To the Graduate Council:

I am submitting herewith a thesis written by Shanmugampillay Loganathan entitled "The Genetic and Environmental Factors Affecting the Performance of Hereford Calves From Birth to Weaning." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a Major in Animal Husbandry.

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THE GENETIC AND ENVIRONMENTAL FACTORS AFFECTING THE PERFORMANCE OF HEREFORD CALVES FROM BIRTH TO WEANING

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Shanmugampillay Loganathan

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CHAPTER I

INTRODUCTION

Spectacular changes have occurred in the conformation of beef cattle since the time of Robert Bakewell, the so-called father of Animal Breeding. Anyone who compares a picture of a beef animal that was existent 200 years ago at Bakewell's time with the present-day beef animal, will be amazed at the striking improvements in the physical form of the beef animal that have taken place during these two centuries. Selection has been mainly responsible for this remarkable success. In olden days the selection criteria were merely empirical. Visual standards were solely relied upon as the estimation of the genotype. Now conditions are changing. Selection in many herds is being based mainly on the records of performance, supplemented by the visual standards only wherever absolutely necessary. Already performance testing has yielded very good results. Records such as birth weight, growth rate, weaning weight, type score, condition grade, and feed efficiency are used for culling cows, selecting bull-prospects and replacement heifers, as a source of information for progeny testing and for merchandising cattle. Environmental factors such as sex of calf, age of dam, year of birth and season of calving affect these performance traits of calves very much. Information on the effects of these environmental factors is of immense value in comparing animals for selection. Appropriate correction factors are necessary for this purpose. These correction factors enable the breeder to more

accurately identify the genetic differences between the individual calves and make the selection procedure more efficient and scientific.

Even selection based on the performance of the individual has its own limitations. When heritability is low, phenotype is a poor indicator of the genotype. For this reason, selection based on the individual performance will be successful only when heritability is high. A reliable estimate of heritability is desirable to decide which kind of breeding plan is most appropriate for the herd. Also knowledge of heritability is necessary in determining the relative emphasis to place on various traits in selection programs.

Heritability is a measure of the proportion of the observed phenotypic variance which is additively genetic. In other words, the heritability estimate tells us how much is attributable to heredity and how much is attributable to the environmental factors which cannot be accounted for by routine adjustment of data. These heritability estimates differ from population to population and from time to time for the same herd.

Repeatability is a concept closely allied to the heritability. In a statistical language, it is the intraclass correlation between the records of the same cow. It tells the breeder the degree or extent to which a particular trait is repeatable from one calf to another calf from the same cow. It is also useful for estimation of the increased accuracy in evaluating inherent qualities from averaging repeated records of the same animal, and for estimating the gain from correcting records for known environmental influences. Logically, repeatability represents the upper limit of heritability, since it includes all type of genetic, as well as

some environmental influences, which contribute to real differences among animals (Dickerson, 1959).

The breeder will also be interested in the interrelationship of various performance traits. A knowledge of the phenotypic, genetic and environmental correlations will be required to formulate efficient selection procedures (such as using a selection index) and to predict response from selection (Dickerson,1959). The phenotypic correlation gives a measure of the relationship between the two variables, without making a distinction between genetic and environmental influences. But the genetic correlations provide a measure of the association between two variables taking into consideration only the genetic component involved. The genetic correlation is of practical importance to the breeder since the selection on the basis of one trait automatically improves the other trait provided these two traits have high positive genetic correlation.

Considerable work has been done in the past on the influence of various environmental factors on the performance traits like average daily gain from birth to weaning and type score at weaning; but such information is limited for the period 'birth to pre-weaning' and 'pre-weaning to weaning' separately. (The term pre-weaning is used here to denote the period from birth to July. Similarly weaning performance refers to the period from birth to weaning. This is a deviation from the common usage in the literature where pre-weaning performance refers to the period from birth to weaning.) Information is inadequate on the heritability and repeatability estimates for the performances in these periods. Although the literature concerning estimates of phenotypic

correlations among traits of beef cattle is abundant, there is considerably less information on genetic correlations.

The objectives of this study are:

1. To evaluate the influence of sex of calf, age of dam, month of birth and year of birth on the following traits: birth weight, average daily gain from birth to July (pre-weaning), average daily gain from July to October (pre-weaning to weaning), average daily gain from birth to October (weaning), type score and condition grade in July, and type score and condition grade in October.

2. To develop appropriate correction factors for these traits for use in adjusting the data for genetic analysis and selection procedures.

3. To calculate the heritability and repeatability estimates for the above traits by using the adjusted data.

4. To estimate the phenotypic, genetic and environmental correlations among the various traits.

5. To evaluate the usefulness of taking weights and grades at about 120 days from birth (July) in measuring the performance of calves from birth to weaning and the mothering ability of beef cows.

CHAPTER II

REVIEW OF LITERATURE

Although there may be differences in the intensity of influence of the sex of calf, age of dam, season of calving, and year of birth on the pre-weaning and weaning performance of calves in various locations, workers agree that these factors do affect the performance of calves considerably.

I. EFFECT OF SEX OF CALF, AGE OF DAM, MONTH AND YEAR OF BIRTH

Birth Weight

The information available on the influence of sex of calf on birth weight is summarized in Table I.

It can be seen from the figures in Table I that the sex difference varied from 2.7 pounds (Paysinger, 1953) to 6.0 pounds (Guill, 1953). These sex differences were significant in most of the cases. Mason (1951) stated that according to Knapp, 38 per cent of the variance in birth weight could be accounted for by length of gestation, calving sequence and the weight of dam together, while 6.5 per cent was due to the difference between the sexes.

Knapp et al. (1942) showed that the birth weight of calves increased as the dam increased in age up to five years, followed by a decline thereafter. Burris and Blunn (1952) reported that the average birth

TABLE I

SEX DIFFERENCE IN BIRTH WEIGHT OF HEREFORD CALVES

Authors	Average for Males (lb.)	Average for Females (lb.)	Average Difference (lb.)
Knapp et al.(1942)	76.9	71.1	5.8
Dawson et al.(1947)			4.2
Gregory et al.(1950)			4 to 5
Burris and Blunn (1952)	69.9	65.4	4.5
Southwell and Warwick (1952)			5.3
Guill (1953)			6.0
Paysinger (1953)			2.7
Koch and Clark (1955a)	78.4	72.8	5.6
McCormick et al.(1956)	77.0	72.5	4.5
Faulk (1957)	70.4	66.2	4.2
Taylor et al.(1960)	70.2	65.1	5.1
Brinks et al.(1961)			5.2
Marlowe (1962)	70.0	66.2	3.8

weight was 63.5 pounds for calves from dams of two to three years of age and it increased steadily to 76.2 pounds for calves from dams of nine to ten years of age. Koch and Clark (1955a) found that age of dam had a marked influence on the birth weight of calves. According to McCormick et al.(1956) the calves from two, three and four-year-old dams weighed approximately 10, 6 and 2 pounds less respectively from those of five-year-old dams. Birth weights of calves from dams more than five years old did not exhibit any consistent trend. Faulk (1957) found that the mean sex-adjusted birth weights of calves tended to increase as the age of dam increased to four years and then showed no trend. Marlowe(1962), in his studies with the Hereford cattle in the Virginia Beef Cattle Improvement Program, reported that the birth weight increased with the age of the cow up to seven years at the rate of 1.67 pounds per year. Koch and Clark (1955a) found that calves born later in the calving season were slightly heavier at birth and postulated that this slight difference could be due to better pasture conditions or some other factor.

Average Daily Gain From Birth to July (Pre-weaning)

The information on the average daily gain for this period is very limited. Rollins and Guilbert (1954) reported that beef calves gained 1.91 pounds per day from birth to four months of age. They also observed a sex difference of 0.13 pound in favor of males in the above period.

Dixon (1959) found that the average unadjusted daily gains of calves at six locations in Tennessee ranged from 1.53 to 1.82 pounds, with an over-all mean of 1.64 pounds. Koch et al.(1959) reported an average daily gain of 1.62 pounds and 1.61 pounds in two different locations for the

period from birth to mid-summer. The sex differences in favor of males were 0.17 pound and 0.13 pound respectively in these places. Taylor et al. (1960) reported that male calves made an average daily gain of 1.75 pounds while female calves made 1.58 pounds with a sex difference of 0.17 pound in favor of males from birth to July.

Average Daily Gain from July to October (Pre-weaning to Weaning)

Information on the average daily gain for this period is also very limited. Rollins and Guilbert (1954) found that beef calves gained 1.93 pounds daily during the period from four to eight months of age. They also observed a sex difference of 0.39 pound in favor of males for this period. Marlowe et al. (1958) reported that the average daily gain of non-creep-fed calves was the same within the 90 to 240 days age range. There was a rapid decline in average daily gains of calves weighed after 240 days of age. Koch et al. (1959) reported an average daily gain of 1.54 pounds and 1.24 pounds for two stations. The sex differences in favor of males were 0.13 and 0.02 pounds respectively in these places. Marlowe (1962) reported that there was a decrease in average daily gain with age from 60 to 300 days among the non-creep fed calves. This study indicated that even within the age range of 120 to 240 days, the difference between the extreme ages amounted to approximately 0.10 pound per day thereby suggesting the desirability of some adjustment for age differences of calves.

Average Daily Gain From Birth to October (Weaning)

Knapp et al. (1941) found that the sex of calf had high influence

on the rate of gain in the suckling period. Faulk (1957) in his studies with Hereford and Angus calves, reported that the average daily gain for calves at all locations was 1.59 ± 0.009 pounds for males and 1.49 ± 0.008 pounds for females with a difference of 0.10 pound in favor of males. This represented a 7 per cent advantage for the males. In the Hereford herds, the average daily gain for male calves was 1.57 pounds while female calves had an average of 1.48 pounds. Marlowe and Gaines (1958) found that heifer calves made an average daily gain of 0.12 pound less than the steers. According to Koch et al.(1959) the daily gain of bull calves from birth to weaning was 1.073 times greater than that of heifers. Taylor et al.(1960) reported that male calves made an average daily gain of 1.77 pounds while the female calves made 1.53 pounds with a sex difference of 0.24 pound in favor of males. Brinks et al.(1961) found that heifer calves gained 5 per cent less than steers and 6 per cent less than bulls from birth to weaning. Marlowe(1962) reported that bull calves grew about 14 per cent faster than heifer calves when no creep-feeding was practiced. Steer calves were intermediate between bulls and heifers or about 7 per cent faster than heifer calves but 7 per cent slower than bull calves.

Faulk (1957) observed that the average daily gain in the suckling period was maximum for calves from dams of six to ten years of age. Marlowe and Gaines (1958) showed that the average daily gain for calves increased as the age of cows increased from two years to seven years. Calves from two-year-old dams and three-year-old dams made an average daily gain of 0.30 and 0.17 pounds less than the calves from seven-year-

old dams. However, Nelms et al. (1956) could not recognize any influence of age of dam on the growth rate in suckling period.

Duncan (1951) reported that calves born in March and April made a faster gain, i.e., 1.72 pounds from birth to weaning than the calves born in January and February which made an average daily gain of 1.63 pounds. Marlowe and Gaines(1958) found that calves born from March 16 through May 31 made faster gain (i.e., 0.4 pound more) daily than the calves born from December 16 through March 15. Griffey (1959), in his studies with 2,443 calves of Hereford and Angus breeds in four locations of Tennessee, reported that differences among average adjusted daily gains for ten-day calving periods were not significant and concluded that the day calved within the season of birth would have relatively little influence on the growth rate of calves born over a limited period of time. Marlowe (1962) reported that the month in which the calf was born had a tremendous influence on his daily gain from birth to weaning. He showed a gradual increase in the gains of calves born between September and March amounting to approximately 0.1 pound per month. He also noticed a slight additional increase during March and April, a decrease in May and a drastic decrease after the first of June.

Type Score in July (Pre-weaning)

Dixon (1959) reported that the average type grade of calves of Hereford and Angus breeds in six locations in Tennessee was 10.8 at 137 days of age. The males graded 11.0 while the females graded 10.7 with a sex difference of 0.3 in favor of males. Taylor et al. (1960) showed that

the males graded 10.9 while females scored 11.2 with a sex difference of 0.3 in favor of females, for the period from birth to July.

Condition Grade in July (Pre-weaning)

Information on the condition grade in July is very much lacking. Dixon (1959) reported that the males scored 7.5 while females scored 8.1 with an over-all average of 7.8 for this period. A sex difference of 0.6 was noticed in favor of females.

Type Score in October (Weaning)

Koch and Clark (1955a) found that the average type score was 7.2 for males and 7.1 for females with a difference of 0.1 in favor of males. Faulk (1957) found that the sex difference in the type grade was not significant. The mean type grade was 11.3 for Hereford males and 11.4 for females with a difference of 0.1 grade in favor of females. He explained that the slight advantage in the weaning type grade observed for females may possibly be accounted for by the effect of condition on the subjective evaluation of the type grade, since the female calves averaged 0.8 grade higher in condition. According to Dixon (1959) the mean type score for weaning for the Alcoa purebreds was 12.0. The males graded 12.2 while the females scored 11.8 with a difference of 0.4 in favor of males. Taylor et al.(1960) reported that males scored 11.2 while females graded 11.5 with a difference of 0.3 in favor of females.

Faulk (1957) found that the effect of age of dam on the weaning type score was highly significant. Calves from two, eleven, twelve, thirteen, and fourteen-year-old dams graded approximately one-sixth of a

type grade lower than calves from cows of three to ten years of age. Calves from cows of three to ten years of age showed no consistent trend.

Marlowe et al.(1958) reported that season of birth was an important source of variation in the type score for weaning. They found a slight decrease in the type score of calves born in May and April, although there was little difference in the type score of calves born between November and March. The type scores as reported by Marlowe (1962) were 11.4, 11.3, 11.2, 11.1 and 11.5 respectively for the months of January, February, March, April and May.

Condition Grade in October (Weaning)

Faulk (1957) reported that sex of calf significantly affected the condition grade. On the average, the females graded 9.7 while the males graded 8.8 with a sex difference of 0.9 in favor of females. Dixon (1959) showed an over-all average of 9.1 for the condition grade at weaning. The average condition grades for the sexes were 8.7 for the males and 9.4 for the females with a sex difference of 0.7 in favor of females.

Faulk (1957) reported that the influence of age of dam on the condition grade at weaning time was considerable. The condition grade increased as the age of dam increased to four years and then remained constant as age of dam increased to thirteen years.

Correction Factors

McCormick et al. (1956) have made adjustments for sex of calf, age of dam and year of birth by using the additive correction factors obtained by simple averages and differences within the various traits. Marlowe and

Gaines (1958) claimed that more risk is involved in overadjusting than underadjusting the data, as regards the application of the correction factors. Koch et al.(1959) recommended that a multiplicative type of correction factor was more appropriate when the data are combined from many herds. Brinks et al.(1961), while discussing the relative merits of additive and the multiplicative correction factors, observed that the additive type is appropriate if the standard deviations for both sexes are equal and the multiplicative type is appropriate when the coefficients of variation are equal. These authors used the multiplicative correction factors for their data, but could not obtain much advantage over the additive correction factors.

II. HERITABILITY STUDIES

Knapp and Nordskog were the first to present estimates of heritability of quantitative traits in beef cattle. According to Warwick (1958), these authors reported small to moderate estimates for birth and weaning weights and extremely high estimates for gains during post-weaning feedlot test. These estimates approached 100 per cent in some cases. The authors postulated that this may be due to the high sampling error or due to the possibility that some environmental variation was included in the estimates of the genetic components of variation.

Mason (1951) reported the heritability estimates of birth weight as varying from 0.23 to 0.45. The various heritability estimates for birth weight that were quoted from time to time were 0.22 (Burris and Blunn, 1952), 0.35 and 0.44 (Koch and Clark, 1955a,c),0.72 (Shelby et al.1955),

0.51 ± 0.46 (Dawson et al.1955). Koch and Clark (1955b) in reviewing the work of various workers, reported a range of 0.22 to 1.0 for the heritability of birth weight. The heritability estimates given by McCormick et al.(1956) were -0.17 for males and 0.68 for females. According to Shelby et al.(1955) the various heritability estimates for birth weight were 0.23, 0.42 and 0.34 by Knapp and Nordskog (1946), 0.29 and 0.11 by Dawson et al. (1947), 0.45 by Knapp and Clark (1950), 0.45 and 1.00 by Gregory et al.(1950), 0.67 ± 0.32 by Lasley et al.(1961).

The heritability estimates for the rate of gain from birth to weaning were 0.to 0.45 by Gregory et al.(1950), 0.07 ± 0.06 and 0.21 by Koch and Clark (1955a,c), 0.20 ± 0.03 by Lehmann et al. (1961). According to Lehmann et al.(1961) the heritability estimates for weaning score as quoted by different authors were 0.53 by Knapp and Nordskog (1946), 0.30 by Koger and Knox (1952), 0.18 and 0.16 by Koch and Clark (1955a,c), 0.36 by Rollins and Wagnon (1956), 0.41 for steers and 0.51 for heifers by Carter and Kincaid (1959). Lehmann et al. (1961) quoted a figure of 0.33 ± 0.04 for the heritability of weaning score.

III. REPEATABILITY ESTIMATES

The information on the repeatabilities of various traits is summarized in Table II.

TABLE II

REPEATABILITY FOR VARIOUS TRAITS

Author	Birth weight	Rate of gain from birth to weaning	Weaning score	Rate of gain from birth to July	Pre-weaning score
Botkin and Whatley (1953)	0.18				
Koch and Clark (1955a)	0.26	0.34	0.22		
Koch and Clark (1955a) (Citing other workers)	-0.03 to 0.25	0.38 to 0.69	0.25 to .33		
McCormick et al. (1956)	0.11				
Dixon (1959)		0.30		0.38	
Taylor et al. (1960)	0.29	0.39	0.28	0.34	0.24

IV. PHENOTYPIC AND GENETIC CORRELATIONS AMONG TRAITS MEASURED FROM BIRTH TO WEANING

Many workers have observed correlations between birth weight and the weaning weight and rate of gain in beef calves. Mason (1951) quoted a figure of 0.4 to 0.6 as the correlation for these variables, reviewing the work of many workers. Nelms and Bogart (1956) found that larger calves at birth gained more rapidly during the suckling period. McCormick et al. (1956) reported that birth weight, either unadjusted or adjusted for age of dam, was positively correlated with the daily gain from birth to weaning. This correlation was 0.23 for steer calves and 0.09 for heifer calves in the grade Hereford herd for the adjusted data. Marlowe (1962) reported that the phenotypic correlation between birth weight and the average daily gain for weaning was 0.23 for males and 0.28 for females.

Chambers et al. (1956) obtained a correlation of 0.86 between daily gain from birth to 112 days and daily gain from birth to 210 days of age. Dixon (1959) reported a correlation of 0.86 between the daily gains from birth to pre-weaning and birth to weaning. His study indicated that the daily gain from birth to an intermediate stage during the suckling period would have a high predictive value with respect to the daily gain from birth to weaning. It was found that 73.3 per cent of the variation in the daily gain from birth to weaning could be accounted for by the differences in the daily gain from birth to 137 days.

Literature on the genetic correlations of the traits of weaning performance is very inadequate. Koch and Clark (1955b) obtained the genetic, environmental and phenotypic correlations among various traits. The correlations among traits included in his study are given in Table III.

The correlations reported by Lehmann et al. (1961) were 0.007 (genetic) and 0.42 (phenotypic) between daily gain and type score at weaning.

TABLE III

GENETIC, ENVIRONMENTAL AND PHENOTYPIC CORRELATIONS AMONG BIRTH WEIGHT, GAIN FROM BIRTH TO WEANING AND WEANING SCORE
(Koch and Clark, 1955b)

Trait	Type of Correlation	Gain from Birth to Weaning	Weaning Score
Birth Weight	Genetic	0.46	0.19
	Environmental	0.12	0.19
	Phenotypic	0.21	0.19
Average Daily Gain from Birth to Weaning	Genetic		0.50
	Environmental		0.67
	Phenotypic		0.64

CHAPTER III

PROCEDURE

Source of Data

The data used in this study were obtained from the performance records of the Alcoa beef cattle herd which is managed as a part of the Agricultural Experiment Station of the University of Tennessee. The period covered in this study was from 1957 to 1961. During this period, the Alcoa herd consisted of purebred and grade Herefords and a few purebred Angus and Angus x Hereford crossbreds. Calves from cows that were one-fourth Angus and three-fourth Hereford were called grade Herefords. Because of the limited number of records from Angus calves and Angus x Hereford crossbred calves, these calves were not included in the study. The plan has been to gradually replace the grade Herefords with purebred Herefords. Therefore the two groups were analyzed separately. A few calves were not included because information was not available on each of the eight performance traits. On the whole, records of 471 purebred Hereford calves (218 males and 253 females) and 196 grade Hereford calves (81 males and 115 females) were utilized for a major part of the analysis. For heritability and correlation studies only 469 records of purebreds and 160 records of grades were used since the sire information was not available for the rest of the calves. Tables IV and V give the number of calves by each sire for the years 1957-1961 for the purebreds and grades respectively. It may be noticed that the

TABLE IV

NUMBER OF CALVES BY EACH SIRE FOR THE PUREBREDS

Sire No.	Year of Birth					Total
	1957	1958	1959	1960	1961	
1233	9	-	-	-	-	9
2914	-	-	4	-	-	4
2623	-	-	14	-	-	14
2825	-	-	3	-	-	3
2037	-	-	-	-	23	23
2974	-	-	4	-	-	4
2892	-	-	-	6	-	6
4033	11	10	21	-	-	42
6432	10	-	-	-	-	10
6653	-	1	-	-	-	1
9000	-	6	-	-	-	6
9505	-	2	-	15	-	17
9605	-	-	-	-	16	16
9107	-	-	-	-	2	2
9609	-	-	-	-	6	6
9110	-	-	-	-	8	8
9611	-	7	-	-	-	7
9513	-	-	-	6	-	6
9416	10	6	8	-	-	24
9217	-	12	9	-	-	21
9618	-	-	-	3	-	3
9119	-	-	-	1	-	1
9120	15	7	-	-	-	22
9023	-	18	7	15	7	47
9529	-	-	-	-	3	3
9533	-	-	-	22	22	44
9046	12	14	-	-	-	26
9156	-	-	-	4	6	10
9264	-	-	-	7	11	18
9171	13	-	-	-	-	13
9075	-	8	6	4	-	18
9484	-	-	-	6	-	6
9487	14	-	-	-	-	14
9490	-	-	-	-	15	15
Total	94	91	76	89	119	469

TABLE V

NUMBER OF CALVES BY EACH SIRE FOR THE GRADES

Sire No.	Year of Birth					Total
	1957	1958	1959	1960	1961	
1233	2	-	-	-	-	2
2037	-	-	-	-	1	1
2825	-	-	4	-	-	4
2892	-	-	-	7	-	7
4033	1	7	-	-	-	8
4315	-	13	-	-	-	13
6432	3	-	-	-	-	3
6653	-	1	-	-	-	1
9023	-	4	2	-	3	9
9033	16	-	-	-	-	16
9046	3	3	-	-	-	6
9075	-	14	3	8	-	25
9120	-	13	-	-	-	13
9156	-	-	7	2	-	9
9171	2	-	-	-	-	2
9209	-	-	-	-	1	1
9217	-	3	4	-	-	7
9264	-	-	-	7	3	10
9309	-	-	-	-	1	1
9416	1	1	4	-	-	6
9505	-	1	-	-	-	1
9513	-	-	-	5	-	5
9605	-	-	-	-	1	1
9609	-	-	-	-	1	1
9611	-	4	-	-	-	4
9618	-	-	-	4	-	4
Total	28	64	24	33	11	160

number of sires used in these two herds was 34 and 26 respectively with 469 calves in the purebreds and 160 calves in the grades. Obviously the average number of calves per sire was larger in the purebred group. With four exceptions, all the sires of grade calves were included among the sires of purebred calves. Records of 193 dams in the purebreds and 96 dams in the grades were available for study.

Herd management. The Alcoa farm is situated about ten miles from Knoxville. The climatic conditions and rainfall are similar to those of other places in East Tennessee. The breeding, feeding and management practices did not differ very much from other experimental stations for the period 1957-1961. The cattle were maintained mainly on forage throughout the year. The summer pasture consisted primarily of orchard-grass and Ladino clover with some alfalfa, fescue and other grasses. During the winter months, the animals were fed on silage and/or hay. Water, salt and mineral mixture were supplied ad libitum.

The calves included in this study were born in the spring. The cows were pasture-bred for a period of about 100 days, that is from April 5-20 to July 5-20. Heifers were bred to calve first as two-year-olds. The number of sires used in the study were 34 for the purebreds and 26 for the grades. The mating of the cows to the sires was not strictly random. In a few cases a bull was mated to a rather select group of cows but rarely. The more common practice was to allot the cows to the bulls on the basis of the cows' previous records. Very little inbreeding has been practiced during the period under study.

The cows calved in the open from late January to about May 1 each year. The calves were dehorned by the hot iron method. Some male calves were castrated soon after birth and others were not castrated. Care was taken to control outbreaks of scours and pink eye. The incidence of any major cattle disease was not recorded. The calves were not creep-fed.

Method of Obtaining Performance Records

Records of performance were being maintained for all calves. The calves were usually weighed within 24 hours after birth. Calves were weighed near the end of the breeding season (late June or early July) and again just before they were weaned (late September or early October). Analysis of data for the years 1957-1961 showed an average of 131 and 135 days as the pre-weaning age and 227 and 228 days as the weaning age for the purebreds and grades respectively. The calves were graded for type and condition by two graders from the Department of Animal Husbandry-Veterinary Science at the same time when they were weighed. In a few cases, only one grader did the grading. Table VI gives the numerical grading system used. Since it is not practical to weigh and grade each calf at a definite age, the entire group of calves is weighed and graded over a period of several days. This procedure, of course, would lead to different weaning ages, necessarily limiting the comparison to the average daily gain based on the weaning weight. Culling of calves was done on the basis of a weaning index for each calf constructed from the average daily gain and type score at weaning.

TABLE V I

METHOD OF SCORING FOR TYPE AND CONDITION GRADES

Numerical Grade	Type Grade	Condition Grade
17 16 15	Fancy	Prime
14 13 12	Choice	Choice
11 10 9	Good	Good
8 7 6	Medium	Standard
5 4 3	Common	Utility

Method of Statistical Analysis

The entire procedure can be summarized as follows.

1. Since the entire data were available in punch cards, these data were listed and checked back with the original records to ensure maximum accuracy.

2. The average daily gain from pre-weaning to weaning was computed by obtaining the difference between the weaning and pre-weaning weights and dividing it by the difference between the ages at weaning and pre-weaning.

3. The dams were classified as two-year-olds if they were 30 months old or less when the calf was born. They were called three-year-olds if they were 31 through 42 months old at calving, four-year-olds if they were 43 through 54 months old at calving, and so on. Since few purebred cows were fifteen years old or older, they were classified under the group "fourteen-year-old dams."

4. The data were then classified according to different possible combinations between sex of calf, age of dam, month, and year of birth to look for interactions. In many cases, no interaction effects could be observed. In some instances, the interaction effects were small in magnitude and hence not considered worthwhile for inclusion in the analysis.

5. The method of least squares was adopted to estimate the effects of year of birth, age of dam, month of birth and sex of calf on the performance traits to be studied. Each calf was classified in four different ways, according to year of birth, age of its dam, month of

birth and sex. No interactions were assumed. The model adopted could be written as:

$$Y_{ijklm} = \mu + a_i + d_j + b_k + s_l + e_{ijklm}$$

$i = 1,2,\ldots,5$

$j = 1,2,\ldots,13$ (purebreds); $1,2,\ldots,9$ (grades)

$k = 1,2,\ldots,5$

$l = 1,2$

where:

Y_{ijklm} = the observation (birth weight or any other trait) on the mth calf born in the ith year to a cow in the jth age group in the kth month and of the lth sex.

μ = the over-all mean of all calves when equal frequencies exist among all subclasses.

a_i = the effect of the ith year.

d_j = the effect due to the jth age of dam.

b_k = the effect of the kth month of birth.

s_l = the effect due to the lth sex of calf.

e_{ijklm} = a random effect peculiar to the calf. It was assumed that the e_{ijklm}'s had an expectation of zero with a constant variance σ^2 and a normal distribution.

Using this model, normal equations were set up. Estimation of the parameters was done by solving these equations and the standard errors were calculated from the inverted matrices by the method described by Harvey (1960).

6. After obtaining the effects of the environmental factors in

the form of constants from the least squares analysis, separately for the purebreds and the grades, they were studied carefully to notice the magnitude and trends, if any. Accordingly these constants were pooled and weighted on the basis of the number of observations of each breeding group to yield a common set of correction factors.

7. The data were then adjusted for the influence of year of birth, age of dam, month of birth and sex of calf wherever appropriate, by making use of the correction factors evolved in step 6.

8. The adjusted data were used for the estimation of:

a. Heritability of each trait by the paternal half-sib correlation method as follows:

$$\text{Heritability} = \frac{4\,\sigma_s^2}{\sigma_w^2 + \sigma_s^2}$$

where: σ_s^2 = between sire variance component.

σ_w^2 = within sire variance component.

Since heritability is obtained by multiplying the intraclass correlation among half-sibs by four, the sampling discrepancies are also increased four-fold. The test of the hypothesis that $h^2 = 0$ is based on the test of significance for the intra-class correlation coefficient which in turn is based on the test of the hypothesis that $\sigma_s^2 = 0$.

b. Repeatability of each trait by the intra-class correlation method as follows:

$$\text{Repeatability } (r^1) = \frac{\sigma_D^2}{\sigma_A^2 + \sigma_D^2}$$

where: σ_D^2 = Between dam variance component

σ_A^2 = Within dam variance component

The test of significance for $r^1 = 0$ is based on the hypothesis that $\sigma_D^2 = 0$.

c. Phenotypic correlations among the various traits by the conventional product-moment method.

d. Genetic correlations among the various traits as per the formula:

$$\frac{S_{x1\ x2}}{\sqrt{S_{x1}^2 \quad S_{x2}^2}}$$

where:

$S_{x1\ x2}$ = the sire component of covariance between traits X_1 and X_2.

S_{x1}^2 = the sire component of variance for trait X_1.

S_{x2}^2 = the sire component of variance for trait X_2.

e. Environmental correlations among the various traits as per the formula:

$$\frac{A_{x1x2}}{\sqrt{A_{x1}^2 \quad A_{x2}^2}}$$

where:

A_{x1x2} = the within sire component of covariance between traits X_1 and X_2.

A_{x1}^2 = the within sire component of variance for trait X_1.

A_{x2}^2 = the within sire component of variance for trait X_2.

f. Standard errors of the heritability and repeatability estimates were calculated as outlined by Hazel and Terrill (1945).

CHAPTER IV

RESULTS AND DISCUSSION

I. EFFECTS OF SEX OF CALF, AGE OF DAM, MONTH AND YEAR OF BIRTH ON THE PERFORMANCE TRAITS

Birth Weight

The average birth weight was 75.6 pounds for males and 71.8 pounds for females in the purebreds, while males weighed 76.0 pounds and females weighed 73.0 pounds in the grades.* The sex difference was 3.8 pounds and 3.0 pounds in favor of males in the two groups. The unadjusted data revealed an average of 73.7 pounds for the males of both the herds while the females averaged 70.2 and 68.7 pounds respectively. These results are given in Table VII .

The effect of sex was significant in both the herds (Table VIII). The sex differences observed in this study were within the range of the findings of Faulk (1957), who reported a sex difference of 3.1 pounds for the Alcoa herd and 4.2 pounds for all the stations. However the estimates of sex difference reported by other workers were somewhat higher; for example 4.5 pounds (McCormick et al. 1956), 5.1 pounds (Taylor et al. 1960), 5.2 pounds (Brinks et al. 1961). One possible explanation may be the different genetic make-up of these herds.

The present study raises a question whether the present practice

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*Averages given are the Least Squares means unless otherwise qualified.

TABLE VII

UNADJUSTED MEANS AND THE LEAST SQUARES ESTIMATES OF THE EFFECTS OF YEAR OF BIRTH OF CALF, AGE OF DAM, MONTH OF BIRTH AND SEX OF CALF ON BIRTH WEIGHT

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Year of Birth											
1957	94	39	68.1	68.8	- 3.2	- 0.3	70.5	74.2	1.7	2.0	2.3
1958	92	66	73.7	70.4	1.8	- 0.3	75.5	74.2	1.8	1.9	- 1.0
1959	76	40	70.7	67.9	- 1.6	- 1.8	72.1	72.7	1.7	2.0	1.7
1960	89	38	73.2	77.0	1.4	4.3	75.1	78.8	1.7	2.0	- 2.3
1961	120	13	73.0	69.3	1.5	- 1.9	75.2	72.6	1.6	2.8	- 1.2
Age of Dam (Yrs.)											
2	41	29	62.3	57.6	-10.3	-14.1	63.4	60.4	1.8	2.2	13.4
3	73	38	69.5	70.3	- 2.0	- 3.4	71.7	71.1	1.6	1.8	4.1
4	69	33	73.6	74.7	1.6	3.0	75.3	77.5	1.5	1.9	0
5	72	19	73.2	74.3	2.2	0.6	75.9	75.1	1.6	2.4	0
6	73	14	72.4	71.1	1.1	- 0.5	74.8	74.0	1.6	2.6	0
7	46	26	76.5	68.8	4.4	- 2.3	78.1	72.2	1.8	2.7	0
8	35	26	74.7	77.8	3.0	6.5	76.7	81.0	2.0	2.4	0
9	29	7	71.3	76.9	- 1.3	7.3	72.4	81.8	2.1	3.7	0
10	19	4	71.3	77.5	- 1.1	3.0	72.6	77.5	2.5	4.7	0
11	5	-	75.0	-	2.3	-	76.0	-	4.4	-	0
12	2	-	68.0	-	- 0.1	-	73.6	-	6.8	-	0
13	3	-	69.3	-	- 1.1	-	72.6	-	5.6	-	0
14	4	-	74.3	-	1.1	-	74.8	-	4.8	-	0

TABLE VII (continued)

Effects Studied	Number of Records		Unadjusted Mean		Least Square Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Month of Birth											
January	77	42	71.5	68.5	-4.1	-7.7	69.6	66.8	1.4	1.5	3.6
February	180	84	72.2	73.8	-2.1	-1.0	71.6	73.5	1.1	1.2	0
March	145	52	71.0	66.2	1.8	-2.6	75.5	71.9	1.1	1.6	-2.3
April	66	15	72.9	74.1	0.2	4.9	73.9	79.4	1.4	2.5	-2.6
May	3	3	75.7	82.0	4.3	6.4	78.0	80.9	5.6	5.4	-7.3
Sex of Calf											
Male	218	81	73.7	73.7	1.9	1.5	75.6	76.0	1.5	1.5	0
Female	253	115	70.2	68.7	-1.9	-1.5	71.8	73.0	1.5	1.5	3.5
Over-all Mean	471	196	71.8	70.8	73.7	74.5			1.4	1.4	

TABLE VIII

ANALYSIS OF VARIANCE OF PERFORMANCE TRAITS STUDIED

Source	Degrees of Freedom	Mean Squares							
		B.Wt.	A.D.G. B-P.W.	A.D.G. P.W-W.	A.D.G. B-W	Type P.W.	Condition P.W.	Type W.	Condition W.
PUREBREDS									
Sex	1	**1487	**2.2906	**3.7965	**2.9790	**14.19	**15.34	5.71	**71.48
Age of Dams	12	** 500	**0.5020	0.1317	**0.2827	** 6.73	** 8.65	**6.41	** 6.68
Month of Birth	4	* 209	**0.2070	0.0613	0.0137	** 5.77	**10.48	**7.87	** 8.45
Year of Birth	4	** 430	**0.1791	**0.6137	**0.2541	**13.92	** 8.54	3.40	** 4.03
Error	449	88	0.0514	0.1266	0.0326	1.40	1.28	1.58	1.32
GRADES									
Sex	1	* 388	**0.3190	**1.6280	**0.7171	1.23	**22.37	0.14	**28.42
Age of Dam	8	** 700	**0.6668	**0.3617	**0.5168	** 3.05	**13.21	**7.53	** 9.38
Month of Birth	4	** 526	*0.1054	*0.1904	**0.1335	** 5.58	1.72	**6.40	5.38
Year of Birth	4	* 190	0.0514	*0.1874	0.0554	** 6.33	2.16	3.61	4.53
Error	178	78	0.0435	0.0729	0.0269	0.86	1.68	1.56	2.69

* P $\angle$ 0.05
** P $\angle$ 0.01

B = Birth
A. D. G. = Average Daily Gain

P.W. = Pre-weaning
W. = Weaning

of using 65 and 70 pounds for male and female birth weights for purebred Herefords, in the absence of records, should be modified.

The influence of age of dam was highly significant (Table VIII). The calves out of two-year-old dams and three-year-old dams were 13.4 pounds and 4.1 pounds lighter at birth than the calves of older cows in the two herds considered together. In the purebreds, there was an increasing trend in birth weight as age of dam increased to five years, thereafter there was no consistency in the trend. The situation was similar in the grades except that the increase was up to four years of age.

These results are in close agreement with the findings of Faulk (1957) who reported that the mean sex-adjusted birth weights of calves increased as age of dam increased to four years and then varied irregularly.

The influence of age of dam could be explained by the positive correlation between the size of the dam at parturition and birth weight of calf. The two-year-old cows and three-year-old cows are under-sized at these ages when compared to the older cows. Naturally their calves also weigh less than those born out of older cows. Another reason could be a nutritional one. The maternal tissues, not being as yet full grown, compete with the foetal tissues for available nutrients in the blood stream (Palsson, 1955).

The month of birth significantly affected the birth weight (Table VIII). The calves born in January were lighter than those born in later months in both purebreds and grades. When the effects were weighted according to the number of records in each group and pooled,

the calves born in March, April and May were 2.3, 2.6 and 7.3 pounds heavier respectively than those born in February.

The effect of year of birth also was significant (Table VIII). However no consistent trend could be observed in the five-year period of study.

Average Daily Gain From Birth To Pre-Weaning

In the purebred herd, the males made an average daily gain of 1.93 pounds while the females made 1.78 pounds with a difference of 0.15 pounds in favor of males. The corresponding figures in the grades were 1.89, 1.80 and 0.09 pounds respectively. The unadjusted data gave slightly different results. These findings are given in Table IX.

The influence of sex of calf on the growth rate in this period was highly significant (Table VIII). Males grew faster than females by 1.07 times from birth to July (pre-weaning) in the two groups considered together. Dixon (1959), in a similar study with the Alcoa herd, reported a sex difference of 0.14 pounds for the purebreds and 0.18 pounds for the grades, by using the unadjusted data. Thus the two findings on the sex difference in the purebreds are identical. Koch et al. (1959) found that bull calves in two different herds grew 1.11 and 1.08 times faster than the heifer calves in the period from birth to mid-summer. His finding in the second herd is in full agreement with that of the present study since the purebred male calves grew 1.08 times faster than the female calves.

The sex difference in growth rate could be partially explained by the positive correlation between birth weight and growth rate. The

TABLE IX

UNADJUSTED MEANS AND THE LEAST SQUARES ESTIMATES OF THE EFFECTS OF YEAR OF BIRTH OF CALF, AGE OF DAM, MONTH OF BIRTH AND SEX OF CALF ON AVERAGE DAILY GAIN FROM BIRTH TO PRE-WEANING

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Year of Birth											
1957	94	39	1.70	1.82	0.01	0.08	1.87	1.93	0.04	0.05	-0.03
1958	92	66	1.77	1.83	0.08	0.02	1.94	1.87	0.04	0.04	-0.05
1959	76	40	1.68	1.66	-0.05	-0.04	1.81	1.81	0.04	0.05	0.05
1960	89	38	1.75	1.74	-0.01	-0.02	1.85	1.83	0.04	0.05	0.01
1961	120	13	1.72	1.72	-0.02	-0.05	1.84	1.80	0.04	0.07	0.02
Age of Dam (Yrs.)											
2	41	29	1.46	1.48	-0.31	-0.31	1.56	1.54	0.04	0.05	x0.23
3	73	38	1.58	1.63	-0.17	-0.18	1.69	1.67	0.04	0.04	x0.14
4	69	33	1.72	1.72	-0.06	-0.06	1.80	1.79	0.04	0.05	x0.07
5	72	19	1.75	1.81	0.02	0.01	1.88	1.86	0.04	0.06	0
6	73	14	1.79	1.89	0.02	0.10	1.88	1.95	0.04	0.06	0
7	46	26	1.81	1.85	0.05	0.00	1.91	1.85	0.04	0.06	0
8	35	26	1.84	2.14	0.10	0.32	1.96	2.17	0.05	0.06	0
9	29	7	1.84	1.81	0.08	0.08	1.94	1.93	0.05	0.09	0
10	19	4	1.88	1.80	0.14	0.04	2.00	1.89	0.06	0.11	0
11	5	-	1.69	-	-0.05	-	1.81	-	0.11	-	x0.02
12	2	-	1.75	-	0.09	-	1.95	-	0.17	-	x0.02
13	3	-	1.88	-	0.17	-	2.03	-	0.14	-	x0.02
14	4	-	1.67	-	-0.08	-	1.78	-	0.12	-	x0.02

TABLE IX (continued)

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Month of Birth											
January	77	42	1.78	1.83	-0.10	-0.07	1.76	1.78	0.03	0.04	0
February	180	84	1.75	1.80	-0.08	-0.04	1.78	1.81	0.03	0.03	0
March	145	52	1.67	1.63	-0.12	-0.09	1.74	1.76	0.03	0.04	0
April	66	15	1.69	1.80	-0.08	0.09	1.78	1.94	0.03	0.06	-0.05
May	3	3	2.02	2.03	0.38	0.10	2.24	1.95	0.14	0.13	-0.33
Sex of Calf											
Male	218	81	1.80	1.86	0.07	0.04	1.93	1.89	0.04	0.04	0
Female	253	115	1.66	1.70	-0.07	-0.04	1.78	1.80	0.04	0.04	x0.07
Over-all Mean	471	196	1.72	1.77	1.86	1.85			0.03	0.03	

male calves being heavier at birth made more rapid gains than the heifer calves.

The influence of age of dam was highly significant (Table VIII). In the purebreds, the average daily gain increased as the age of dam increased from two-year-old dams to eight-year-old dams, followed by no regular trend. However there was a sizable decrease in the average daily gain of the calves of eleven-year-olds and fourteen-year-olds. In the grade herd, the increasing trend was observed as the age of dam increased from the two-year-olds to six-year-olds; thereafter, no regular trend could be observed.

The effect of age of dam on the growth rate could be partially due to the heavier calves born out of older cows. Higher milk production on the part of older cows might be another reason. The dairy cows reach their highest lactation yield in their seventh year of age (Mahadevan, 1958). This might be true for the beef cows also. Considerable evidence for this possibility is available from the present study, wherein the highest growth rate was obtained for calves from the six-year-old cows (grades) and eight-year-old cows (purebreds).

Month of birth significantly affected the pre-weaning growth rate (Table VIII). Calves born in May had the highest growth rate in the purebreds, while in the grades, the calves born in April and May grew faster than those born in January, February, and March. The better pasture conditions in April and May could possibly explain the influence of the month of birth on the pre-weaning growth rate. Also younger calves may gain faster than older calves.

The year effect was highly significant in the purebreds while it lacked significance in the grades (Table VIII). However there was no specific trend in either of the herds.

Average Daily Gain From Pre-weaning to Weaning

In the purebreds the males gained 1.76 pounds daily while females gained 1.58 pounds daily with a difference of 0.18 pounds per day in favor of males. In the grades, the corresponding figures were 1.89, 1.69 and 0.20 pounds respectively. The over-all average was 1.67 pounds for the purebreds and 1.79 pounds for the grades. These results are shown in Table X. Koch et al. (1959) reported averages of 1.61 and 1.25 pounds of average daily gain for bull calves with 1.48 and 1.23 pounds for heifer calves in two different herds for the period midsummer to weaning. Rollins and Guilbert (1954) observed an average daily gain of 1.93 pounds from four to eight months of age. Considering these results, the findings of the present study are well within the range. The growth rate for this period was lower than the pre-weaning period by 0.19 and 0.06 pounds respectively in the purebreds and grades. Similar decreases reported by different authors were 0.05 pounds (Marlowe et al. 1958), 0.08 and 0.37 pounds (Koch et al. 1959), 0.11 pounds (Marlowe, 1962). This decrease could probably be explained by the lower rate of milk production of cows in the advanced stages of lactation.

The influence of sex of calf was highly significant (Table VIII). Male calves grew faster than female calves by 1.11 and 1.12 times in the two herds. Similar figures quoted by Koch et al. (1959) were 1.09 and 1.02 for two different locations. The increase in the sex difference

TABLE X

UNADJUSTED MEANS AND THE LEAST SQUARES ESTIMATES OF THE EFFECTS OF YEAR OF BIRTH OF CALF, AGE OF DAM, MONTH OF BIRTH AND SEX OF CALF ON AVERAGE DAILY GAIN FROM PRE-WEANING TO WEANING

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Year of Birth											
1957	94	39	1.57	1.77	-0.09	0.03	1.58	1.82	0.06	0.06	0.06
1958	92	66	1.80	1.84	0.13	0.08	1.80	1.87	0.07	0.06	-0.11
1959	76	40	1.70	1.77	0.04	0.09	1.71	1.88	0.06	0.06	-0.05
1960	89	38	1.67	1.64	-0.02	-0.04	1.65	1.75	0.07	0.06	0.02
1961	120	13	1.62	1.49	-0.05	-0.16	1.62	1.63	0.06	0.08	0.06
Age of Dam (Yrs.)											
2	41	29	1.56	1.71	-0.15	-0.08	1.52	1.71	0.07	0.07	x0.11
3	73	38	1.62	1.66	-0.08	-0.15	1.59	1.64	0.06	0.06	x0.11
4	69	33	1.65	1.68	-0.05	-0.04	1.62	1.75	0.06	0.06	x0.06
5	72	19	1.65	1.71	-0.01	-0.04	1.66	1.75	0.06	0.07	x0.06
6	73	14	1.69	1.63	-0.01	-0.08	1.66	1.71	0.06	0.08	x0.06
7	46	26	1.82	1.81	0.09	0.07	1.76	1.86	0.07	0.08	0
8	35	26	1.71	2.11	-0.01	0.29	1.66	2.08	0.08	0.07	0
9	29	7	1.63	1.64	-0.04	-0.01	1.63	1.78	0.08	0.11	0
10	19	4	1.70	1.61	0.04	0.03	1.71	1.82	0.10	0.14	0
11	5	-	1.76	-	0.08	-	1.75	-	0.17	-	0
12	2	-	1.62	-	-0.03	-	1.64	-	0.26	-	0
13	3	-	1.72	-	0.08	-	1.75	-	0.21	-	0
14	4	-	1.82	-	0.09	-	1.76	-	0.18	-	0

TABLE X (continued)

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Month of Birth											
January	77	42	1.67	1.68	0.00	-0.17	1.67	1.62	0.05	0.05	0
February	180	84	1.66	1.77	0.04	-0.03	1.71	1.76	0.04	0.04	0
March	145	52	1.69	1.74	0.06	-0.02	1.73	1.77	0.04	0.05	0
April	66	15	1.66	1.76	0.04	0.03	1.71	1.82	0.05	0.07	0
May	3	3	1.36	2.12	-0.14	0.18	1.53	1.97	0.21	0.16	0
Sex of Calf											
Male	218	81	1.77	1.90	0.09	0.10	1.76	1.89	0.06	0.05	0
Female	253	115	1.58	1.65	-0.09	-0.10	1.58	1.69	0.06	0.05	x0.11
Over-all Mean	471	196	1.67	1.75	1.67	1.79			0.05	0.04	

noticed in this period (pre-weaning to weaning) suggests some kind of interaction between age of calf and sex as regards the average daily gain.

The effect of age of dam was not significant in the purebreds; however it was highly significant in the grades (Table VIII). Calves born to cows of two to six years of age made slower gains than those of older cows, in both the herds. In the purebreds there was an increasing trend in the growth rate as age of dam increased to seven years. A similar trend was not observed in the grades. There was a difference of 0.07 pound per day between calves out of two-year-old and three-year-old dams and 0.03 pound per day between calves out of three-year-old and four-year-old dams in the purebreds for this period. Corresponding figures in the period from birth to pre-weaning were 0.13 and 0.11 pounds per day respectively. This difference in magnitude of the influence of age of dam on the growth rate could probably be due to the lesser dependence of calves on their dams at this stage of growth.

The effect of month of birth was not significant in the purebreds while it was significant in the grades (Table VIII). In the purebreds calves born in January and May grew slower than those born in the other months. In the grades there was an increasing trend in the growth rate as the month of birth shifted from January to May.

The year effect was significant in both the herds (Table VIII). However no definite trend could be observed in the purebreds. In the grades the calves born in 1957, 1958, and 1959 made faster gains than those born in 1960 and 1961.

Average Daily Gain From Birth to Weaning

Obviously the results given here represent the pooled effects of factors on daily gain from birth to pre-weaning and from pre-weaning to weaning. The unadjusted means, least squares estimates and the correction factors are given in Table XI.

The average daily gain for this period was 1.75 pounds for the purebreds and 1.83 pounds for the grades. Males made a daily gain of 1.83 pounds while females made 1.66 pounds with a sex difference of 0.17 pounds in favor of males, in the purebreds. Corresponding figures in the grades were 1.89, 1.76 and 0.13 pounds respectively.

Some of the estimates of the average daily gain for males and females in this period reported by various workers were 1.58 and 1.47 by Faulk (1957), 1.65 and 1.54 by Koch et al. (1959), 1.77 and 1.53 by Taylor et al. (1960). The findings of Faulk (1957) pertained to the Alcoa herd during the period 1953 to 1956. The findings of the present study for the purebreds, i.e., 1.83 and 1.66 pounds daily gain for males and females for the period 1957 to 1961 might suggest an improvement in the growth rate of the calves of Alcoa herd.

Table XII will facilitate an easy comparison of the sex differences for the three periods namely, birth to pre-weaning, pre-weaning to weaning and birth to weaning.

The influence of sex of calf was highly significant, in both the herds (Table VIII). The sex difference of 0.17 pound for the purebreds and 0.13 pound for the grades were well within the range of findings of other workers; for example, 0.12 pound by Marlowe et al. (1958), 0.11

TABLE XI

UNADJUSTED MEANS AND THE LEAST SQUARES ESTIMATES OF THE EFFECTS OF YEAR OF BIRTH OF CALF, AGE OF DAM, MONTH OF BIRTH AND SEX OF CALF ON THE AVERAGE DAILY GAIN FROM BIRTH TO WEANING

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Year of Birth											
1957	94	39	1.64	1.77	-0.04	0.01	1.71	1.84	0.03	0.04	0.02
1958	92	66	1.79	1.84	0.10	0.06	1.85	1.89	0.03	0.03	-0.08
1959	76	40	1.69	1.71	-0.01	0.03	1.74	1.86	0.03	0.04	0
1960	89	38	1.72	1.70	-0.01	-0.02	1.74	1.81	0.03	0.04	0.02
1961	120	13	1.68	1.63	-0.03	-0.08	1.72	1.75	0.03	0.05	0.04
Age of Dam (Yrs.)											
2	41	29	1.51	1.55	-0.23	-0.24	1.52	1.60	0.03	0.04	x0.18
3	73	38	1.60	1.64	-0.14	-0.16	1.61	1.67	0.03	0.03	x0.12
4	69	33	1.67	1.71	-0.08	-0.05	1.67	1.78	0.03	0.04	x0.07
5	72	19	1.71	1.76	0.00	-0.02	1.75	1.81	0.03	0.04	x0.03
6	73	14	1.76	1.78	0.01	0.03	1.76	1.86	0.03	0.05	0
7	46	26	1.82	1.83	0.06	0.07	1.81	1.90	0.03	0.05	0
8	35	26	1.79	2.13	0.05	0.30	1.80	2.13	0.04	0.04	0
9	29	7	1.76	1.75	0.03	0.04	1.78	1.87	0.04	0.07	0
10	19	4	1.80	1.72	0.09	0.02	1.84	1.85	0.05	0.09	0
11	5	-	1.73	-	0.02	-	1.77	-	0.08	-	0
12	2	-	1.70	-	0.04	-	1.79	-	0.13	-	0
13	3	-	1.80	-	0.12	-	1.87	-	0.11	-	0
14	4	-	1.76	-	0.02	-	1.77	-	0.09	-	0

TABLE XI (continued)

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Month of Birth											
January	77	42	1.74	1.78	-0.02	-0.12	1.73	1.71	0.03	0.03	0.05
February	180	84	1.72	1.79	0.01	-0.04	1.76	1.79	0.02	0.02	0.01
March	145	52	1.68	1.66	-0.02	-0.08	1.73	1.75	0.02	0.03	0.03
April	66	15	1.68	1.78	0.01	0.07	1.76	1.90	0.03	0.05	-0.02
May	3	3	1.56	2.08	0.02	0.17	1.77	2.00	0.11	0.10	-0.09
Sex of Calf											
Male	218	81	1.79	1.87	0.08	0.07	1.83	1.89	0.03	0.03	0
Female	253	115	1.63	1.67	-0.08	-0.07	1.66	1.76	0.03	0.03	x0.09
Over-all Mean	471	196	1.70	1.76	1.75	1.83			0.03	0.03	

TABLE XII

SEX DIFFERENCES IN THE AVERAGE DAILY GAIN FOR THE PERIODS 'BIRTH TO PRE-WEANING,' 'PRE-WEANING TO WEANING' AND 'BIRTH TO WEANING'

Herd	Birth to P.W. (lbs.)	P.W. to Weaning (lbs.)	Birth to Weaning (lbs.)
Purebreds			
Sex difference (M-F)	0.15	0.18	0.17
Sex difference (M/F)	1.08	1.11	1.10
Grades			
Sex difference (M-F)	0.09	0.20	0.13
Sex difference (M/F)	1.05	1.12	1.07
Pooled sex difference (M/F)	1.07	1.11	1.09

pound by Koch et al. (1959), 0.24 pound by Taylor et al. (1960), 0.09 pound by Brinks et al. (1961) and 0.12 pound by Marlowe (1962).

The effect of age of dam was also highly significant in both the herds (Table VIII). Calves of two, three, four and five-year-old cows made poorer gains than those of older cows. In the purebreds the growth rate of the calves increased as the age of dam increased from two to seven years with no regular trend thereafter. The situation was similar in the grades except that the increasing trend went up to eight years. These findings are in general agreement with those of Faulk (1957) who reported that the average daily gain from birth to weaning was maximum for calves out of six to ten-year-old cows.

The influence of month of birth lacked significance in the purebreds while it was highly significant in the grades (Table VIII). The calves born in April and May made faster gains than those born in January, February and March, in both the herds. The trends from January to May in the growth rate were parallel in the two groups. The pooled data gave a difference of 0.09 pounds in the average daily gain between calves born from January through March and those born in April and May. This result agreed with the findings of Duncan (1951) who reported a similar difference between gains of calves born in these months.

The year effect was highly significant in the purebreds while it lacked significance in the grades (Table VIII). However no definite trend could be observed in the growth rate in either of the groups.

Type Score at Pre-weaning

The unadjusted means, least squares estimates and the correction factors are given in Table XIII. The average type score for pre-weaning was 11.6 for the purebreds and 11.4 for the grades. Males scored 11.8 while females graded 11.5 in the purebreds with a sex difference of 0.3 in favor of males. Corresponding figures in the grades were 11.5, 11.3 and 0.2 respectively. The unadjusted data gave a sex difference of 0.3 in both the groups. The sex difference of 0.3 in the pre-weaning type grade was identical with the one obtained by Dixon (1959) in studies with Herefords and Angus. Analysis of variance showed that the influence of sex of calf was highly significant in the purebreds while it lacked significance in the grades (Table VIII).

Age of dam had a highly significant influence (Table VIII). The calves born to two-year-old dams and three-year-old dams graded lower than those from the older dams in both the groups. No definite trend could be observed in either of the groups after the cows reached four or five years of age.

The effect of month of birth was highly significant (Table VIII). However, no specific trend was apparent in the type score in either of the groups.

Year of birth also had a highly significant influence (Table VIII). There was an increase from 1957 to 1961 with the exception of 1960 in the purebreds. Such a trend was not apparent in the grades. However the highest average score in both the groups was in 1961.

TABLE XIII

UNADJUSTED MEANS AND THE LEAST SQUARES ESTIMATES OF THE EFFECTS OF YEAR OF BIRTH OF CALF, AGE OF DAM, MONTH OF BIRTH AND SEX OF CALF ON THE TYPE SCORE AT PRE-WEANING

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Year of Birth											
1957	94	39	11.1	11.3	-0.52	-0.32	11.12	11.07	0.22	0.21	0.46
1958	92	66	11.5	10.9	-0.23	-0.58	11.41	10.81	0.22	0.20	0.38
1959	76	40	12.0	11.5	0.28	0.29	11.92	11.68	0.21	0.21	-0.28
1960	89	38	12.0	11.3	-0.01	-0.20	11.63	11.19	0.22	0.21	0.07
1961	120	13	12.3	12.4	0.48	0.81	12.12	12.20	0.20	0.29	-0.52
Age of Dams (Yrs.)											
2	41	29	10.6	10.4	-0.99	-0.58	10.65	10.81	0.23	0.24	1.06
3	73	38	11.2	10.7	-0.43	-0.48	11.21	10.91	0.20	0.19	0.68
4	69	33	11.8	11.7	0.17	0.07	11.81	11.46	0.19	0.20	0
5	72	19	11.9	11.7	0.19	0.02	11.83	11.41	0.20	0.25	0
6	73	14	11.9	12.1	0.17	0.65	11.81	12.04	0.20	0.28	0
7	46	26	12.4	11.8	0.51	0.43	12.15	11.82	0.23	0.28	0
8	35	26	12.2	11.4	0.07	0.27	11.71	11.66	0.26	0.25	0
9	29	7	12.8	11.8	0.67	-0.15	12.31	11.24	0.27	0.38	0
10	19	4	12.5	11.5	0.49	-0.24	12.13	11.15	0.32	0.49	0
11	5	-	11.4	-	-0.38	-	11.26	-	0.55	-	0
12	2	-	11.9	-	-0.12	-	11.52	-	0.87	-	0
13	3	-	11.8	-	0.35	-	11.99	-	0.71	-	0
14	4	-	11.2	-	-0.71	-	10.93	-	0.61	-	0

TABLE XIII (continued)

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Month of Birth											
January	77	42	12.3	11.7	0.49	0.36	12.13	11.75	0.17	0.16	0
February	180	84	12.0	11.6	0.28	0.40	11.92	11.79	0.13	0.12	0
March	145	52	11.4	10.6	-0.11	-0.45	11.53	10.94	0.14	0.16	0
April	66	15	11.5	11.2	-0.10	0.36	11.54	11.75	0.18	0.26	0
May	3	3	10.8	10.2	-0.56	-0.67	11.08	10.72	0.71	0.56	0
Sex of Calf											
Male	218	81	12.0	11.5	0.18	0.09	11.82	11.48	0.19	0.16	0
Female	253	115	11.7	11.2	-0.18	-0.09	11.46	11.30	0.19	0.16	0
Over-all Mean	471	196	11.8	11.3	11.64	11.39			0.18	0.14	

Type Score at Weaning

The over-all mean type score at weaning was 11.9 for the purebreds and 12.0 for the grades. The males graded 12.0 while females scored 11.8 with a sex difference of 0.2 in favor of males in the purebreds. Corresponding figures for the grades were 12.1, 12.0 and 0.1 respectively. Table XIV gives these findings.

An increase of type score is apparent for males and females of both groups from pre-weaning to weaning. This increase is more pronounced in the grades.

The influence of sex was not significant in either of the herds (Table VIII). The sex difference of 0.1 in type score in favor of males in the grades is identical with the findings of Koch and Clark (1955a). However, the sex differences observed in the weaning type score by other workers are in favor of heifer calves; for example, 0.1 by Faulk (1957), 0.5 by Marlowe et al. (1958), 0.3 by Taylor et al. (1960), 0.5 by Marlowe (1962).

The age of dam had a highly significant influence on the type score (Table VIII). The calves of two and three-year-old dams graded 1.0 and 0.8 grade point lower, respectively, than those from the older cows in both the groups. An increasing trend in calf grades was noticed as age of dam increased from two to seven years in the purebreds, but such a trend could not be observed in the grades. In the purebreds, calves of eleven to fourteen-year-old dams graded approximately two-thirds of a grade point less than those from four to ten-year-old dams. The findings on the purebreds agree with those of Marlowe et al. (1958) who reported

TABLE XIV

UNADJUSTED MEANS AND THE LEAST SQUARES ESTIMATES OF THE EFFECTS OF YEAR OF BIRTH OF CALF, AGE OF DAM, MONTH OF BIRTH AND SEX OF CALF ON THE TYPE SCORE AT WEANING

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Year of Birth											
1957	94	39	11.8	12.4	-0.22	-0.46	11.70	11.58	0.23	0.29	0.29
1958	92	66	12.2	11.9	0.13	-0.17	12.05	11.87	0.24	0.26	0
1959	76	40	12.0	11.5	-0.12	-0.24	11.80	11.80	0.22	0.28	0.16
1960	89	38	12.2	12.0	-0.05	0.01	11.87	12.03	0.23	0.28	0.03
1961	120	13	12.4	13.1	0.26	0.86	12.18	12.90	0.21	0.39	-0.32
Age of Dam (Yrs.)											
2	41	29	11.0	11.1	-0.91	-0.50	11.01	11.54	0.24	0.32	1.03
3	73	38	11.6	11.3	-0.47	-0.55	11.45	11.49	0.21	0.26	0.79
4	69	33	12.0	12.0	-0.05	-0.09	11.87	11.95	0.20	0.27	0
5	72	19	12.3	12.1	0.25	-0.20	12.17	11.84	0.21	0.34	0
6	73	14	12.5	12.9	0.37	0.66	12.29	12.70	0.21	0.37	0
7	46	26	12.7	13.4	0.39	1.48	12.31	13.52	0.24	0.28	0
8	35	26	12.5	12.1	0.31	0.01	12.23	12.05	0.28	0.33	0
9	29	7	12.7	11.6	0.34	-0.83	12.26	11.21	0.29	0.52	0
10	19	4	12.8	12.6	0.55	0.02	12.47	12.06	0.34	0.67	0
11	5	-	11.7	-	-0.45	-	11.47	-	0.59	-	0
12	2	-	11.8	-	-0.27	-	11.65	-	0.92	-	0
13	3	-	12.5	-	0.53	-	12.44	-	0.75	-	0
14	4	-	11.5	-	-0.58	-	11.34	-	0.65	-	0

TABLE XIV (continued)

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Month of Birth											
January	77	42	12.8	12.6	0.60	0.51	12.52	12.55	0.18	0.22	0
February	180	84	12.3	12.3	0.34	0.31	12.26	12.35	0.14	0.17	0
March	145	52	11.9	11.2	0.01	-0.52	11.93	11.52	0.15	0.22	0
April	66	15	11.6	11.9	-0.23	0.37	11.69	12.41	0.19	0.35	0
May	3	3	10.7	10.7	-0.72	-0.67	11.20	11.37	0.75	0.76	0
Sex of Calf											
Male	218	81	12.3	12.1	0.12	0.03	12.04	12.07	0.20	0.22	0
Female	253	115	12.1	12.0	-0.12	-0.03	11.80	12.01	0.20	0.21	0
Over-all Mean	471	196	12.2	12.0	11.92	12.04			0.19	0.19	

an increasing trend in the type score as age of dam increased to seven years.

Month of birth significantly affected the type score at weaning (Table VIII). Calves born in January and February graded higher in the purebreds while those born in January, February and April scored higher in the grades. The findings are in general agreement with those of Marlowe (1962) who reported a similar trend in type score for these months.

Year of birth did not significantly affect type score in either of the herds (Table VIII). The trends observed in both the groups were parallel. There was an increase from the year 1957 to 1958, followed by a decrease in 1959, which was again followed by a gradual increase to 1961.

Condition Grade at Pre-weaning

The average condition grade for pre-weaning was 7.9 for the purebreds and 8.4 for the grades. The males graded 7.7 and the females 8.1 with a difference of 0.4 in favor of females in the purebreds. Corresponding figures in the grades were 8.0, 8.7 and 0.7, respectively. These findings along with the unadjusted means and the correction factors are given in Table XV.

Sex of calf had a highly significant influence on the condition grade (Table VIII). The unadjusted data gave a sex difference of 0.3 and 0.4 grade point for the two herds. These estimates are smaller in magnitude than those of Dixon (1959) who reported sex differences of 0.6 and 0.7 grade point for the purebreds and grades.

TABLE XV

UNADJUSTED MEANS AND THE LEAST SQUARES ESTIMATES OF THE EFFECTS OF YEAR OF BIRTH OF CALF, AGE OF DAM, MONTH OF BIRTH AND SEX OF CALF ON THE CONDITION GRADE AT PRE-WEANING

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Year of Birth											
1957	94	39	8.4	8.9	0.54	0.50	8.45	8.88	0.21	0.30	-0.80
1958	92	66	8.0	8.0	-0.04	-0.22	7.87	8.16	0.21	0.27	0.17
1959	76	40	7.7	7.9	-0.26	-0.01	7.65	8.37	0.20	0.29	0.25
1960	89	38	7.9	8.2	-0.26	-0.21	7.65	8.17	0.21	0.29	0.34
1961	120	13	8.2	8.5	0.02	-0.07	7.93	8.31	0.19	0.40	0.01
Age of Dam (Yrs.)											
2	41	29	6.8	6.9	-0.97	-1.41	6.94	6.97	0.22	0.33	1.51
3	73	38	7.5	7.2	-0.60	-1.19	7.31	7.19	0.19	0.27	1.17
4	69	33	8.1	8.1	0.09	-0.27	8.00	8.11	0.18	0.28	0.32
5	72	19	8.2	8.8	0.06	0.50	7.97	8.88	0.19	0.35	0.15
6	73	14	8.4	8.7	0.26	0.37	8.17	8.75	0.19	0.39	0
7	46	26	8.7	9.5	0.66	0.60	8.57	8.98	0.22	0.39	0
8	35	26	8.1	8.9	0.18	0.70	8.09	9.08	0.25	0.35	0
9	29	7	8.7	9.3	0.62	0.57	8.53	8.95	0.26	0.54	0
10	19	4	8.8	8.8	0.68	0.13	8.59	8.51	0.30	0.69	0
11	5	-	8.5	-	0.51	-	8.42	-	0.53	-	0
12	2	-	8.0	-	-0.11	-	7.80	-	0.83	-	0.45
13	3	-	7.8	-	-0.24	-	7.67	-	0.67	-	0.57
14	4	-	6.6	-	-1.12	-	6.79	-	0.58	-	1.46

TABLE XV (continued)

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Month of Birth											
January	77	42	8.8	8.8	0.59	0.14	8.50	8.52	0.17	0.22	0
February	180	84	8.3	8.5	0.29	0.16	8.20	8.54	0.13	0.17	0
March	145	52	7.7	7.5	-0.15	-0.31	7.76	8.07	0.13	0.23	0.50
April	66	15	7.4	7.6	-0.37	-0.26	7.54	8.12	0.17	0.36	0.76
May	3	3	7.5	8.0	-0.36	0.28	7.55	8.66	0.68	0.79	0.76
Sex of Calf											
Male	218	81	7.9	8.0	-0.18	-0.36	7.73	8.02	0.18	0.23	.0
Female	253	115	8.2	8.4	0.18	0.36	8.09	8.74	0.18	0.22	-0.45
Over-all Mean	471	196	8.1	8.2	7.91	8.38			0.17	0.20	

The influence of age of dam was highly significant (Table VIII). Calves from two and three-year-old dams graded lower than those from the older cows in both the herds. In the purebreds, calves from twelve, thirteen and fourteen-year-old dams also graded less. Condition grade increased as the age of dam increased from two to four years in the purebreds and from two to five years in the grades.

Month of birth was significant in the purebreds and not significant in the grades (Table VIII). Calves born in January and February graded higher than those born in March and April in both the groups. Calves born in May scored highest in the grades but not in the purebreds.

The influence of year of birth was highly significant in the purebreds while it lacked significance in the grades (Table VIII). No consistent trend could be observed in either of the groups. However, the calves born in 1957 graded higher than those born in the other years.

Condition Grade at Weaning

The mean condition grade was 9.4 for the purebreds and 9.7 for the grades. The males graded 9.1 and females 9.8 with a sex difference of 0.7 in favor of females, in the purebreds. Corresponding figures in the grades were 9.3, 10.1 and 0.8 respectively. These results along with the unadjusted means and correction factors are given in Table XVI. An increase in the condition grade was observed from pre-weaning to weaning, for all the groups.

The influence of sex of calf was highly significant in both the herds (Table VIII). The sex difference of 0.7 and 0.8 in favor of

TABLE XVI

UNADJUSTED MEANS AND THE LEAST SQUARES ESTIMATES OF THE EFFECTS OF YEAR OF BIRTH OF CALF, AGE OF DAM, MONTH OF BIRTH AND SEX OF CALF ON THE CONDITION GRADE AT WEANING

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Year of Birth											
1957	94	39	9.5	10.4	-0.11	-0.33	9.34	9.37	0.21	0.37	0.17
1958	92	66	9.8	9.7	0.10	-0.49	9.55	9.21	0.22	0.35	0.14
1959	76	40	9.6	9.7	-0.06	-0.02	9.39	9.68	0.20	0.36	0.06
1960	89	38	9.5	10.5	-0.24	0.54	9.21	10.24	0.21	0.37	0
1961	120	12	10.1	10.5	0.30	0.30	9.75	10.00	0.20	0.51	-0.30
Age of Dam (Yrs.)											
2	41	29	8.4	9.3	-1.03	-0.42	8.42	9.28	0.22	0.42	1.17
3	73	38	9.2	9.3	-0.49	-0.63	8.96	9.07	0.19	0.34	0.94
4	69	33	9.7	9.9	0.03	-0.51	9.48	9.19	0.18	0.36	0.54
5	72	19	10.0	10.1	0.17	-0.32	9.62	9.38	0.19	0.44	0.33
6	73	14	10.1	10.2	0.33	0.02	9.78	9.72	0.19	0.49	0
7	46	26	10.4	11.6	0.48	1.56	9.93	11.26	0.22	0.49	0
8	35	26	9.8	10.3	0.08	0.68	9.53	10.38	0.25	0.44	0
9	29	7	10.0	10.6	0.14	-0.37	9.59	9.33	0.26	0.68	0
10	19	4	10.3	11.4	0.44	-0.01	9.89	9.69	0.31	0.87	0
11	5	-	9.9	-	-0.15	-	9.30	-	0.54	-	0
12	2	-	10.3	-	0.11	-	9.56	-	0.84	-	0
13	3	-	10.2	-	0.46	-	9.91	-	0.68	-	0
14	4	-	9.1	-	-0.58	-	8.87	-	0.59	-	0

TABLE XVI (continued)

Effects Studied	Number of Records		Unadjusted Mean		Least Squares Estimates		Adjusted Mean		Standard Error		Common Correction Factor
	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	Pure-bred	Grade	
Month of Birth											
January	77	42	10.4	10.5	0.67	0.64	10.12	10.34	0.17	0.28	0
February	180	84	9.9	10.3	0.36	0.58	9.81	10.28	0.13	0.22	0
March	145	52	9.5	9.5	0.15	-0.08	9.60	9.62	0.14	0.29	0.41
April	66	15	9.0	9.5	-0.27	0.24	9.18	9.94	0.18	0.45	0.68
May	3	3	8.3	8.0	-0.90	-1.38	8.55	8.32	0.69	1.00	1.64
Sex of Calf											
Male	218	81	9.3	9.6	-0.40	-0.41	9.05	9.29	0.19	0.29	0
Female	253	115	10.1	10.4	0.40	0.41	9.85	10.11	0.18	0.28	-0.80
Over-all Mean	471	196	9.7	10.1	9.45	9.70			0.17	0.25	

heifers in the two groups, is in line with the findings of Faulk (1957) who reported a sex difference of 0.9 in favor of females in the Alcoa herd.

Age of dam also had a highly significant influence on the condition grade (Table VIII). The calves from two and three-year-old dams graded lower than those from the older cows, in both the groups. Pooled differences were 1.2 and 0.9, respectively. Condition grade increased as the age of dam increased from two to seven years in the purebreds, and from three to seven years in the grades. The higher condition grade for the calves of the two-year-old dams in the grades is hard to explain.

Month of birth was highly significant in the purebreds while it lacked significance in the grades (Table VIII). Calves born in January and February graded higher than those born in the later months in both the groups. Pooled data indicated that the calves born in March, April, and May scored 0.4, 0.7 and 1.6 grade points lower respectively than those born in January and February.

Year effect was significant in the purebreds while it lacked significance in the grades (Table VIII). No definite trend could be observed in either of the groups. The highest average grades were in 1961 and 1960 for the purebreds and grades, respectively.

II. HERITABILITY ESTIMATES

The heritability estimates for various traits are shown in Table XVII.

TABLE XVII

HERITABILITY ESTIMATES WITH STANDARD ERRORS

Trait	Purebreds	Grades
Birth Weight	**0.88 ± 0.22	**0.89 ± 0.33
Average Daily Gain from birth to pre-weaning	**0.51 ± 0.17	**0.62 ± 0.30
Average Daily Gain from pre-weaning to weaning	**0.21 ± 0.12	*0.42 ± 0.28
Average Daily Gain from birth to weaning	**0.39 ± 0.15	**1.28 ± 0.36
Type Score at pre-weaning	**0.36 ± 0.14	-0.33 ± 0.13
Condition Grade at pre-weaning	**0.48 ± 0.16	0.16 ± 0.24
Type Score at weaning	*0.19 ± 0.11	**0.75 ± 0.32
Condition Grade at weaning	**0.22 ± 0.12	**1.06 ± 0.35

Purebreds	n = 469	No. of progeny per sire	13.49
Grades	n = 160	No. of progeny per sire	5.95

The heritability of birth weight was 0.88 for the purebreds and 0.89 for the grades. Birth weight is a highly heritable character and evidence indicates that heritability can be anything up to 100 per cent. Heritability estimates based on paternal half-sib correlations ranging from 0.11 to 1.00 have been reported by various workers (Knapp and Nordskog, 1946; Dawson, et al. 1947; Knapp and Clark, 1950; Gregory et al. 1950; Burris and Blunn, 1952; Shelby et al. 1955; Koch and Clark, 1955a; Lasley et al. 1961).

The heritability estimates for average daily gains in the periods birth to pre-weaning, pre-weaning to weaning and birth to weaning were respectively 0.51, 0.21 and 0.39 in the purebreds. The estimates for these periods were higher in the grades. Some of the estimates for the heritability of rate of gain from birth to weaning, reported by other workers were 0.21 by Koch and Clark (1955a), 0.00 to 0.45 by Gregory et al. (1950) and 0.20 by Lehman et al. (1961).

Type score at pre-weaning and weaning had heritability estimates of 0.36 and 0.19 respectively in the purebreds. These estimates were less consistent in the grades. The estimates for heritability of weaning type score reported by other investigators range from 0.16 to 0.53 (Knapp and Nordskog, 1946; Koch and Clark, 1955a; Rollins and Wagnon, 1956; Lehmann et al. 1961).

The heritability estimates for the condition grade were 0.48 and 0.16 at pre-weaning, 0.22 and 1.06 at weaning in the purebreds and grades, respectively.

In the purebreds, the heritability estimates for all the traits

except weaning type score were highly significant. The heritability estimate of weaning type score was significant at 5 per cent level, however. In the grades, some of the estimates were not significantly different from zero.

An over-all glance of Table XVII will reveal some interesting features. In the first place, most of the estimates were of higher magnitude than the ones quoted in the literature. Many reasons could be postulated for this kind of situation. Possibly some environmental contribution might have been included in the sire component of variation. Also environmental conditions in this herd might have been more uniform than in the herds studied by other workers. Or, maybe some epistatic influences could have exaggerated these estimates. But a question may arise whether the latter explanation based on the inherent drawback of the paternal half-sib correlation method would suffice to account for the high estimates obtained in this study. It might seem that the breeding plan adopted in the herd would have something to do with this kind of situation. This possibility is out of question as could be seen from the following history of the breeding plan adopted in the past. In a few cases there was deviation from random mating; a bull was mated to a rather select group of cows--but rarely. The more common practice was to allot the cows to the bull on the basis of cows' previous records so as to make the progeny test more accurate. This would increase the 'within-sire variation' and decrease the 'between-sire variation';which will bias the heritability estimates downward and not upward. Selection also could not be blamed since it will only bias the heritability

downward. The possibility of enough of the cows being half-sibs to elevate the relationship of the sire progeny groups from .25 to .3 or so might be a factor. However, a better explanation would be the high magnitude of the standard errors of these estimates.

Another interesting feature is about the estimates which exceed unity. The possibility of inclusion of some full sibs in the analysis was investigated and it was found that only four full-sibs have actually been included. All the full-sibs were purebreds. Hence this could not be a plausible explanation. Probably the high amount of sampling error may be a cause.

The negative heritability estimate for type score at pre-weaning might be due to the slight deviation from random mating or due to the sampling variation.

The grades have higher heritability than the purebreds for most of the traits; this might suggest more genetic variability in these traits for the grades.

The high standard errors for the heritability estimates of the grades is due to the smaller number of sires (26 versus 34) and the smaller number of progeny per sire (6.0 versus 13.5) among the grades than the purebreds.

The high heritability estimates obtained in this study suggest that selection based on individuality will be highly effective for the simple reason that there is high correlation between genotype and phenotype.

III. REPEATABILITY ESTIMATES

The repeatability estimates for the various traits are shown in Table XVIII. The repeatability estimate for birth weight was 0.28 for the purebreds and 0.23 for the grades. These findings are well within the range of other estimates such as 0.26 by Koch and Clark (1955a), 0.11 by McCormick et al.(1956), 0.29 by Taylor et al.(1961). Average daily gains for the periods birth to pre-weaning, pre-weaning to weaning and birth to weaning had repeatabilities of 0.46, 0.10 and 0.42 respectively in the purebreds. The grades had lower estimates for the periods birth to pre-weaning and birth to weaning. This situation might be due to more intense selection among the grade cows than the purebred cows. Some of the repeatability estimates for gains from birth to pre-weaning and birth to weaning reported by other workers were 0.38 and 0.30 by Dixon (1959) and 0.34 and 0.39 by Taylor et al. (1960). The close agreement between the repeatability of rate of gain for birth to pre-weaning and birth to weaning might enable an accurate selection of cows on the basis of growth rate of their calves at a time prior to weaning.

The type score at pre-weaning and weaning had repeatabilities of 0.31 and 0.23 respectively in the purebreds. The grades had lower estimates for these periods. Taylor et al. (1960) reported estimates of 0.24 and 0.28 for these periods. Koch and Clark (1955a) reported a range of 0.25 to 0.33 for the repeatability of type score at weaning, reviewing the work of others. Again more culling among the grade cows could account for the lower repeatability of type score for the two periods in this

TABLE XVIII

REPEATABILITY ESTIMATES WITH STANDARD ERRORS

Trait	Purebreds	Grades
Birth Weight	**0.28 ± 0.05	**0.23 ± 0.09
Average Daily Gain from birth to pre-weaning	**0.46 ± 0.05	*0.20 ± 0.10
Average Daily Gain from pre-weaning to weaning	*0.10 ± 0.06	0.10 ± 0.10
Average Daily Gain from birth to weaning	**0.42 ± 0.05	**0.25 ± 0.09
Type Score at pre-weaning	**0.31 ± 0.05	*0.18 ± 0.10
Condition Grade at pre-weaning	**0.19 ± 0.06	*0.20 ± 0.10
Type Score at weaning	**0.23 ± 0.06	0.12 ± 0.10
Condition Grade at weaning	0.07 ± 0.06	0.16 ± 0.10

Purebreds	n = 471	No. of records per cow	2.44
Grades	n = 196	No. of records per cow	2.04

study. The repeatability of condition grade was lower at weaning than at pre-weaning in both groups.

The repeatability estimates of grades had higher standard errors than the purebreds due to fewer dams in the grades (96 versus 193) and fewer progeny per cow (2.0 versus 2.4) for the grades than the purebreds.

The repeatability estimates obtained in this study are high enough that cows raising a first calf or first and second calves with low birth weight, growth rate or type score, could be safely culled with little chance of culling a cow that would be a high producer in later years. These findings also suggest that the individuality of cows adds a significant contribution to the variation in the various traits.

The lower repeatability estimates for some of the traits such as condition grade at weaning indicate that the trait in question is less repeatable and as such the cow cannot be culled earlier on the basis of the condition grade of its calves.

The repeatability estimates are smaller than the corresponding heritability estimates. The main reason is that the calves by the same cow had different sires and a different sample of genes from the dam and this contributes to the variation between records of the same cow. Use of repeatability as an upper limit for heritability seems more justified in cases where the 'sire variation' does not come to play; for example, fleece weight wherein only temporary environmental influences contribute to variation among records by the same animal.

IV. INTER-RELATIONSHIP AMONG VARIOUS TRAITS

The phenotypic, genetic and environmental correlations are given in Table XIX.

The correlations between birth weight and average daily gain from birth to pre-weaning and weaning were positive and fairly large. The phenotypic correlations obtained in this study compare favorably with the finding of various workers like McCormick et al. (1956) and Marlowe (1962). At least in the purebreds, the genetic correlations were higher than the phenotypic correlations. The phenotypic, genetic and environmental correlations between birth weight and growth rate from birth to weaning were 0.36, 0.55 and 0.33, respectively, in the purebreds. The corresponding figures reported by Koch and Clark (1955a) were 0.21, 0.46 and 0.12. These large and highly significant genetic correlations indicate that when selection was based on birth weight, automatically the growth rate also will improve and vice versa.

The phenotypic correlations being lower than their genetic counterparts together with smaller positive environmental correlations suggest that the genes governing birth weight and growth rate are similar but the environments pertaining to the expression of these traits have a low correlation (Searle, 1961).

The relationship between birth weight and type scores and condition grades was low.

The correlations between growth rate from birth to pre-weaning and the other traits were large and significant in most of the cases. The

TABLE XIX

PHENOTYPIC, GENETIC AND ENVIRONMENTAL CORRELATIONS AMONG VARIOUS TRAITS

Trait	Correlation	Group	A.D.G. B-P.W.	A.D.G. P.W-W	A.D.G. B-W	Type P.W.	Condn. P.W.	Type W.	Condn. W.
B. Wt.	Phen.	P	0.32	0.21	0.36	0.06	0.22	0.02	0.02
		G	0.25	0.04	0.22	-0.01	0.05	-0.13	-0.13
	Gen.	P	0.70	0.03	0.55	0.30	0.64	0.08	0.001
		G	0.61	-0.32	0.06	-0.25	0.18	-0.59	-0.59
	Envr.	P	0.25	0.24	0.33	0.02	0.15	0.01	0.03
		G	0.17	0.10	0.27	0.02	0.04	-0.01	0.01
A.D.G. B-P.W.	Phen.	P		0.20	0.82	0.40	0.49	0.37	0.30
		G		0.43	0.78	0.25	0.39	0.06	0.05
	Gen.	P		0.19	0.88	0.38	0.64	0.40	0.31
		G		0.65	0.77	-0.77	0.31	-0.97	-0.46
	Envr.	P		0.20	0.82	0.41	0.47	0.37	0.30
		G		0.40	0.80	0.35	0.41	0.25	0.17

TABLE XIX (continued)

Trait	Correlation	Group	A.D.G. B-P.W.	A.D.G. P.W-W	A.D.G. B-W	Type P.W.	Condn. P.W.	Type W.	Condn. W.
	Phen.	P			0.68	0.04	0.11	0.20	0.30
		G			0.62	-0.08	0.06	0.03	0.15
A.D.G. P.W-W	Gen.	P			0.63	-0.37	0.22	0.17	1.01
		G			0.82	0.44	1.28	0.10	0.33
	Envr.	P			0.68	0.07	0.11	0.20	0.26
		G			0.61	-0.12	-0.03	-0.02	0.12
	Phen.	P				0.32	0.43	0.39	0.40
		G				0.22	0.40	0.19	0.29
A.D.G. B-W	Gen.	P				0.15	0.66	0.41	0.67
		G				-0.13	1.20	-0.03	0.36
	Envr.	P				0.34	0.40	0.39	0.38
		G				0.28	0.33	0.25	0.27
	Phen.	P					0.65	0.68	0.42
		G					0.59	0.66	0.38
Type P.W.	Gen.	P					0.58	0.50	-0.35
		G					-0.93	-0.06	0.07
	Envr.	P					0.66	0.70	0.47
		G					0.63	0.71	0.41

TABLE XIX (continued)

Trait	Correlation	Group	A.D.G. B-P.W.	A.D.G. P.W-W	A.D.G. B-W	Type P.W.	Condn. P.W.	Type W.	Condn. W.
Condn. P.W.	Phen.	P						0.48	0.38
		G						0.41	0.40
	Gen.	P						0.07	-0.23
		G						-0.44	0.33
	Envr.	P						0.52	0.44
		G						0.50	0.43
Type W.	Phen.	P							0.65
		G							0.68
	Gen.	P							0.36
		G							0.96
	Envr.	P							0.66
		G							0.61

Size of the significant correlation is as follows:	Purebred		Grade	
	$P < .05$	$P < .01$	$P < .05$	$P < .01$
Phenotypic Correlation	0.09	0.12	0.14	0.19
Genetic and Environmental Correlation	0.35	0.45	0.39	0.50

Number of Records = 196 for grades and 471 for purebreds

B = Birth P.W. = Pre-weaning W = Weaning A.D.G. = Average Daily Gain P = Purebred G = Grade

correlations between birth to pre-weaning growth rate and birth to weaning growth rate were remarkably large. These phenotypic correlations were 0.82 and 0.78 for the two groups. Chambers et al. (1956) and Dixon (1959) reported a correlation of 0.86 for these traits. Corresponding genetic correlations were 0.88 and 0.77 in the present study. These significant and large correlations lend support to the conclusion that the pre-weaning growth rate will be a very good indicator of the growth rate from birth to weaning. This will enable the breeder to cull his calves earlier on the basis of pre-weaning growth rate.

Birth to pre-weaning growth rate was also related to the type and condition grades at pre-weaning and weaning. However this relationship was more pronounced with the type and condition grades at pre-weaning.

The correlations between the growth rates from pre-weaning to weaning and from birth to weaning were large and highlyh significant. This might be partially the result of the "part to whole" relationship since the growth rate for weaning included the growth rate for pre-weaning to weaning. The correlations between pre-weaning to weaning growth rate and type and condition grades were either small or less consistent.

The correlations between the birth to weaning growth rate and the type and condition grades were of considerable magnitude. The phenotypic, genetic and environmental correlations between birth to weaning growth rate and the weaning score were 0.39, 0.41 and 0.39, respectively, in the purebreds. Corresponding estimates reported by Koch and Clark (1955a) were 0.64, 0.50 and 0.67, respectively. Lehmann et al. (1961) reported a genetic correlation of 0.007 among these two

traits. The results of the present study suggest that if a calf is selected on the basis of its growth rate from birth to weaning then there will be a simultaneous improvement in the type also. It can be realized that the mutual interdependence of these factors makes the selection procedures in the beef cattle breeding operations easier.

The correlations among the pre-weaning type and condition grades and the weaning type and condition grades were large and significant in most cases. The phenotypic correlations between pre-weaning type score and the weaning type score were 0.68 for the purebreds and 0.66 for the grades. In other words about 49 per cent of the variation in weaning grade was linearly associated with the variation in the pre-weaning grade. These results suggest that the pre-weaning type score will be a fairly good indicator of the weaning type score. The phenotypic, genetic and environmental correlations between the pre-weaning type score and the pre-weaning condition grade were large.

The phenotypic and environmental correlations between the condition grade at pre-weaning and the type and condition grades at weaning were highly significant but not very large.

The correlations between the weaning type score and the weaning condition grade were large and significant. The phenotypic correlation was 0.65 for the purebreds and 0.68 for the grades. These results again indicate that the type score is influenced by the condition of the animal in the subjective evaluation of type.

V. APPLICATION OF RESULTS

The high heritability of birth weight and the positive genetic correlations between birth weight and the average daily gains from birth to pre-weaning and from birth to weaning indicate the predictive value of birth weight as an indicator of later performance. These findings point out that some attention should be paid to birth weight in selecting herd replacements. However, the breeder should remember that too much emphasis on birth weight in selection may lead to calving difficulties.

The relationship between the daily gains from birth to pre-weaning and birth to weaning is of immense value to the breeders since it could be used as a tool in guiding early selection. The high (significant) phenotypic and genetic correlations between the daily gains in these two periods and the high repeatability estimates of these two traits obtained in this study indicate that the average daily gain from birth to pre-weaning would be a reliable indicator of the weaning performance.

The economics of beef cattle operation is mainly based on how fast a calf grows from its birth. A beef cow has to be fed the year round whether she weans a light or a heavy calf and the cost of keeping her will vary but little with the weight of calf raised (Rice, 1957). The growth rates from birth to pre-weaning and birth to weaning besides serving as a selection criteria for culling calves are important to the breeder from another point of view. They can be used to indicate the milk producing capacity of cows. The high repeatability estimates for these two traits obtained in this study indicate that cows can be culled

on the basis of performance of their earlier calves.

The positive phenotypic correlations between the type scores at pre-weaning and weaning and between the condition grades at pre-weaning and weaning, indicate the possibility that the pre-weaning performance might serve as an indicator of the weaning performance for these traits.

CHAPTER V

SUMMARY AND CONCLUSIONS

The birth to weaning performance records of 471 purebred Hereford calves and 196 grade Hereford calves born in the Alcoa herd during the years 1957 through 1961 were studied. The calves were born from late January to early May and were not creep-fed. The traits studied were: (1) birth weight, (2) average daily gain from birth to July (pre-weaning), (3) average daily gain from July to October (pre-weaning to weaning), (4) average daily gain from birth to October (birth to weaning), (5) type score in July, (6) condition grade in July, (7) type score in October, (8) condition grade in October. The objectives of this study were: (1) to evaluate the influence of sex of calf, age of dam, month and year of birth on these traits, (2) to develop appropriate correction factors, (3) to estimate heritability and repeatability of these traits, (4) to calculate phenotypic, genetic and environmental correlations among the traits and (5) to evaluate the usefulness of taking weights and grades in July.

Sex of calf, age of dam, month and year of birth significantly influenced birth weight. Males were heavier than females at birth by 3.8 pounds and 3.0 pounds in the two groups. The pooled data indicated that the calves of two-year-old dams and three-year-old dams were about 13.4 pounds and 4.1 pounds lighter than calves of the older cows.

Sex of calf and age of dam significantly influenced the average

daily gains from birth to pre-weaning and birth to weaning. Male calves grew 1.07 and 1.09 times faster than female calves in the two periods. The growth rate increased as the age of dam increased from two years to six, seven or eight years.

Calves born in April and May made faster gains than those born in January, February and March. The daily gain for pre-weaning to weaning was lower than from birth to pre-weaning suggesting the possible influence of age of calf on growth rate.

The average pre-weaning and weaning type scores were 11.6 and 11.9 for the purebreds and 11.4 and 12.0 for the grades indicating an improvement in type in the latter period. Age of dam and month of birth significantly influenced the type scores in these periods. Calves born to two and three-year-old dams graded lower than those from the older dams. Calves born in January and February had higher weaning score in the purebreds while those born in January, February and April scored higher in the grades.

The average pre-weaning and weaning condition grades were 7.9 and 9.4 for the purebreds and 8.4 and 9.7 for the grades, indicating an improvement in condition in the latter period.

Sex of calf and age of dam significantly influenced the condition grade. Female calves graded higher in condition than the male calves by 0.4 to 0.8 grade point. Calves from two, three and four-year-old dams graded lower than those from the older dams. Month of birth had a significant influence on the condition grade in the purebreds. Calves

born in January and February scored higher than those born in the later months both at pre-weaning and at weaning.

Heritability and repeatability estimates have been calculated for the various traits and their significance has been explained. The high heritability estimates obtained in this study indicate that phenotype is a good indicator of the genotype or breeding value. The high repeatability estimates obtained for some of the traits indicate that culling of cows can be practiced on the basis of her first or first and second calves.

The phenotypic, genetic and environmental correlations have been evaluated and explained. The high correlation between birth weight and growth rate indicated that birth weight might be a good indicator of later performance. Similarly the growth rate from birth to pre-weaning might serve as an indicator of the weaning performance because of the high correlation between the growth rates in these two periods.

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