Poor life-time production of weaned calf.

(4) Age over nine years.

Herd Management and Collection of Data

Cows with calves at foot were maintained on dry land pastures with creepfeeding provided for calves (no supplemental feed for cows except as necessitated by failure of pasture). They were pasture bred with exposure to breeding limited to six weeks (June 15 to August 1). Calves were born between the third week of March and the first week of May. Within 18 hours after calving, the cow and her calf were individually weighed. At this initial weighing the calf was identified by the use of both eartag and ear tattoo. Cows were weighed again during the period between June 1 and June 10. All calves were weaned when they were 180 ± 3 days old at which time both cow and calf were weighed. The cows were weighed again in December. All bulls were semen tested prior to the breeding season to identify those that produce no or few sperm. All cows were palpated for pregnancy approximately three months after the close of the breeding season.

The data available for the analyses of this study comprised 456 records of birth weight and 429 records of weaning weight of bull and heifer calves from 129 cows. The records of the weight of the cow at parturition, in June, October (weaning) and December were also available with each record of the calf. The records used in this study were collected from 1961 through 1969. Records of birth weight and weaning weight of calves born in 1961 were not used because records of the cows' weights in 1960 were not available. Records of birth weight and weaning weight of five pairs of twins born over this period of time were also discarded.

Analysis of Data

Traits studied were birth weight, average daily gain from birth to weaning and weaning weight. Birth weight, weaning weight and gain from birth to weaning were known for each calf as was age of dam at the time the trait was expressed. Year of record, size of calf, sex, and dam of each calf were also recorded. Cow weight at parturition, in June, October and December prior to parturition were known.

The least squares method, described by Harvey (1960) for multiple classifications with unequal subclass numbers, was used in the analyses of the data. The model included year of record, sire, age of cow, sex of calf, birth weight, weights of cow at four different times, cow weight changes and percent changes in weights during these periods. All variables except sire, were considered fixed. Percent weight changes of the cows were considered independent continuous variables while the others were considered discrete variables.

Records of calves from 2 year old heifers were not used since there were no records available of dams' weights prior to parturition. The youngest age class of the cows in this study is therefore three. To minimize the age classes of the cows so that the least squares computer program could handle the analyses of data, the following age classes were utilized in the grouping of data.

(1) 3 year old cows.

(2) 4 year old cows.

(3) 5, 6, and 7 year old cows.

(4) 8, 9, and 10 year old cows.

(5) 11, 12, and 13 year old cows.

Cows' weights were grouped into six classes with a class interval of 110 pounds. The six weight classes were as follows:

(1) Cows weighing 899 pounds or less.

(2) Cows weighing 900 to 1009 pounds.

(3) Cows weighing 1010 to 1119 pounds.

(4) Cows weighing 1120 to 1229 pounds.

(5) Cows weighing 1230 to 1339 pounds.

(6) Cows weighing 1340 pounds or more.

Cow weight changes were broken into six classes. The first class consisted of all the cows that lost 50 pounds or more in weight. The last class included those which gained 151 pounds or more. The other four classes had a class interval of 50 pounds each. The six classes of cow weight changes were: ≤ -50, -49 to 0, 1 to 50, 51 to 100, 101 to 150 and ≥ 151. Birth weights of calves were grouped into six classes. Any calf weighing 49 pounds or less was classified as class one while the last class consisted of calves weighing 90 pounds or more. The rest were broken into four classes with a class interval of 10 pounds each. These classes were: ≤ 49, 50 to 59, 60 to 69, 70 to 79, 80 to 89 and ≥ 90.

Each observation was assumed to be the sum of the influences of effects of the identifiable variables. This linear combination of effects is referred to hereafter as the mathematical model. Least squares analysis indicated that sire x cow age, cow age x sex, and year x sex interactions were not significant at the 5 percent probability level, and they were dropped from the mathematical models. To obtain the full efficiency of the constants for other sets of effects, all other interactions were assumed non-significant for the variability in preweaning traits studied and were excluded from the mathematical models.

Mathematical Models

(1) For birth weight:

$$Y_{ijklmnqrstu}=U+V_i+S_j+A_k+B_l+P_m+X_n+T_q+Z_r+C_s+H_t+G_u+e_{ijklmnqrstu}$$

where $Y_{ijklmnqrstu}$ is the birth weight of the calf

U is the general mean

V_i is an effect due to the i^{th} year of record (i = 1,2,---,8)

S_j is an effect due to the j^{th} sire of the calf (j = 1,2,---,6)

A_k is an effect due to the k^{th} age class of the cow (k = 1,2,---,5)

B_l is an effect due to the l^{th} sex of the calf (l = 1,2)

P_m is an effect due to the m^{th} weight of the cow at parturition (m = 1,2,---,6)

X_n is an effect due to the n^{th} weight of the cow in the previous June before parturition (n = 1,2,---,6)

T_q is an effect due to the q^{th} weight of the cow in the previous October before parturition (q = 1,2,---,6)

Z_r is an effect due to the r^{th} weight of the cow in the previous December before parturition (r = 1,2,---,6)

C_s is an effect due to the s^{th} weight change of the cow from the previous June to parturition (s = 1,2,---,6)

H_t is an effect due to the t^{th} weight change of the cow from the previous October to parturition ($t = 1,2,---6$)

G_u is an effect due to the u^{th} weight change of the cow from the previous December to parturition ($u = 1,2,---6$)

$e_{ijklmnqrstu}$ is a random effect particular to each individual calf.

(2) For weaning weight:

$$Y_{ijklmnpqrtuv}=U+V_i+S_j+A_k+B_l+P_m+J_n+O_p+T_q+X_r+H_t+Z_u+W_v+e_{ijklmnpqrtuv}$$

where $Y_{ijklmnpqrtuv}$ is the weaning weight of the calf

J_n is an effect due to the n^{th} weight of the cow in June following parturition ($n = 1,2,---6$)

O_p is an effect due to the p^{th} weight of the cow in October following parturition ($p = 1,2,---6$)

X_r is an effect due to the r^{th} weight change of the cow from parturition to October following parturition ($r = 1,2,---6$)

Z_u is an effect due to the u^{th} weight change of the cow from June to October following parturition ($u = 1,2,---6$)

W_v is an effect due to the v^{th} birth weight of the calf ($v = 1,2,---6$)

$e_{ijklmnpqrtuv}$ is a random effect particular to each individual calf.

All other terms are as previously defined.

(3) For preweaning average daily gain:

$$Y_{ijklmnpqrtuv} = U+V_i+S_j+A_k+B_l+P_m+J_n+O_p+T_q+X_r+H_t+Z_u +N_v+b_1D+b_2E+b_3F+e_{ijklmnpqrtuv}$$

where $Y_{ijklmnpqrtuv}$ is the preweaning average daily gain of the calf

b_1 is the regression coefficient of preweaning average daily gain on the percent cow weight change from parturition to October following parturition

D is the percent cow weight change from parturition to October following parturition

b_2 is the regression coefficient of preweaning average daily gain on the percent cow weight change from June to October following parturition

E is the percent cow weight change from June to October following parturition

b_3 is the regression coefficient of preweaning average daily gain on the percent cow weight change from the previous October to parturition

F is the percent cow weight change from the previous October to parturition

$e_{ijklmnpqrtuv}$ is a random effect particular to each individual calf.

All other terms are as previously defined.

All the actual records of birth weight, weaning weight and preweaning average daily gain of the calf were then adjusted for differences due to year of record, age of cow and sex of calf using constant estimates revealed by the least squares analyses. The year of record, age of cow and sex of calf effects were non-random contributions to the temporary environment in which a record was made. Each observation was adjusted by subtracting from it an appropriate linear function of the estimates of these effects. A corrected record would then be:

$$\hat{y} = y - \hat{V}_i - \hat{A}_k - \hat{B}_l$$

where $\hat{y}$ is the adjusted birth weight, weaning weight or preweaning average daily gain

y is the actual birth weight, weaning weight, or preweaning average daily gain

$\hat{V}_i$ is the least squares estimate of the effect of the i^{th} year of record

$\hat{A}_k$ is the least squares estimate of the effect of the k^{th} age of cow

$\hat{B}_l$ is the least squares estimate of the effect of the l^{th} sex of calf.

For example, a male calf weighing 83 pounds at birth and 515 pounds at weaning was born to a 6 year old cow in 1965. His average daily gain from birth to weaning was

2.4 pounds per day. The corrected records for birth weight, preweaning average daily gain and weaning weight of this bull calf would be:

(1) birth weight;

$$\hat{y} = 83 - \hat{V}_4 - \hat{A}_3 - \hat{B}_1$$
$$= 83 - (-1.69) - (1.88) - (2.5)$$
$$= 80.31 \text{ pounds}$$

(2) preweaning average daily gain;

$$\hat{y} = 2.4 - \hat{V}_4 - \hat{A}_3 - \hat{B}_1$$
$$= 2.4 - (0.026) - (0.044) - (0.099)$$
$$= 2.231 \text{ pounds per day}$$

(3) weaning weight;

$$\hat{y} = 515 - \hat{V}_4 - \hat{A}_3 - \hat{B}_1$$
$$= 515 - (5.94) - (7.05) - (17.55)$$
$$= 484.46 \text{ pounds.}$$

For another example, a 3 year old cow gave birth to a female calf in 1968 weighing 65 and 371 pounds at birth and at weaning, respectively. The preweaning average daily gain of this heifer calf was 1.7 pounds per day. The corrected records for birth weight, preweaning average daily gain and weaning weight of the calf would be

(1) birth weight;

$$\hat{y} = 65 - \hat{V}_7 - \hat{A}_1 - \hat{B}_2$$

$= 65 - (0.68) - (0.16) - (-2.5)$

$= 66.66$ pounds

(2) preweaning average daily gain

$\hat{y} = 1.7 - \hat{V}_7 - \hat{A}_1 - \hat{B}_2$

$= 1.7 - (0.08) - (-0.04) - (-0.10)$

$= 1.76$ pounds per day

(3) weaning weight

$\hat{y} = 371 - \hat{V}_7 - \hat{A}_1 - \hat{B}_2$

$= 371 - (14.10) - (-5.35) - (-17.55)$

$= 379.80$ pounds

Least squares estimates of factors affecting birth weight, preweaning average daily gain and weaning weight are listed in Appendix Tables 1D, 2D and 3D, respectively.

Nested analyses of these adjusted data were employed to obtain the variance components between sires, between dams within sires and progeny within dams. Estimates of variance components were computed for birth weight, preweaning average daily gain and weaning weight of calves. The biological models postulated have been previously described. The effects S_i, D_j and W_{ijk} are assumed to be independent random variables with mean zero and variance σ^2_S, σ^2_D and σ^2_W, respectively. The analysis of variance and corresponding expected mean squares based on the biological models are given in Table 1. The analysis of variance of each trait with mean squares and k values are as follows:

Table 1. Analysis of variance and expected mean squares for the three preweaning traits

Source of Variation	Degrees of Freedom	Expected Mean Squares
Between sires	S-1	$\sigma_W^2+k_2\sigma_D^2+k_3\sigma_S^2$
Between dams within sires	D-S	$\sigma_W^2+k_1\sigma_D^2$
Progeny within dams	N-D	σ_W^2

where:

$$k_1 = \frac{N - \sum_i \frac{\sum_j n_{ij}^2}{n_{i.}}}{D-S}$$

$$k_2 = \frac{\sum_i \frac{\sum_j n_{ij}^2}{n_{i.}} - \frac{\sum_i\sum_j n_{ij}^2}{N}}{S-1}$$

$$k_3 = \frac{N - \frac{\sum_i n_{i.}^2}{N}}{S-1}$$

S = number of sires

D = total number of dams

N = total number of progeny

$n_{i.}$ = number of progeny per sire

n_{ij} = number of progeny per dam

σ_W^2 = variance of progeny within dams

σ_D^2 = variance of dam effects

σ_S^2 = variance of sire effects

(1) Birth Weight

Source of Variation	Degrees of Freedom	Mean Square	(k)* Value
S	5	487.3999	$k_2=4.9$, $k_3=75.8$
D	123	94.4959	$k_1=3.5$
W	327	66.3822	

*(k) values are defined in Table 1, along with the analysis of variance.

(2) Preweaning Average Daily Gain

Source of Variation	Degrees of Freedom	Mean Square	k Value
S	5	0.4013	$k_2=4.7$, $k_3=71.2$
D	119	0.0696	$k_1=3.4$
W	304	0.0309	

(3) Weaning Weight

Source of Variation	Degrees of Freedom	Mean Square	k Value
S	5	12969.5977	$k_2=4.7$, $k_3=71.2$
D	119	2665.1428	$k_1=3.4$
W	304	1195.4209	

Paternal half-sib heritability and repeatability estimates of the traits were computed using these variance components as described by Becker (1968). The formulae used to compute the estimates of heritability, repeatability and their standard errors are as follows:

(1) Heritability:

$$h_S^2 = \frac{\frac{4}{(1+F_S)} \cdot \sigma_S^2}{\sigma_S^2 + \sigma_D^2 + \sigma_W^2}$$

where h_S^2 is the estimate of heritability,

F_S is the inbreeding coefficient of the paternal line. The inbreeding coefficient of each animal was not calculated when the program started. Since the same sires were mated to the same cows each year and female replacement was minimized, it can be assumed that the inbreeding coefficient of animals in this line is zero,

σ_S^2 is the variance of sire effects

σ_D^2 is the variance of dam effects

σ_W^2 is the variance of progeny within dams.

$$S\cdot E(h_S^2) = \frac{4\sqrt{\text{var.}(\sigma_S^2)}}{\sigma_S^2 + \sigma_D^2 + \sigma_W^2}$$

where $S\cdot E(h_S^2)$ is the standard error of the estimate of heritability.

$$\text{var.}\ (\sigma_S^2) = \frac{2}{k_3^2}\left(\frac{MS_S^2}{S+1} + \frac{MS_D^2}{D-S+2}\right)$$

(2) Repeatability

$$R = \frac{\sigma_D^2}{\sigma_D^2 + \sigma_W^2}$$

where R is the estimate of repeatability

$$S{\cdot}E(R) = \left(\frac{2(N-1)(1-R)^2[1+(k_1-1)R]^2}{k_1^2(N-D)(D-1)}\right)^{\frac{1}{2}}$$

where S·E(R) is the standard error of the estimate of repeatability.

N is the total number of progeny

D is the total number of dams.

The corrected records, after being adjusted for year of record, age of cow and sex of the calf, were then adjusted for differences caused by sires. Simple correlation analyses were employed to obtain the correlation coefficients among the preweaning traits studied and between each of these traits and the cow weight at parturition.

RESULTS AND DISCUSSION

Means, standard errors and analysis of variance were used in the evaluation of the environmental factors affecting birth weight, preweaning average daily gain and weaning weight of calves. Analyses of variance are given in Tables 2, 3, and 4 for birth weight, preweaning average daily gain and weaning weight, respectively. Means and standard errors are presented in Tables 5, 7 and 8. Estimates of heritability and repeatability for birth weight, preweaning average daily gain and weaning weight are given in Table 12. The simple correlations and regression coefficients among preweaning traits are shown in Table 13.

Factors Influencing Birth Weight

Sex of Calf

The influence of sex of the calf on birth weight was highly significant ($p<0.01$) as shown in Table 2. The average birth weight of the 456 beef Shorthorn calves born in 1962 through 1969 was 69.66 ± 0.75 pounds (Table 5). Bull calves weighed 5.0 pounds on the average more than heifer calves. The results agree well with those reported

Table 2. Least squares analysis of variance for birth weight of the calf.

Source of variation	Degrees of Freedom	Mean Square	F
Sex of calf	1	2490.40	43.25**
Age of cow	4	128.48	2.23
Cow weight at parturition	5	86.51	1.50
Cow weight in the previous June	5	54.61	0.95
Cow weight in the previous October	5	32.49	0.56
Cow weight in the previous December	5	55.63	0.97
[1]Cow weight change 1	5	193.89	3.37**
[2]Cow weight change 2	5	34.71	0.60
[3]Cow weight change 3	5	50.10	0.87
Sire	5	580.49	10.08**
Year of Record	7	51.00	0.89
Error	403	57.59	

[1]Cow weight change 1 - cow weight change from the previous June to parturition.

[2]Cow weight change 2 - cow weight change from the previous October to parturition.

[3]Cow weight change 3 - cow weight change from the previous December to parturition.

**highly significant, $(P<0.01)$.

by Gregory *et al.* (1950), Botkin and Whatley (1953), Koch and Clark (1955), Brinks *et al.* (1961), Singh *et al.* (1970) and Vesely and Robison (1971).

Age of Cow

Although the effect of age of cow on birth weight of the calf was not statistically significant, it approached significance at the five percent level of probability and showed a curvilinear trend. Cows, 5 to 7 years old, produced the heaviest calves at birth (71.54±0.85 pounds); whereas the lightest calves (67.72±1.69 pounds) were those from cows 11 to 13 years of age. Calves from 3, 4 and 8 to 10 year old cows weighed 69.82±1.62, 68.66±1.26 and 70.56±1.03 pounds, respectively. The results agree with the findings of Venge (1949), Koch and Clark (1955), Lasley (1961), Swiger (1961), Vaccaro and Dillard (1966), Kumazaki and Mutsuo (1969a), Singh *et al.* (1970), Vesely and Robison (1971).

Weight (Size) of Cow and Cow Weight Change

The effects of weight of cow at parturition, in the previous June, in the previous October and in the previous December on the birth weight of the calf were not statistically significant (Table 2). Birth weight of the calf did tend to increase, however, as the weight of the cow increased at parturition. The heaviest cows at

Table 3. Least squares analysis of variance for preweaning average daily gain of the calf.

Source of Variation	Degree of Freedom	Mean Square	F
Sex of calf	1	3.31	92.55**
Age of cow	4	0.06	1.62
Cow weight at parturition	5	0.03	0.86
Cow weight in the previous October	5	0.01	0.17
Cow weight in June	5	0.06	1.68
Cow weight in October	5	0.05	1.42
Cow weight change 2	5	0.04	1.26
[1]Cow weight change 4	5	0.05	1.32
[2]Cow weight change 5	5	0.07	1.85
[3]B_1 linear	1	0.00	0.00
[4]B_2 linear	1	0.05	1.31
[5]B_3 linear	1	0.03	0.95
Birth weight of calf	5	0.21	6.01**
Sire	5	0.20	5.46**
Year of record	7	0.22	6.02**
Error	368	0.04	

[1]Cow weight change 4 - Cow weight change from parturition to October.

[2]Cow weight change 5 - Cow weight change from June to October.

[3]B_1 linear - Linear regression coefficient of preweaning average daily gain on percent weight change of the cow from parturition to October.

[4]B_2 linear - Linear regression coefficient of preweaning average daily gain on percent weight change of the cow from June to October.

[5]B_3 linear - Linear regression coefficient of preweaning average daily gain on percent weight change of the cow from the previous October to parturition.

**highly significant, ($P<0.01$)

Table 4. Least squares analysis of variance for weaning weight of the calf.

Source of Variation	Degrees of Freedom	Mean Square	F
Sex of calf	1	103676.94	89.61**
Age of cow	4	1420.41	1.23
Cow weight at parturition	5	661.03	0.57
Cow weight in the previous October	5	109.30	0.09
Cow weight in June	5	2039.21	1.76
Cow weight in October	5	1541.03	1.33
Cow weight change 2	5	1510.47	1.31
Cow weight change 4	5	1554.86	1.34
Cow weight change 5	5	1675.78	1.45
Birth weight of calf	5	21048.84	18.19**
Sire	5	6406.19	5.54**
Year of record	7	7007.31	6.06**
Error	371	1157.04	

**highly significant, ($P < 0.01$)

parturition (1340 pounds and more) produced the heaviest calves at birth (73.63±2.38 pounds) as shown in Table 5. The lightest calves at birth (63.80±2.96 pounds) were produced by the lightest cows (899 pounds and less). These results agree well with those reported in the literature (Dawson *et al.*, 1947; Gregory *et al.*, 1950; Brinks *et al.*, 1962; Singh *et al.*, 1970).

Birth weight of calves tended to decrease as the cows' weight in the previous June increased. The lightest cows (899 pounds and less) produced the heaviest calves (72.92±2.42 pounds), whereas the lightest calves (68.06 ±1.35 pounds) were produced by the cows weighing 1120 to 1229 pounds.

As the cow's weight in the previous October increased, birth weight of calves also increased (Table 5). The lightest cows (899 pounds and less) produced the lightest calves (67.71±2.38 pounds), whereas the heaviest calves (73.38±2.61 pounds) were produced by the heaviest cows (1340 pounds and more). The relationship between the cows' weight in the previous December and birth weight of calves was not consistent. However, the heaviest calves (71.54±1.27 pounds) were born to cows weighing 1010 to 1119 pounds, whereas the heaviest cows (1340 pounds and more) produced the lightest calves (66.58±2.89 pounds).

The effect of the cow weight change from the previous June to parturition on birth weight of the calf

Table 5. Least squares means and standard errors of birth weight according to the factors influencing the trait.

Factor	N	Birth Weight (lbs.)
General mean	456	69.66±0.75
Sex of calf		
Bulls	209	72.16±0.85
Heifers	247	67.16±0.83
Age of cow (yrs.)		
3	57	69.82±1.62
4	66	68.66±1.26
5-7	191	71.54±0.85
8-10	112	70.56±1.03
11-13	30	67.72±1.69
Cow weight at parturition (lbs.)		
≤899	33	63.80±2.96
900 -1009	59	65.97±2.13
1010-1119	96	69.98±1.38
1120-1229	127	71.53±1.02
1230-1339	105	73.04±1.39
≥1340	36	73.63±2.38
Cow weight in the previous June (lbs.)		
≤899	83	72.92±2.42
900 -1009	67	69.70±1.78
1010-1119	101	68.62±1.31
1120-1229	106	68.06±1.35
1230-1339	71	69.45±1.90
≥1340	28	69.20±2.82
Cow weight in the previous October (lbs.)		
≤899	55	67.71±2.38
900 -1009	70	67.88±1.65
1010-1119	104	68.50±1.24
1120-1229	111	69.64±1.33
1230-1339	78	70.85±1.83
≥1340	38	73.38±2.61

Factor	N	Birth Weight (lbs.)
Cow weight in the previous December (lbs.)		
≤899	43	70.34±2.56
900 -1009	55	69.78±1.80
1010-1119	124	71.54±1.27
1120-1229	105	71.19±1.41
1230-1339	91	68.53±1.87
≥1340	38	66.58±2.89
Cow weight change from the previous June to parturition (lbs.)		
≤-50	60	71.05±1.87
-49-0	58	72.86±1.45
1-50	86	71.59±1.13
51-100	93	67.76±1.09
101-150	84	67.02±1.24
≥151	75	67.68±1.60
Cow weight change from the previous October to parturition (lbs.)		
≤-50	108	68.82±1.56
-49-0	65	69.46±1.33
1-50	91	69.08±1.14
51-100	90	70.57±1.25
101-150	35	68.78±1.76
≥151	67	71.25±1.92
Cow weight change from the previous December to parturition (lbs.)		
≤-50	87	70.95±1.40
-49-0	107	70.99±1.10
1-50	119	69.05±1.00
51-100	76	70.07±1.23
101-150	46	69.64±1.58
≥151	21	67.26±2.33

Factors	N	Birth Weight (lbs.)
Sires		
4P	71	73.79±1.19
18P	94	67.65±1.09
106P	82	65.78±1.08
3P	68	67.70±1.21
41N	67	70.32±1.32
11P	74	72.70±1.16
Year of Record		
1962	53	70.04±1.39
1963	57	69.63±1.32
1964	53	70.41±1.36
1965	61	67.97±1.41
1966	58	70.76±1.32
1967	62	70.19±1.31
1968	68	70.34±1.45
1969	44	67.94±1.81

was highly significant ($p<0.01$). The effects of change in cow weight from the previous October and December to parturition on birth weight of the calf were not significant (Table 2).

Cows that lost weight during the period from the previous June to parturition produced heavier calves at birth than cows that gained weight during the same period (Table 5). Cows losing up to 49 pounds in weight produced the heaviest calves at birth (72.86±1.45 pounds), whereas the lightest calves (67.02±1.24 pounds) were produced by cows that gained 101 through 150 pounds in weight during the same period. As shown in Table 6 the majority of the cows that lost weight during the period from the previous June to parturition were in the age groups of 5 to 7, 8 to 10 and 11 to 13 years. Out of the total cows of each age class, 26 percent, 39 percent and 50 percent of the cows in the age classes 5 to 7, 8 to 10 and 11 to 13 years of age, respectively, lost weight during the period from the previous June to parturition; whereas only 5 percent and 9 percent of the cows in the age classes of 3 and 4, respectively, lost weight during the same period. The mature cows may have lost weight as a result of heavier milk production during the suckling period and were not able to recover this loss before parturition in the following year.

Table 6. Numbers of cows by age classes in each class of cow weight change from the previous June until parturition.

Cow Weight Change (lbs.)	Age of the Cows (yrs.)					
	3	4	5-7	8-10	11-13	Total
<-50	-	2	23	24	11	60
-49-0	3	4	27	20	4	58
1-50	7	10	32	25	12	86
51-100	6	15	48	21	3	93
101-150	27	13	29	15	-	84
≥151	14	22	32	7	-	75
Total	57	66	191	112	30	456

Sire of the Calf

The variation among the birth weights of calves from the six sires in this study (Table 2) was found to be highly significant ($p<0.01$). While sire 4P produced the heaviest calves at birth (73.79±1.19 pounds), sire 106P produced the lightest ones (65.78±1.08 pounds) as shown in Table 5. Gregory *et al.* (1950), Brown and Galvez M. (1969), Singh *et al.* (1970), Vesely and Robison (1971) all found significant effects of sire on birth weight of calves.

Year of Record

Although the effects of year of record on birth weight of calves born in 1962 through 1969 were not statistically significant (Table 2), calves born in 1966 were the heaviest at birth (70.76±1.32 pounds) whereas calves born in 1969 were the lightest ones (67.94±1.81 pounds) as shown in Table 5.

Factors Influencing Preweaning Average Daily Gain

The least squares mean of daily gain from birth to weaning of 429 beef Shorthorn calves was 1.83±0.03 pounds per day (Table 7).

Table 7. Least squares means and standard errors of preweaning average daily gain according to the factors influencing the trait.

Factor	N	Preweaning Average Daily Gain (lbs.)
General mean	429	1.83±0.03
Sex of calf		
Bulls	192	1.93±0.04
Heifers	237	1.73±0.04
Age of cow (yrs.)		
3	55	1.80±0.05
4	63	1.84±0.04
5-7	182	1.88±0.04
8-10	102	1.84±0.04
11-13	27	1.81±0.05
Cow weight in the previous October (lbs.)		
≤899	52	1.83±0.06
900 -1009	65	1.84±0.05
1010-1119	98	1.85±0.04
1120-1229	105	1.83±0.04
1230-1339	75	1.82±0.05
≥1340	34	1.84±0.08
Cow weight at parturition (lbs.)		
≤899	27	1.81±0.09
900 -1009	57	1.79±0.06
1010-1119	88	1.84±0.04
1120-1229	121	1.84±0.04
1230-1339	102	1.89±0.05
≥1340	34	1.84±0.07
Cow weight in June (lbs.)		
≤899	54	1.85±0.07
900 -1009	68	1.80±0.05
1010-1119	109	1.79±0.04
1120-1229	113	1.86±0.05
1230-1339	64	1.90±0.06
≥1340	21	1.80±0.08

Factor	N	Preweaning Average Daily Gain (lbs.)
Cow weight in October (lbs.)		
<899	27	1.76±0.08
900 -1009	46	1.83±0.06
1010-1119	99	1.84±0.04
1120-1229	137	1.84±0.04
1230-1339	81	1.81±0.05
>1340	39	1.92±0.07
Cow weight change from the previous October to parturition (lbs.)		
≤-50	91	1.86±0.07
49-0	64	1.87±0.06
1-50	87	1.78±0.05
51-100	89	1.86±0.05
101-150	36	1.83±0.06
≥151	62	1.82±0.07
Cow weight change from parturition to October (lbs.)		
≤-50	148	1.88±0.05
49-0	77	1.87±0.04
1-50	69	1.86±0.06
51-100	63	1.88±0.06
101-150	26	1.75±0.07
≥151	46	1.75±0.07
Cow weight change from June to October (lbs.)		
≤- 50	42	1.71±0.07
49-0	68	1.77±0.06
1-50	113	1.86±0.04
51-100	100	1.85±0.04
101-150	68	1.86±0.05
≥151	38	1.97±0.06
Birth weight of calf (lbs.)		
≤49	4	1.72±0.10
50-59	25	1.70±0.05
60-69	130	1.86±0.03
70-79	189	1.90±0.03
80-89	75	1.95±0.03
≥90	6	1.87±0.09

Factor	N	Preweaning Average Daily Gain (lbs.)
Sires		
4P	66	1.80±0.04
18P	90	1.90±0.04
106P	79	1.88±0.04
3P	63	1.80±0.04
41N	60	1.74±0.04
11P	71	1.89±0.04
Year of Record		
1962	54	1.83±0.05
1963	55	1.81±0.05
1964	53	1.89±0.05
1965	57	1.86±0.05
1966	54	1.89±0.05
1967	60	1.72±0.05
1968	59	1.92±0.05
1969	37	1.75±0.05

Sex of Calf

Based on the size of the mean squares as shown in Table 3, sex is the most important source of variation in preweaning average daily gain of calves. Bull calves grew 0.20 pounds per day faster than heifer calves (Table 7). Since the correlation coefficient between birth weight and preweaning average daily gain is 0.22, as given in Table 13, the data suggest that bulls grew faster than heifers partly due to the heavier birth weight of the bulls.

The value 0.20 pounds per day for the difference in preweaning growth rate between bulls and heifers, found in the current study, is larger than the values reported in the literature which vary from 0.11 to 0.16 (Brinks, 1961; Swiger, 1961; Cunningham and Henderson, 1965; Tanner *et al.*, 1970). In the current study the calves were provided with creepfeed, whereas in the other results cited creepfeeding was not provided to the calves. Marlowe and Gaines (1958) pointed out that the sex difference for preweaning growth rate of calves in the creepfed group was larger than the difference in the non-creepfed group and creepfeeding appeared to increase growth rate of calves approximately 0.1 pounds per day.

Age of Cow

The influence of age of cows on growth rate of calves from birth to weaning was not statistically significant

(Table 3). However, preweaning average daily gain of calves increased curvilinearly as cow age increased (Table 7). Calves from cows 5 to 7 years old showed the fastest growth rate from birth to weaning (1.88 ±0.04 pounds per day), whereas 3 year old cows produced the slowest gaining calves (1.80 ±0.05 pounds per day). Calves from 4, 8 to 10, and 11 to 13 year old cows grew 1.84 ±0.04, 1.84 ±0.04 and 1.81 ±0.05 pounds per day from birth to weaning, respectively. The result is similar to the finding of Singh *et al.* (1970) and agrees with others reported in the literature (Rollins and Guilbert, 1954; Marlowe and Gaines, 1958; Marlowe *et al.*, 1964). Christian *et al.* (1965) indicated that milk and butterfat production of the cows influenced growth rate of creepfed calves from birth to 60 days of age significantly but failed to exert its influence beyond this age. They pointed out that gains of calves having access to creepfeed might be no longer influenced by the dams' milk production.

Weight (Size) of Cow and Cow Weight Change

The effects of weight of cows in the previous October, at parturition, and in the June and October following parturition, on preweaning average daily gain of calves were not statistically significant (Table 3). However, cows weighing 1,010 through 1,119 pounds in the previous October produced calves with the highest preweaning average daily gain (1.85 ±0.04 pounds per day) whereas the slowest gaining calves (1.82 ±0.05 pounds per day) were from cows weighing 1,230 to 1,339 pounds. At parturition and in June cows weighing 1,230 through 1,339 pounds produced the fastest gaining calves during the suckling period, (1.89 ±0.05 and 1.90 ±0.06 pounds per day), whereas cows weighing 900 to 1,009 and 1,010 to 1,119 pounds at parturition and in June, respectively, produced the slowest gaining calves (1.79 ±0.06 and 1.79 ±0.04 pounds per day). In October, the heaviest cows (1,340 pounds and more) produced calves that showed the highest growth rate from birth to weaning (1.92 ±0.07 pounds per day) while the smallest cows (899 pounds and less) produced the slowest gaining calves (1.76 ±0.08 pounds per day) as shown in Table 7. Previous workers have reported that heavier cows produced faster gaining calves (Gregory *et al.*, 1950: Brinks *et al.*, 1962; Vaccaro and Dillard, 1966; Nelson and Cartwright, 1967; Singh *et al.*, 1970).

The effects of the cow weight changes during the period from the previous October to parturition, from parturition to October and from June to October on preweaning average daily gain of calves were not significant (Table 3). Except for the calves from cows gaining 51 to 100 pounds in weight, calves from cows losing weight both during the period from the previous October to parturition and from parturition to October grew faster from birth to weaning than calves from cows which gained weight during the same periods (Table 7). The data suggest that good milking cows produced milk heavily to nurse their calves and lost much weight during the suckling period so that they could not recover this loss before parturition in the following year.

During the period from June to October preweaning average daily gain of calves increased as cows gained weight (Table 7). Calves from cows which gained the most (151 pounds or more) during this period, showed the highest preweaning average daily gain (1.97 ±0.06 pounds per day), whereas, cows which lost most weight (50 pounds and more) produced the slowest gaining calves (1.71 ±0.07 pounds per day). The result agrees with the findings of Brinks *et al.* (1962) and Vaccaro and Dillard (1966). The data suggest that cows with faster gaining calves tended to gain weight during the latter part of lactation. While some of these cows could not recover the loss the others could and gained 51 to 100 pounds either during the suckling period or during the period from weaning to parturition in the following year. The distributions of cows by age classes and the cow weight changes are presented in Tables 9, 10 and 11 for the period from the previous October to parturition, from parturition to October and from June to October, respectively.

Birth Weight of Calf

The influence of birth weight on preweaning average daily gain of calves is highly significant ($p<0.01$) as shown in Table 3. Except for the calves weighing 50 through 59 pounds at birth, preweaning growth rate increased as birth weight of calves increased up to 89 pounds and declined thereafter (Table 7). As shown in Table 13, the correlation coefficient between preweaning average daily gain and birth weight of the calf is 0.22 which is highly significant ($p<0.01$). The regression coefficient of preweaning average daily gain on birth weight of the calf found in the current study is 0.006 pounds per day. The results agree with those reported in the literature (Gregory *et al.*, 1950; Bogart *et al.*, 1956; Nelms and Bogart, 1956; Gottleib *et al.*, 1962; Vaccaro and Dillard, 1966; Singh *et al.*, 1970).

Sire of the Calf

Sires significantly ($p<0.01$) influenced preweaning average daily gain of calves. The means and standard errors of preweaning average daily gain of calves according to sires are presented in Table 7. Calves from sire 18P grew the most rapidly (1.90 ±0.04 pounds per day) from birth to weaning, whereas, calves from sire 41N showed the slowest gain (1.74 ±0.04 pounds per day).

Year of Record

The influence of year of record on preweaning growth rate of calves is highly significant ($p<0.01$) as shown in Table 3. The means and standard errors of preweaning average daily gain of calves according to year of record are presented in Table 7. Calves born in 1968 grew the most rapidly from birth to weaning (1.92 ±0.05)pounds per day). The slowest gaining calves (1.72 ±0.05 pounds per day) were those born in 1967.

Factors Influencing Weaning Weight

The least squares mean for weaning weight of 429 beef Shorthorn calves was 399.14 ±5.40 pounds, presented in Table 8.

Sex of Calf

As with preweaning growth rate, sex was the most important source of variation in weaning weight of calves (Table 4). Bull calves were 35.1 pounds heavier than heifer calves at weaning (Table 8). The result falls in the range of those reported in the literature which are 22.4 to 68 pounds (Rollins and Guilbert, 1954; Marlowe and Gaines, 1958; Brown, 1960; Minyard and Dinkel, 1960; Brinks *et al.*, 1961; Cundiff *et al.*, 1966; Kumazaki and Mutsuo, 1969a; Urick *et al.*, 1971; Vesely and Robison, 1971).

Table 8. Least squares means and standard errors of weaning weight according to the factors influencing the trait.

Factor	N	Weaning Weight (lbs.)
General mean	429	399.14±5.40
Sex of calf		
Bulls	192	416.68±5.76
Heifers	237	381.58±5.65
Age of cow (yrs.)		
3	55	393.79±7.97
4	63	398.82±7.01
5-7	182	406.19±5.96
8-10	102	399.39±6.64
11-13	27	397.49±8.90
Cow weight in the previous October (lbs.)		
≤899	52	397.01±10.98
900 -1009	65	401.32±7.78
1010-1119	98	401.17±6.34
1120-1229	105	399.44±7.34
1230-1339	75	397.78±9.30
≥1340	34	398.10±13.61
Cow weight at parturition (lbs.)		
≤899	27	392.20±14.79
900-1009	57	391.05±9.97
1010-1119	88	399.29±7.23
1120-1229	121	400.48±6.70
1230-1339	102	408.62±8.82
≥1340	34	403.18±12.41
Cow weight in June (lbs.)		
≤899	54	403.69±12.31
900-1009	68	394.06±8.59
1010-1119	109	391.93±7.55
1120-1229	113	403.56±7.51
1230-1339	64	410.44±9.92
≥1340	21	391.14±13.88

Factor	N	Weaning Weight (lbs.)
Cow weight in October (lbs.)		
≤899	27	389.02±13.82
900-1009	46	397.78±10.20
1010-1119	99	399.15±7.33
1120-1229	137	398.80±6.53
1230-1339	81	394.29±8.01
≥1340	39	415.77±11.00
Cow weight change from the previous October to parturition (lbs.)		
≤-50	91	395.02±7.41
49-0	64	395.79±6.44
1-50	87	392.79±6.02
51-100	89	406.90±6.79
101-150	36	403.81±9.26
≥151	62	400.50±10.34
Cow weight change from parturition to October (lbs.)		
≤-50	148	406.69±7.43
49-0	77	406.02±6.58
1-50	69	402.54±6.58
51-100	63	406.61±7.23
101-150	26	383.24±10.08
≥151	46	389.72±11.55
Cow weight change from June to October (lbs.)		
≤-50	42	385.95±9.52
49-0	68	394.13±7.38
1-50	113	399.49±6.35
51-100	100	397.34±6.68
101-150	68	400.22±7.05
≥151	38	417.68±9.74

Factor	N	Weaning Weight (lbs.)
Birth weight of calf (lbs.)		
≤ 49	4	345.46±17.97
50-59	25	361.16±8.12
60-69	130	399.73±4.69
70-79	189	416.54±4.50
80-89	75	436.34±5.50
≥ 90	6	435.59±15.32
Sires		
4P	66	391.99±6.86
18P	90	411.26±6.67
106P	79	408.04±6.61
3P	63	394.12±7.13
41N	60	381.36±6.91
11P	71	408.05±6.73
Year of Record		
1962	54	400.53±7.72
1963	55	395.46±7.36
1964	53	408.30±7.72
1965	57	405.08±7.48
1966	54	410.36±7.80
1967	60	378.99±8.06
1968	59	413.24±8.24
1969	37	381.13±9.16

Age of Cow

Although the effects of age of cows on weaning weights of calves were not significant, weaning weights increased as cow age increased up to 5 to 7 years of age and declined thereafter. Analysis of variance for weaning weight is given in Table 4, whereas the least squares means of weaning weight according to age classes of the cows are presented in Table 8. Since gains of calves from birth to weaning in the current study were not influenced by age of cows, it is logical to expect a lack of significance for the influence of age of cow on weaning weight of calves. The result agrees with those reported by Koch and Clark, 1955; Minyard and Dinkel, 1960; Marlowe *et al.*, 1965; Kumazaki and Mutsuo, 1969; Singh *et al.*, 1970; Vesely and Robison, 1971.

Weight (Size) of Cow and Cow Weight Change

The effects of weight of cows in the previous October, at parturition, in June and in October following parturition on weaning weight of calves are not statistically significant (Table 4). However, heavier cows tended to produce heavier calves at weaning (Table 8). Cows weighing 900 through 1,009 pounds in the previous October produced the heaviest calves at weaning (401.32 ±7.78 pounds). Both at parturition and in June, cows weighing 1,230 through 1,339 pounds produce the heaviest calves at weaning

(408.62 ±8.82 and 410.44 ±9.92 pounds). The heaviest cows in October (1,340 pounds and more) weaned the heaviest calves (415.77 ±11.00 pounds). Previous studies have indicated that heavier cows tended to produce heavier calves at weaning (Gregory *et al.*, 1950; Vaccaro and Dillard, 1966; Singh *et al.*, 1970).

The effects of the cows' weight changes during the periods from the previous October to parturition, from parturition to October and from June to October, on weaning weight of calves, as given in Table 4 are not statistically significant. However, cows which gained 51 through 100 pounds in weight during the period from the previous October to parturition, weaned the heaviest calves (406.90 ± 6.79 pounds). Except for weaning weights of calves from cows gaining 51 through 100 pounds in weight, weaning weights of calves from cows which lost weight during the period from parturition to October were higher than those of calves from cows which gained weight during the same period (Table 8). The results agree with the findings of Brinks *et al.* (1962) and Singh *et al.* (1970).

As presented in Table 8, weaning weight of calves increased as cows gained weight during the period from June to October. Cows which gained the most (151 pounds and more) from June to October weaned the heaviest calves (417.68 ±9.74 pounds). Since preweaning average daily gain of calves increased as the cows gained weight during

Table 9. Percent of cows which lost or gained weight during the period from the previous October to parturition.

Cow Weight Change	Age of Cows (yrs.)				
	3	4	5-7	8-10	11-13
Lost Weight	21.82	23.81	30.22	51.96	74.16
Gained Weight	78.18	76.19	69.78	48.04	25.90

Table 10. Percent of cows which lost or gained weight during the period from parturition to October.

Cow Weight Change	Age of Cows (yrs.)				
	3	4	5-7	8-10	11-13
Lost Weight	32.73	38.95	60.44	63.73	29.63
Gained Weight	67.27	61.05	39.56	36.27	70.36

Table 11. Percent of cows which lost or gained weight during the period from June to October.

Cow Weight Change	Age of Cows (yrs.)				
	3	4	5-7	8-10	11-13
Lost Weight	12.73	23.81	30.22	27.45	18.52
Gained Weight	87.27	76.19	69.78	72.55	81.48

the period from June to October and cows which gained the most during this period produced calves which showed the highest preweaning growth rate, it is logical to expect the heavier calves at weaning produced by cows which gained weight from June to October.

Birth Weight of Calf

Birth weight significantly ($p < 0.01$) influenced weaning weight of calves (Table 4). Weaning weight increased with increasing birth weight. Calves weighing 80 to 89 pounds at birth were the heaviest at weaning. Weaning weight declined when calves weighed 90 pounds and more at birth (Table 8). The correlation coefficient between birth weight and weaning weight of calbes was found to be 0.47 ±0.04 which is highly significant (Table 13). The regression coefficient of weaning weight on birth weight of calves was 2.42 pounds. The estimates agree with those reported in the literature (Cartwright and Warwick, 1955; Gottlieb *et al.*, 1962; Christian *et al.*, 1965; Singh *et al.*, 1970; Vesely and Robison, 1971).

Sire of the Calf

Sires significantly ($p < 0.01$) influenced weaning weight of calves (Table 4). The mean and standard error of weaning weight according to sires are presented in Table 8. Calves from sire 18P were the heaviest at weaning (411.26 ±6.67 pounds), whereas, sire 41N produced the lightest calves (381.36 ±6.91 pounds).

Year of Record

The influence of year of record on weaning weight of calves, as presented in Table 4, is highly significant ($p<0.01$). Calves born in 1968 were the heaviest (413 ±8.24 pounds), whereas, calves born in 1967 were the lightest at weaning (378.99 ±8.06 pounds) as shown in Table 8.

Heritability and Repeatability Estimates

Heritability

Paternal half-sib heritability estimates and standard errors, shown in Table 12 for birth weight, preweaning average daily gain and weaning weight of calves are 0.25 ±0.17, 0.38 ±0.26 and 0.31 ±0.22, respectively. Previous estimates of heritability of birth weight in beef cattle reported in the literature have been in the intermediate range (0.20-0.4) although some workers reported the trait to be highly heritable (Swiger, 1961; Swiger *et al.*, 1962; Brinks *et al.*, 1964; Lombard, 1964; Brown and Galvez M., 1969; Vesely and Robison, 1971).

The estimate of 0.38 for the heritability of preweaning average daily gain of calves in the current study is similar to the finding of Marlowe and Vogt (1965) and

Table 12. Paternal half-sib heritability and repeatability estimates of birth weight, preweaning average daily gain and weaning weight.

Trait	Heritability	Repeatability
Birth Weight	0.25±0.17	0.11±0.05
Preweaning Average Daily Gain	0.38±0.26	0.27±0.05
Weaning Weight	0.31±0.22	0.27±0.05

close to the value of 0.39 reported by Loganathan *et al.* (1965) for the same trait. The estimate found in the current study is higher than some from previous studies which have reported estimates of heritability of preweaning average daily gain from -0.02 to 0.22 (Lehmann *et al.*, 1961; Swiger *et al.*, 1962; Brinks *et al.*, 1964; Lombard, 1964). Creepfed calves with a high potential growth rate in the current study might have had a greater chance to express their genetic ability to grow during the suckling period than calves in the non-creepfed groups from other studies. This resulting higher variation in growth rate among creepfed calves in the current study might have caused the sire component of variance to be larger and therefore resulted in the higher estimates of heritabilities of both preweaning average daily gain and weaning weight of calves than the estimates computed from the non-creepfed calves. Martin *et al.* (1970) reported the value of 0.78 for the heritability of weaning weight of creepfed calves, whereas it was only 0.41 for the estimate among the non-creepfed group. Willham (1970) reported the value of 0.25 and 0.27 for the estimates of heritability of weaning weight of creepfed and non-creepfed calves, respectively. However, this difference was not significant.

In general, heritability estimates of weaning weight of beef calves have been in the range of 0.18 and 0.50 with the majority of the reports giving heritability estimates of approximately 0.30 (Minyard and Dinkel, 1960; Pahnish *et al.*, 1961; Gottlieb *et al.*, 1962; Sewell *et al.*, 1964; Minyard and Dinkel, 1965; Vesely and Robison, 1971). The estimate of 0.31 for the heritability of weaning weight found in the current study agrees well with those reported, but is somewhat higher than the estimates found in range calves which are 0.25 (Swiger, 1961), 0.27 and 0.25 (Willham, 1970), 0.24 (Hohenboken and Brinks, 1971).

Repeatability

The estimates of repeatability computed from intra-class correlation were 0.11 ±0.05, 0.27 ±0.05 and 0.27 ±0.05 for birth weight, preweaning average daily gain and weaning weight of calves, respectively. All the estimates of repeatability of the preweaning traits studied are lower than the estimates of heritability of the corresponding trait.

Cunningham and Henderson (1965), Gregory *et al.* (1950) and Koch and Clark (1955) have all documented the tendency for repeatability of weaning weight based on the likeness of adjacent records to be higher than repeatability based on the likeness of non-adjacent records. A correlation of 0.48 between adjacent records of weaning weight was reported by Cunningham and Henderson (1965). For non-adjacent with four intervening records the correlation between them was only 0.15. Records even further apart in time were not essentially correlated. Repeatability in the current study was interpreted as the correlation of all the calves from a cow. The numbers of records per cow varied from one to eight. The method of computation was therefore probably responsible for the fact that the estimate was lower than those calculated from the adjacent records. The probable cause of the low estimate of repeatability of weaning weight as explained above might also explain the low estimates of repeatability of birth weight and preweaning average daily gain of calves in the current study.

Repeatability estimates of birth weight ranging from 0.06 to 0.29 with an average of 0.18 were reported by Taylor *et al.* (1960). Botkin and Whatley (1953) reported an estimate of 0.18 for the repeatability of birth weight in Hereford calves.

Some of the previous estimates of repeatability of weaning weight reported are 0.32 to 0.53 (Hoover *et al.*, 1956; Minyard and Dinkel, 1965; Sewell *et al.*, 1964; Martin *et al.*, 1970). The estimate of 0.27 found in the current study is similar to the finding of Hohenboken and Brinks (1969) who calculated repeatability of weaning weight from non-adjacent and randomly chosen records. Previous estimates of repeatability of preweaning average daily gain have been reported to be 0.30 (Taylor *et al.*, 1957), 0.39 (Loganathan *et al.*, 1965) higher than the estimate of 0.27

found in the current study.

Table 13. Simple correlation and regression coefficients among the preweaning traits.

Trait	Weaning Weight	Preweaning Average Daily Gain	Cow Weight at Parturition
Birth Weight	0.47*±0.05	0.22*±0.05	0.26*±0.05
Weaning Weight		0.83*±0.03	0.32*±0.04
Preweaning Average Daily Gain			0.29*±0.05

b_1 = 0.006 pounds per day

b_2 = 2.42 pounds

b_1 - regression coefficient of preweaning average daily gain on birth weight.

b_2 - regression coefficient of weaning weight on birth weight.

*highly significant, $(p<0.01)$

SUMMARY AND CONCLUSIONS

Environmental influences on the birth weight, preweaning average daily gain and weaning weight of purebred Shorthorn calves were studied by analysing the data from 456 records of birth weight and 429 records of weaning weight. The data were collected from 1961 until 1969 from the control herd of a selection experiment. All calves were born during a restricted period in spring and weaned at the age of 180±3 days in October. Sex of the calf, age, weight and weight changes of the cow, sire of the calf and year of record were the factors studied for their influences on the preweaning traits of the calf. Birth weight of the calf was also included to examine the environmental factors influencing preweaning growth rate and weaning weight of the calf. Means and standard errors were 69.66 ±0.75, 399.14 ±5.40 pounds and 1.83 ±0.03 pounds per day for birth weight, weaning weight and preweaning average daily gain, respectively. Bulls were significantly ($p<0.01$) heavier than heifers at birth, grew faster from birth to weaning and were heavier at weaning. Sex differences for birth weight, weaning weight, preweaning average daily gain were 5.00, 35.10 pounds and

0.2 pounds per day, respectively.

Birth weight, preweaning average daily gain and weaning weight of calves increased with increasing age of cows. Maximum production was reached when cows were 5 to 7 years old. Heavier cows tended to produce heavier calves at birth, the calves grew faster and were heavier at weaning than those from lighter cows. Calves from cows weighing 1230 through 1340 pounds and more were heavier at birth, grew faster to weaning and were heavier at weaning than calves from lighter cows. However, the effects of age and weight of cows on birth weight, preweaning average daily gain and weaning weight of calves were not statistically significant. Except for the effect of cow weight change from the previous June to parturition on birth weight, all the effects of cow weight changes before and after parturition on preweaning traits studied were not significant. Calves from cows losing weight during the period from the previous June to parturition were heavier at birth than those from cows gaining weight during the same period. Cows that lost weight during the period from the previous October to parturition or lost weight during the period from parturition to the following October produced calves which grew faster from birth to weaning than calves from cows which gained weight during these two periods. Cows gaining 51 to 100 pounds in weight during the period from the previous October to parturition weaned the heaviest calves. During the period from parturition to October, cows losing weight weaned the heaviest calves.

Birth weight significantly ($p<0.01$) influenced both preweaning average daily gain and weaning weight of calves. Calves with heavier birth weight grew faster during the suckling period and were heavier at weaning than calves lighter at birth. Calves weighing 80 through 89 pounds at birth grew faster during the suckling period and were heavier at weaning than did lighter or heavier calves.

The effects of sire on birth weight, preweaning average daily gain and weaning weight were highly significant ($p<0.01$). Except for birth weight, the effects of year of record on preweaning traits studied were also highly significant ($p<0.01$).

Correlation coefficients between birth weight and weaning weight, birth weight and preweaning average daily gain and birth weight and weight of the cow at parturition were 0.47 ±0.04, 0.22 ±0.05, and 0.26 ±0.05, respectively. The correlation coefficients between weaning weight and preweaning average daily gain, weaning weight and cow weight at parturition, preweaning average daily gain and cow weight at parturition were 0.83 ±0.03, 0.32 ±0.04 and 0.29 ±0.05, respectively. Coefficients of regression of preweaning average daily gain and weaning weight on birth weight of calves were 0.006 pounds per day and 2.42 pounds, respectively.

Paternal half-sib heritability estimates of birth weight, preweaning average daily gain and weaning weight of beef calves were 0.25 ±0.17, 0.38 ±0.26 and 0.31 ±0.22. The estimates of repeatability of birth weight, preweaning average daily gain and weaning weight of beef calves are 0.11 ±0.05, 0.27 ±0.05 and 0.27 ±0.05, respectively.

In conclusion, it is evident that selection for heavier birth weight will result in an increase in cow productivity in terms of preweaning average daily gain and weaning weight of the calf. However, it would probably be inefficient to expend selection pressure on birth weight. Higher birth weight, if desired, can be achieved more easily through the use of crossbred cows or exotic breeds in a crossbreeding program. High birth weight may not even be desirable, however. It is now well established that the frequency of calving problems increases with increasing birth weight.

The effects of cow weight changes on preweaning traits of the calf are not completely clear. There is some indication, however, that those cows with a weight at parturition of 1230-1339 pounds, although not producing calves with the largest birth weights, did produce those with the fastest preweaning average daily gain and the largest weaning weights. Also those cows that gained weights during the latter part of lactation produced the fastest gaining calves.

It would seem from the present study that what is needed for good cow productivity is a cow that weighs between 1230 and 1339 pounds at parturition, milks heavily during the early part of lactation and then, in spite of good milk yields, is able to gain weight during the latter part of lactation. Both age and milk production of the cow as well as body weight and body weight changes should be further investigated to clarify their effects on preweaning traits in the calf.

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APPENDIX A

Table 1A. Unadjusted means of birth weight of male and female calves by age class of cows.

Age of Cow (yrs)	N	Male (lbs)	N	Female (lbs)
3	29	69.62 ±6.02	28	64.25 ±7.13
4	27	70.19 ±5.62	39	66.10 ±7.08
5-7	80	74.88 ±8.60	111	70.66 ±7.67
8-10	56	75.71 ±7.72	56	70.64 ±10.15
11-13	17	74.94 ±10.11	13	64.15 ±11.39

Table 2A. Unadjusted means of preweaning average daily gain of male and female calves by age class of cows.

Age of Cow (yrs)	N	Male (lbs)	N	Female (lbs)
3	27	1.92 ±0.18	28	1.73 ±0.21
4	26	2.03 ±0.22	37	1.78 ±0.25
5-7	75	2.10 ±0.23	107	1.89 ±0.18
8-10	49	2.05 ±0.25	53	1.88 ±0.20
11-13	15	2.01 ±0.27	12	1.63 ±0.28

Table 3A. Unadjusted means of weaning weight of male and female calves by age class of cows.

Age of Cow (yrs)	N	Male (lbs)	N	Female (lbs)
3	27	413.96 ±32.15	28	377.68 ±40.94
4	26	432.96 ±38.10	37	384.86 ±47.07
5-7	75	451.72 ±44.45	107	409.45 ±35.87
8-10	49	444.82 ±46.62	53	409.02 ±40.65
11-13	15	440.00 ±53.08	12	356.83 ±58.14

APPENDIX B

Table 1B. Unadjusted means of birth weight of male and female calves by sires.

Sire	N	Male (lbs)	N	Female (lbs)
4P	37	75.22 ±6.12	34	73.26 ±8.64
18P	29	71.69 ±7.50	65	69.68 ±8.66
106P	47	71.23 ±8.89	35	66.66 ±7.28
3P	31	70.74 ±8.05	37	65.57 ±7.53
41N	31	75.58 ±7.93	36	68.11 ±10.45
11P	34	78.59 ±7.19	40	69.48 ±7.92

Table 2B. Unadjusted means of preweaning average daily gain of male and female calves by sire.

Sire	N	Male (lbs)	N	Female (lbs)
4P	36	2.01 ±0.23	30	1.76 ±0.20
18P	26	2.10 ±0.23	64	1.92 ±0.17
106P	43	2.06 ±0.25	36	1.91 ±0.25
3P	28	1.97 ±0.20	35	1.80 ±0.20
41N	27	1.96 ±0.23	33	1.70 ±0.19
11P	32	2.16 ±0.23	39	1.83 ±0.24

Table 3B. Unadjusted means of weaning weight of male and female calves by sire.

Sire	N	Male (lbs)	N	Female (lbs)
4P	36	436.00 ±40.07	30	391.60 ±38.88
18P	26	448.92 ±43.53	64	415.20 ±35.87
106P	43	441.58 ±48.34	36	410.06 ±49.32
3P	28	424.96 ±39.93	35	390.80 ±38.88
41N	27	427.44 ±39.94	33	372.70 ±40.79
11P	32	466.03 ±45.04	39	398.15 ±45.97

APPENDIX C

Table 1C. Unadjusted means of birth weight of male and female calves by year.

Year	N	Male (lbs)	N	Female (lbs)
1962	22	73.55 ±7.69	31	68.65 ±9.21
1963	20	72.70 ±12.22	37	68.46 ±7.42
1964	24	75.63 ±8.88	29	70.41 ±7.78
1965	27	71.85 ±7.53	34	67.91 ±8.44
1966	29	74.62 ±5.60	29	70.38 ±7.96
1967	26	75.62 ±5.55	36	69.94 ±10.39
1968	41	73.51 ±8.83	27	69.26 ±7.51
1969	20	72.35 ±8.20	24	65.38 ±10.61

Table 2C. Unadjusted means of preweaning average daily gain of male and female calves by year.

Year	N	Male (lbs)	N	Female (lbs)
1962	22	2.08 ±0.23	32	1.83 ±0.27
1963	20	2.03 ±0.32	35	1.85 ±0.17
1964	24	2.08 ±0.27	29	1.88 ±0.22
1965	25	2.10 ±0.20	32	1.88 ±0.14
1966	26	2.14 ±0.21	28	1.95 ±0.22
1967	24	1.96 ±0.16	36	1.71 ±0.22
1968	33	2.05 ±0.21	26	1.86 ±0.17
1969	18	1.88 ±0.22	19	1.72 ±0.24

Table 3C. Unadjusted means of weaning weight of male and female calves by year.

Year	N	Male (lbs)	N	Female (lbs)
1962	22	446.50 ±44.00	32	398.66 ±54.69
1963	20	435.50 ±57.27	35	401.51 ±34.42
1964	24	447.08 ±51.01	29	407.66 ±37.49
1965	25	448.84 ±39.31	32	404.94 ±30.52
1966	26	458.50 ±41.96	28	419.86 ±43.41
1967	24	429.58 ±30.78	36	377.42 ±44.52
1968	33	442.70 ±40.45	26	405.38 ±34.26
1969	18	410.28 ±44.67	19	374.37 ±51.23

APPENDIX D

Table 1D. Least squares estimates of factors affecting birth weight of calves.

Factor	Estimate
Sex of calf	
Bulls	2.50
Heifers	-2.50
Age of Cow (yrs.)	
3	0.16
4	-1.00
5-7	1.88
8-10	0.90
11-13	-1.94
Cow weight at parturition (lbs.)	
≤899	-5.86
900-1009	-3.69
1010-1119	0.32
1120-1229	1.87
1230-1339	3.38
≥1340	3.97
Cow weight in the previous June (lbs.)	
≤899	3.26
900-1009	0.05
1010-1119	-1.04
1120-1229	-1.60
1230-1339	-0.21
≥1340	-0.46
Cow weight in the previous October (lbs.)	
≤899	-1.95
900 -1009	-1.78
1010-1119	-1.16
1120-1229	-0.02
1230-1339	1.19
≥1340	3.72

Factor	Estimate
Cow weight in the previous December (lbs.)	
≤899	0.68
900 -1009	0.12
1010-1119	1.88
1120-1229	1.53
1230-1339	-1.13
≥1340	-3.08
Cow weight change from the previous June to parturition (lbs.)	
≤-50	1.39
-49-0	3.20
1-50	1.93
51-100	-1.90
101-150	-2.64
≥151	-1.98
Cow weight change from the previous October to parturition (lbs.)	
≤-50	0.84
-49-0	-0.20
1-50	-0.58
51-100	0.91
101-150	-0.88
≥151	1.59
Cow weight change from the previous December to parturition (lbs.)	
≤-50	1.29
-49-0	1.33
1-50	-0.61
51-100	0.41
101-150	-0.02
≥151	-2.40
Sires	
4P	4.13
18P	-2.01
106P	-3.88
3P	-1.95
41P	0.66
11P	3.04

Factor	Estimate
Year of Record	
1962	0.38
1963	-0.03
1964	0.75
1965	-1.69
1966	1.10
1967	0.53
1968	0.68
1969	-1.72

Table 2D. Least squares estimates of factors affecting preweaning average daily gain of calves.

Factor	Estimate
Sex of calf	
Bulls	0.1
Heifers	-0.1
Age of cow (yrs)	
3	-0.04
4	0.01
5-7	0.04
8-10	0.00
11-13	-0.02
Cow weight in the previous October (lbs)	
≤899	0.00
900-1009	0.01
1010-1119	0.01
1120-1229	-0.01
1230-1339	-0.02
≥1340	0.01
Cow weight at parturition (lbs)	
≤899	-0.03
900-1009	-0.05
1010-1119	0.01
1120-1229	0.00
1230-1339	0.06
≥1340	0.01
Cow weight in June (lbs)	
≤899	0.02
900-1009	-0.03
1010-1119	-0.04
1120-1229	0.02
1230-1339	0.07
≥1340	-0.03
Cow weight in October (lbs)	
≤899	-0.07
900-1009	0.00
1010-1119	0.01
1120-1229	0.01
1230-1339	-0.03
≥1340	0.08

Factor	Estimate
Cow weight change from the previous October to parturition (lbs)	
≤ -50	0.02
-49-0	0.03
1-50	-0.05
51-100	0.02
101-150	0.00
≥151	-0.02
Cow weight change from parturition to October (lbs)	
≤ -50	0.04
-49-0	0.04
1-50	0.02
51-100	0.04
101-150	-0.08
≥151	-0.06
Cow weight change from June to October (lbs)	
≤ -50	-0.13
-49-0	-0.07
1-50	0.02
51-100	0.01
101-150	0.03
≥151	0.13
Birth weight of calf (lbs)	
≤49	-0.11
50-59	-0.14
60-69	0.02
70-79	0.07
80-89	0.12
≥90	0.04
Sires	
4P	-0.04
18P	0.07
106P	0.05
3P	-0.03
41N	-0.10
11P	0.05

Factor	Estimate
Year of record	
1962	0.00
1963	-0.03
1964	0.06
1965	0.03
1966	0.06
1967	-0.16
1968	0.08
1969	-0.08

Table 3D. Least squares estimates of factors affecting weaning weight of calves.

Factor	Estimate
Sex of calf	
Bulls	17.55
Heifers	-17.55
Age of Cow (yrs)	
3	-5.35
4	-0.32
5-7	7.06
8-10	0.25
11-13	-1.64
Cow weight in the previous October (lbs)	
≤899	-2.13
900-1009	2.18
1010-1119	2.04
1120-1229	0.30
1230-1339	-1.35
≥1340	-1.04
Cow weight at parturition (lbs)	
≤899	-6.94
900-1009	-8.09
1010-1119	0.16
1120-1229	1.34
1230-1339	9.49
≥1340	4.04
Cow weight in June (lbs)	
≤899	4.55
900-1009	-5.08
1010-1119	-7.21
1120-1229	4.43
1230-1339	11.31
≥1340	-8.00
Cow weight in October (lbs)	
≤899	-10.10
900-1009	-1.36
1010-1119	0.02
1120-1229	-0.34
1230-1339	-4.85
≥1340	16.63

Factor	Estimate
Cow weight change from the previous October to parturition (lbs.)	
<-50	-4.11
-49-0	-3.35
1-50	-6.34
41-100	7.76
101-150	4.68
>≥151	1.37
Cow weight change from parturition to October (lbs.)	
≤-50	7.55
-49-0	6.89
1-50	3.41
51-100	7.48
101-150	-15.90
≥151	-9.42
Cow weight change from June to October (lbs.)	
≤-50	-13.18
-49-0	-5.01
1-50	0.36
51-100	-1.79
101-150	1.09
≥151	18.54
Birth weight of calf (lbs.)	
≤49	-53.68
50-59	-37.98
60-69	0.59
70-79	17.40
80-89	37.21
≥90	36.45
Sires	
4P	-7.15
18P	12.13
106P	8.90
3P	-5.02
41P	-17.78
11P	8.91

Factor	Estimate
Year of record	
1962	1.40
1963	-3.68
1964	9.16
1965	5.94
1966	11.23
1967	-20.15
1968	14.10
1969	-18.00