SOME FACTORS AFFECTING PRODUCTION TRAITS IN BRAHMAN CATTLE IN MEXICO

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
MANUEL VILLARREAL
1975

ABSTRACT

SOME FACTORS AFFECTING PRODUCTION TRAITS IN BRAHMAN CATTLE IN MEXICO

by

Manuel Villarreal

The purpose of this study was to determine the relative importance of some environmental factors influencing production traits and to estimate heritabilities for the traits after adjusting for the effects of these environmental factors in a Brahman herd in northeastern Mexico.

The data included records on 1130 Brahman calves born over a 13-year period 1961 to 1973 inclusive, at a ranch on the gulf coast of Mexico (Huasteca Potosina). The animals were kept under range conditions to two years of age. Traits studied were birth, weaning, yearling and two-year weight as well as average daily gain to weaning, weaning to yearling and yearling to two-year old. The influence of age and sex of calf (bulls or heifers), age of dam and year and month of birth on the traits studied

was analyzed by the method "Least Square analysis of data with unequal subclass numbers" (Harvey, 1960). All the factors were shown to have highly significant influences ($P < .01$) on the traits except age of dam did not have a significant influence on postweaning growth and two-year weight and month of birth did not have a significant effect on birth weight.

Least square estimates of the mean performance for each of the factor-trait combinations was calculated. The mean values found for age of dam effect on influenced traits increased with age of dam from 3 to 8 years of age and slightly declined after 10 years of age. An unusually high value was found for effect of the 2-years-old age of dam class. The later onset of puberty in Brahman cattle is the apparent reason for this unusual effect.

The least square means for sex showed that bulls were heavier than heifers by 1.2, 15.6, 30.8, 59 kg for birth, weaning, yearling and two-year weight, respectively.

Month of birth values indicated that calves born before summer (when the grazing conditions are best) had the highest weights and gains. Calves born during the rainy season (May through August), had the lowest growth rate. There was not a defined trend over the rest of the year.

Linear regression coefficients of .337, .295, and .323 kg per day were calculated for age at weaning, yearling and two-years-old weights, respectively.

Paternal half-sib heritability estimates were: birth weight, .27; weaning weight, .48; yearling weight, .44; two-year weight, .29; average daily gain to weaning, .40; ADG to yearling, .19; and ADG to two years .09.

SOME FACTORS AFFECTING PRODUCTION TRAITS IN BRAHMAN CATTLE IN MEXICO

By

Manuel Villarreal

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Animal Husbandry

1975

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd.)

LIST OF TABLES

INTRODUCTION

It is well documented that sources of variation such as age, sex, year, and month of birth of calves and age of dam have important influences on growth rate of beef cattle. The accuracy of any evaluation of genetic differences among animals is increased by adjusting the data for these environmental effects. The greatest increase in accuracy is obtained when the adjustment factors used have been developed from animals raised under the same conditions as those existing in the population being studied.

Estimates of the relative magnitude of these environmental sources of variation on Brahman cattle in Mexico are scarce. The population in this study is different enough in climate and management to assume differences in performance from populations previously studied.

We were interested in evaluating environmental sources of variation in this cattle population and evaluating genetic differences among animals after the effect of these environmental factors had been removed from sire effects. To do this a mathematical model was used which fit all of the above environmental effects and sire effects simultaneously.

The specific objectives of this study include the following:

1. Estimate the influence of the following factors:

    a. Age of dam

    b. Sex

    c. Age of offspring

    d. Month and year of birth

    On the following production traits of Brahman cattle:

    a. Birth weight

    b. Weaning weight

    c. Yearling weight

    d. Two-year weight

    e. Average daily gain to weaning

    f. Average daily gain to yearling

    g. Average daily gain to two years

2. Obtain heritability estimates for the same productive traits.

REVIEW OF LITERATURE

Very few studies have been conducted on Brahman cattle to evaluate the influence on performance of several factors such as age, sex, month and year of birth of calves and age of dam. These sources of variation are widely known as having an important effect on the performance of cattle.

For this review we have concentrated our efforts on studies dealing with beef breeds. The similarity in management and production goals among these breeds make the findings of the studies relevant to the present study.

In order to present this review in a logical manner we have chosen to study each of the sources of variation as affecting the traits of interest.

Birth Weight

Sex of Calf

It has long been noted that bull calves are significantly heavier at birth than heifers. Among the beef breeds the sex difference ranged from 1 to 3 kg. Among others, Burris and Blunn (1952); Dawson et al. (1947); Gregory et al. (1950); Koch and Clark (1955); Koch et al. (1959); and Brink et al. (1961) have contributed to establish this.

Burris and Blunn (1952) found the weight difference among sexes to be associated with the longer gestation length of bull calves. They also reported a net difference even when the weights are adjusted for gestation length.

Birth weights by breed and sex are reported by several authors as shown in Table 1.

TABLE 1

SUMMARY OF BIRTH WEIGHTS OF BEEF CATTLE BY BREED AND SEX[a]

Breed	Male	Female	Source
Hereford	31.8	29.7	Burris & Blunn (1952)
Hereford	32.0	31.2	Dawson et al. (1947)
Hereford	35.5	33.7	Brinks et al. (1961)
Angus	30.5	28.1	Burris & Blunn (1952)
Angus	28.3	26.3	Alexander & Bogart (1961)
Shorthorn	30.3	28.1	Burris & Blunn (1952)
Indobrazil	27.7	25.2	Mattoso (1959)
Nellore	26.2	23.3	"
Guzerat	28.3	26.7	"
Git	21.7	20.2	"

[a]kg.

Age of Dam

The research studying the influence of age of dam on birth weight in beef cattle conclude in general that the birth weights of calves increased with age of dam until 6 to 7 years of age, the greatest change being between the ages of 3, 4, and 10 years or older (Burris and Blunn (1952), and Koch and Clark (1955). It has been reported by Dawson et al. (1947) in a regression study of birth weight on age of dam a linear increase of .100 kg for each increase of one month in the age of dam to six years of age. The regressions done separately for males and females did not deviate significantly from linearity.

Month of Birth

Koch and Clark (1955) found that calves born later in the calving season were slightly heavier at birth. This slight difference could be due to better pasture conditions or possibly to the weight difference caused by variation in gestation length of cows. The regression of birth weight on weaning age reported was -.04 kg per day.

Everett and Magee (1965) reported significant effects of years and seasons on birth weight in Holstein calves. Brown and Galvez (1969) found differences due to season of birth on birth weight. Beltran et al. (1975) reported a significant year and month of birth effect on birth weight of Brahman cattle. In general these authors agree with Koch and Clark (1955) indicating heavier weights at birth for calves born later in the calving season. In these studies the calving seasons were about 90 days in the spring.

Average Daily Gain to Weaning

Sex of Calf

Several authors have reported that sex has a highly significant influence in preweaning growth. Marlowe et al. (1965) and Marlowe and Gaines (1958) found that steer calves grew approximately 6% faster than heifer calves and bull calves grew approximately 6.6% faster than steer calves. This represents in a 210 adjusted weaning weight that males outweigh heifers in 12.23 kg and 22.70 kg respectively. These differences were somewhat larger when all calves were creep fed.

Brinks et al. (1961) reported a difference of 0.04 kgs in ADG in favor of steers over heifers. Koch et al. (1959) found that bull calves gained 0.050 kg faster per day or 1.075 times greater than heifers from birth to weaning.

Rollins and Guilbert (1954) found that when growth was at a high level throughout the season, bulls gained .06 kg per day faster than heifers during the first 120 days. Cunningham and Henderson (1965) in a similar study found a difference of 0.05 kg in ADG between bulls and steers and a difference of .06 kg between steers and heifers.

Age of Dam

Brown (1960), Cunningham and Henderson (1965), Marlowe et al. (1965) and Francoice et al. (1973) concluded that calves' gains increased with age of dam from 2 to 7 years. There was no significant difference in gains of calves from 7 through 11 year old cows. Calf gains decreased slightly as cow age increased beyond 11 years. The values reported by Cunningham and Henderson (1965) are presented in Table 2.

TABLE 2

ESTIMATE OF AGE OF DAM EFFECT
ON PREWEANING GROWTH
(Cunningham and Henderson (1965))

Age of Dam (years)	ADG[a]
2	-.118
3	-.072
4	-.031
5	-.016
6	-.011
7-10	.00
>10	-.013

[a]kg.

Month of Birth

Marlowe et al. (1965) pointed out the influence of month of birth in the preweaning growth. Calves dropped during March and April made fastest gains when other environmental factors were held constant. Calves born during August and September made the slowest gain. This difference was approximately 0.11 kg per day for non-creep calves. Creep feeding tended to decrease the magnitude of these differences.

Rollins and Guilbert (1954) reported that calves born during August through November 15 gained .12 kg per day less from birth to 4 months of age than calves born during March through May. Calves born from November 15 through February were intermediate in growth rate. Similar findings were reported by Lehmann, et al. (1961).

Koch and Clark (1955) reported a non-significant influence of time of birth on preweaning growth. Nelms and Bogart (1956) and Swiger et al. (1962) reported that early calves gained at a considerably higher rate than did calves born late in the calving season.

Year of Birth

The effect of year has been found highly significant by Cunningham and Henderson (1965) and Marlowe et al. (1965). The last study also reported a breed by year interaction for ADG to weaning.

Weaning Weight

Age at Weaning

The comparison of animals for genetic differences requires that the calves are compared at a constant age. Some correction factors are needed to put the calves on an equal basis. According to Marlowe et al. (1965) as calves increased in age their gains decreased. In the same study it was shown that growth is essentially linear for non-creep-fed calves from 120 days to weaning.

A previous study by Swiger et al. (1962) reported a linear regression on age from birth to 130 days, but a significant curvilinear effect from 120 to 200 days; however, their age and seasonal effects were confounded. Johnson and Dunkel (1951) reported a linear correction factor of .460 kg per day based on 182 days weaning weight. Kroger and Knox (1945) found the regression of weight on age to be .602 kg per day. Botkin and Whatley (1953) reported a value of .66 kg per day for Hereford calves. Burgess et al. (1954) found a value of .75 kg increase in weight for each day increase in age of calf.

Sex of Calf

As a consequence of the higher growth rate of males they tend to have higher weights at weaning. In general reports in the literature indicate an average sex difference range from 12-30 kg. Studies that included all three sex classes indicate an average difference of 15-30 kg between steers and bulls and of 12-20 between steers and heifers. It is also suggested that the bull-steer difference can be affected by the selection involved in retaining the better male calves as bulls. Koch and Clark (1955); Botkin and Whatley (1953), Burgess et al. (1954); Brinks et al. (1961); Cunningham and Henderson (1965); and Marlowe et al. (1965) have discussed the effect of sex of calf on weaning weight.

Age of Dam

Weaning weight and preweaning growth are an expression of the genes trasmitted to the calves and the maternal environment they are provided. Physiological change in function such as increased milk production which may accompany the aging process might be expected to influence the offspring's environment.

Research has shown that age of dam affects the weaning weight of calves presumably through changes in udder development, milking ability and cow's ability to withstand the rigors of range conditions (Koch, 1951).

In general the researchers agree that the weaning weight increased steadily from two to six years of age for the dam and then declined after 10 years. Botkin and Whatley (1953), and Koch and Clark (1955), Burgess et al. (1954), Rollins and Guilbert (1954), Rollins and Wagnon (1956), Kroger and Knox (1945b), Lehmann *et al*. (1961), Francoise *et al*. (1973) and Cundiff *et al*. (1966) have contributed to the study of this matter and presented different sets of constants.

Month of Birth

Reports in the literature are in close agreement about the effect of month of birth. Brown (1958 and 1960), Marlowe and Gaines (1958), Marlowe (1962), Marlowe *et al*. (1965) and Cundiff *et al*. (1966) have concluded that calves born in February, March and April had an advantage in adjusted 205-day weaning weights over those born in any other season. Calves born in August, September and October were at the greatest disadvantage. There was a steady increase in weights of calves born from November through March.

Year of Birth

The effect of year on weaning weight has been reported to have a highly significant effect by Brown (1960), Swiger (1961) and Cardellino and Frahm (1971).

Average Daily Gain from Weaning to Yearling

Few reports are found in the literature in which studies of post-weaning gain had been conducted. Most of the research has been oriented to a lifetime growth rate (birth to final weight) hence the factors affecting pre-weaning growth would be of similar importance. We will present a review of literature in both cases.

Sex of Calf

Guilbert and Gregory (1952), Dahmen and Bogart (1952) and Swiger (1961) have reported a gain difference between heifers and bulls of up to .25 kg. The study of Swiger included comparison in various post-weaning periods of the sex differences. He found an increasing trend in gain difference between sexes. In these studies all animals were fed the same ration.

Age of Dam

Some studies have reported significant age of dam effects on the lifetime growth rate of yearling cattle (Koch and Clark, 1955; Shaller and Marlowe, 1967; and Taylor, 1967). In a study by Waugh and Marlowe (1970) it was shown that the size of coefficients reported were only one half to three-fourths the size of the constants estimates reported by Marlowe et al. (1965) for weaning calves, the decrease in the size of the constants appears to be simply a result of spreading the differences at weaning over an additional period of the animal's life. This is in agreement with the findings of Swiger et al. (1963) who reported no significant effect of age of dam on gains during the post-weaning period. A nonsignificant effect of age of dam on ADG to yearling was also reported by Brinks et al. (1962).

Month of Birth

According to Waugh and Marlowe (1970) month of birth appeared to have no significant influence on the continuous growth of yearling cattle.

Yearling Weight

Age of Yearling

Brinks et al. (1962) reported age of animal to have a significant effect on final weight. The regression of yearling weight found was .754 kg per day based on a 376-day yearling age.

Sex of Calf

Brown et al. (1956a and 1956b) reported an average yearling weight difference of 60 kg between bulls and heifers at yearling. The studies on ADG to yearling mentioned earlier support this difference given the higher lifetime bull's gain.

Age of Dam

Koch and Clark (1955) reported that the yearling weight increased progressively with the age of dam until the cow reached six years old. However, other studies suggest that this may be due to the effect of age on preweaning growth (mentioned when reviewing post-weaning gain.)

Month of Birth

Waugh and Marlowe (1970) in a study on supplemented yearling cattle reported a nonsignificant influence of month of birth on continuous growth.

Year of Birth

Waugh and Marlowe (1970) reported a highly significant year effect on yearling weight.

Two-Year Weight

No reports are found in the literature about influences on cattle performance to twoyears of age. The characteristics of rapid growth of the British origin breeds studied, the intensive post-weaning management in contrast with the lower growth on range conditions of Brahman cattle, limit its importance.

We believe that the sources of variation with effect on post-weaning growth will tend to have a similar effect on growth and weight to two years old.

Interactions of Certain Factors of Calf Performance

Several authors have conducted studies to determine the importance of interactions in beef cattle data, since the assumption of zero interactions may lead to biased estimates of the effects studied. Landblom (1954) reported a significant interaction of sex and age of dam using an approximate method for testing the significance of the two-factor interaction and the three-factor interaction involving sex, age of dam, and year. Swiger (1961) tested the significance of all two-factor interactions involving age of calf, year, sex and age of dam, and found only the interactions age of calf by sex and age of dam by year to be significant. Panish et al. (1961) reported a significant sex by year interaction, but no evidence of a sex by sire interaction within ranches and years. Vernon et al. (1964) reported the interaction between age of dam by years. The effects of age of dam were larger in poor years. Harwin et al. (1966) in a study on all the two-factor interactions involving year, sex, mating system, age of dam found the interactions effects of year x age of dam, sex x age of dam, sex x mating system, and year x age of calf significant. Schaeffer and Wilton (1974) also reported a significant age of dam x sex interaction and age of dam by level of herd performance. Other studies have reported a nonsignificant age of dam by sex, age of dam by creep feeding and sex of calf by creep feeding interactions. See Cunningham and Henderson

(1965), Cundiff *et al.* (1966), Cardellino and Frahm (1971), Marlowe and Gaines (1958). A study on all three-way interactions involving age of dam, sex, and environmental factors was reported by Schaeffer and Wilton (1974). There was no evidence that three-way interactions were significant except for age of dam by sex by feeding system for Herefords.

The practical importance of these interactions is limited to the extent of the degree of improvement by using them on the beef cattle selection programs. None of the interactions appear to be large enough to justify including them in correction factors used to adjust for environmental effects. Such corrections are not yet recommended by the Beef Improvement Federation (1974).

Heritability Estimates

The literature contains numerous studies of heritability estimates for economic traits in beef cattle. Warwick (1958) summarized those which were known up until that time. Using the Warwick's summary as a base

Dunn (1968) reviewed the literature. His attempt to summarize heritability studies since Warwick completed his summary are shown in Table 3.

TABLE 3

SUMMARY OF HERITABILITY ESTIMATES FOR BEEF CATTLE CHARACTERISTICS

Character	No. of Estimates	Av. of Estimates	Range of Estimates
Birth Weight	17	44	11 - 100%
Weaning Weight	40	35	-12 - 100
Final Feed Lot Weight	17	55	2 - 100
Long Yearling Pasture Weight	10	40	10 - 71

The estimate is a simple arithmetic average of the values reported by the research workers. No attempt was made to adjust values to number of head of cattle included and variance of the estimates. When more than one value was reported (different sexes, different breeds, different planes of nutrition, etc.) one combined average value was obtained.

Gregory (1961), and Clark et al. (1963) presented summaries similar to that of Warwick.

Petty and Cartwright (1966) prepared a summary of genetic and environmental statistics for growth and conformation traits of young beef cattle. They presented unweighted and weighted averages of paternal half-sib estimates. The weighted average estimates were obtained by weighting them with either the number of sires included in each estimate or the estimated number of sires based on the average number of offspring per sire in the other estimates of that trait. These estimates are essentially the same as those reported by Dunn (1968). The authors tried to select the most independent and pertinent information available dating back to the first studies (1946).

Very few reports are found in the literature on heritability estimates of productive traits in Brahman cattle. Authors and estimates are presented in Table 4. All these estimates were obtained by paternal half-sib method.

TABLE 4

SUMMARY OF HERITABILITY ESTIMATES REPORTED FOR BRAHMAN CATTLE

AUTHOR	TRAIT			
	Birth Weight	Weaning Weight	ADG (weaning)	Feed Lot Gain
Berruecos and Robison (1968)	.41±.16	.47±.18	.43±.17	--
Miquel and Cartwright (1963)	.16	.44	--	--
Beltran _et al_. (1975)	.40±.14	--	--	--

DATA AND ANALYSIS METHODS

Data

The performance records of 1,130 Brahman calves raised at a privately owned ranch located on the Gulf Coast of Mexico (Huasteca Potosina) during the period of 1961 through 1973 were used in this study.

The climate of the area of study is classified as Aw according to Köppen's climatic classification. This tropical climate is characterized by a dry and rainy season with 75% of the average annual rainfall, 1200 mm., occurring from May to November.

The ranch is a purebred operation under resident management. The animals graze on improved pasture of tropical grasses including Pangola (*Digitaria decumbes*) and Guinea (*Panicum maximun*) with limited supplementation during adverse weather conditions.

The calves were weaned in approximately the seventh month after the month of birth.

Data were collected by the ranch personnel supervised by the staff of the Mexican Livestock Research Institute, Mexican Department of Agriculture (Instituto Nacional de Investigaciones Pecuarias, Palo Alto D.F.). The information available for each animal was the following: identification number, sire, dam, age of dam, birth date, birth weight (BW), weaning weight (WW), yearling weight (YW), two-year weight (TYW) and days of age for each of the weights.

The average daily gains were calculated in the following manner:

To weaning:

$$ADW = (WW - BW) / \text{weaning age}$$

From weaning to yearling:

$$ADY = (YW - WW) / (\text{Yearling age-weaning age})$$

From yearling to two years old:

$$ADT = (TYW - YW) / (\text{2 years age-yearling age})$$

Method of Analysis

Model

A mathematical model that would describe the sources of variation was selected for each of the traits of interest. The objectives of the study and the data available determine, in part, the elements of the model.

For traits weaning weight, yearling weight and two-year-old weight the model was Model I.

Model I

$$y_{ijkmnp} = \mu + B_i + \alpha_j + \gamma_k + \rho_m + \ell_n + b_1 X_{ijkmnp} + e_{ijkmnp}$$

Where:

Y_{ijkmnp} = an observation on weaning weight, yearling weight or two years weight

μ = constant to all observations

B_i = a random effect common to progeny of the i^{th} sire

$i = 1 \ldots 27$ B_i assumed to be normally independent, distributed with mean zero and variance σ_s^2 which is symbolized as NID $(0, \sigma_s^2)$

α_j = fixed effect due to j^{th} age of dam

$j = 2 \ldots 10, >10$

γ_k = fixed effect due to k^{th} sex

$k = 1, 2$; 1 = bulls, 2 = heifers

ρ_m = fixed effect due to m^{th} year

$m = 1...13$

ℓ_n = fixed effect due to n^{th} month

$n = 1...12$

b_1 = regression coefficient of y_{ijkmnp} on age

x_{ijkmnp} = age of the $ijkmnp^{th}$ observation

e_{ijkmnp} = random error associated with $ijkmnp^{th}$ observation

assumed to be: $e \sim NID(0, \sigma_e^2)$

For traits birth weight, average daily gains to weaning, yearling and two years old, Model II was used. Model II was the same as Model I except the co-variant for age was deleted.

Interactions were not included in the model because work by other authors has shown that the interactions of these factors were not of enough biological importance to include them in any correction of data for performance record programs.

It was decided to use the age as a co-variant rather than adjust the weights to a constant age by using the average daily gain for each animal for some fixed number of days.

The ages of dam were from 2 to 10 years and cows over 10 years of age.

The calving was spread through the year with less number of births during September, August and October. The distribution of births by age of dam is shown in Table 5.

TABLE 5

DISTRIBUTION OF BIRTHS BY AGE OF DAM

Age of Dam	No. Births
2	16
3	136
4	106
5	87
6	99
7	102
8	103
9	87
10	73
>10	321

The method of analyzing used was the one described by Harvey, "Least Square Analysis of Data with Unequal Subclass Numbers" (1960).

The method of Least Squares is based upon a philosophy of deriving estimates which minimize the probability of error, which can be expressed in the following way:

$$\sum_{i=1}^{n} \left[Y_i - E\ (Y_i) \right]^2$$

The idea is to minimize predictor error by minimizing the squared error. The process is described as follows in matrix notation. Our basic model is of the form:[1]

$$\underline{y} = \underline{Xb} + \underline{e}$$

Where $\underline{y}$ is an n x 1 vector of observations; $\underline{b}$ is a $\underline{p}$ x 1 vector of parameters (levels of factors); and $\underline{e}$ is a vector of random error terms. The matrix $\underline{X}$ is n x p of o's and 1's. It is called the designed matrix or the incidence matrix, because the location of o's and 1's throughout its element represents the incidence of terms of the model among the observations and hence of the classification in which the observation lie. In Model I where age

---

[1]Underlined small case letter = vector; underlined large case letter = matrix.

is used as a relationship variable, the value of the observation is used instead of the 1 or o of the classification variables.

Using the calculus procedures to obtain the minimum value for Σe^2 we can derive a set of normal equations used to solve for $\underline{b}$. In matrix notation the normal equations were:

$$
\begin{array}{ccccccc}
\tilde{\mu} & \tilde{B}_i & \tilde{\alpha}_j & \tilde{\gamma}_k & \tilde{\rho}_m & \tilde{\ell}_n & \hat{b}_1
\end{array}
$$

$$
\begin{bmatrix}
n_{.....} & n_{i....} & n_{.j...} & n_{..k..} & n_{...m.} & n_{....n} & X_{.....} \\
n_{i....} & n_{i....} & n_{ij...} & n_{i.k..} & n_{i..m.} & n_{i...n} & X_{i....} \\
n_{.j...} & n_{ij...} & n_{.j...} & n_{.jk..} & n_{.j.m.} & n_{.j..n} & X_{.j...} \\
n_{..k..} & n_{i.k..} & n_{.jk..} & n_{..k..} & n_{..km.} & n_{..k.n} & X_{..k..} \\
n_{...m.} & n_{i..m.} & n_{.j.m.} & n_{..km.} & n_{...m.} & n_{...mn} & X_{...m.} \\
n_{....n} & n_{i...n} & n_{.j..n} & n_{..k.n} & n_{...mn} & n_{....n} & X_{....n} \\
X_{.....} & X_{i....} & X_{.j...} & X_{..k..} & X_{...m.} & X_{....n} &
\end{bmatrix}
\begin{bmatrix}
\tilde{\mu} \\ \tilde{B}_i \\ \tilde{\alpha}_j \\ \tilde{\gamma}_k \\ \tilde{\rho}_m \\ \tilde{\ell}_n \\ \hat{b}_1
\end{bmatrix}
\begin{bmatrix}
Y_{.....} \\ Y_{i....} \\ Y_{.j...} \\ Y_{..k..} \\ Y_{...m.} \\ Y_{....n} \\
\end{bmatrix}
$$

$$\sum_{ijkmnp}\Sigma\Sigma\Sigma\Sigma\Sigma X^2_{ijkmnp}$$

$$\sum_{ijklmn}\Sigma\Sigma\Sigma\Sigma\Sigma X_{ijkmnp} Y_{ijkmnp}$$

The normal equations for Model II were the same except that the column and row correspondent to $\hat{b}_1$ was deleted.

The $\underline{X}'\underline{X}$ matrix is not of full rank because the sum of the equations for each set is equal to the sum of each other set and to the $\tilde{\mu}$ equation.

Thus the inverse does not exist and the equations can not be solved. In order to obtain a set of solutions some restrictions must be imposed. One method used to obtain a full-rank matrix is to impose the restrictions that sum of effects for each set is equal to zero.

For Model I the restrictions are:

$$\sum_i \hat{B}_i = \sum_j \tilde{\alpha}_j = \sum_k \tilde{\gamma}_k = \Sigma \tilde{\rho}_m = \Sigma \tilde{\ell}_n = 0$$

When restrictions are imposed the coefficients of one equation in each of the sets must be subtracted from other coefficients in the set by columns and then by rows. This gives a restricted $\underline{X}'\underline{X}$ matrix and corresponding Right Hand Side (R.H.S.).

In our study the restrictions required to develop the restricted $\underline{X}'\underline{X}$ matrix and R.H.S. were imposed as the individual data were read into the computer. To do this we generated variables by setting a specific dummy variable equal to 1 for each of the d-1 parameters within a set or setting all the dummy variables associated with the set equal to -1 for the dth parameter (where d is the number of parameter in any set). This was done on a CDC 6500 computer using a subroutine trans.

The rest of the analysis was executed using the computer programs "ICMATRIX" and "LS" of the M.S.U. Stat System.

The reduced least square equations were inverted and solved using ordinary procedures to obtain a set of solutions of the constants $\tilde{\mu}$, $\tilde{B}_i$ $\tilde{\alpha}_j$ $\tilde{\gamma}_k$ $\tilde{\rho}_m$ ℓ_n and $\hat{b}_1$ when they apply.

The reduced constant of any set is equal to the sum of the estimated effects in the set, with the sign changed, e.g.,

$$\tilde{B}_d = - \sum_{i=1}^{d-1} B_i$$

The subclass mean (mean effects) were computed in the following manner for Model I.

$$\hat{\mu}_j = \tilde{\mu} + \tilde{\alpha}_j + \hat{b}_1 \bar{x}$$

$\bar{x}$ = unadjusted age mean.

For Model II,

$$\hat{\mu}_j = \tilde{\mu} + \tilde{\alpha}_j$$

The calculations to obtain sums of square for each set of effects was done following the procedure outlined by Harvey (1960). Thus the value for each set was:

$$\text{Sum of Squares} = \underline{\tilde{b}}' \, \underline{Z}^{-1} \, \underline{\tilde{b}}$$

Where $\underline{\tilde{b}}'$ is a row vector of the estimates for a given set (such as the $\tilde{\alpha}_j$); $\underline{Z}^{-1}$ is the inverse of the segment of the inverse of the $\underline{X}'\underline{X}$ matrix corresponding by row and column, to this set of estimates; and $\underline{\tilde{b}}$ is a column vector of the set of estimates. The sum of squares for a set is equal to the reduction in sum of squares due to fitting all estimates minus the reduction in sum of squares due to fitting all estimates except the set being considered.

Heritability Estimates

Heritability in the narrow sense is defined by Lush (1948) as:

$$h^2 = \frac{\sigma_G^2}{\sigma_H^2 + \sigma_E^2}$$

where: σ_G^2 = variance due to addititive gene effects

σ_H^2 = variance due to all gene effects

σ_E^2 = environmental variance

The estimates of variance components from half-sib analyses are widely used to estimate heritability.

$$h^2 = \frac{4\,\hat{\sigma}_s^2}{\hat{\sigma}_s^2 + \hat{\sigma}_w^2}$$

This is based on the expected values for sire component (σ_s^2) which is approximately equal to 1/4 σ_G^2 and the within sire component (σ_w^2) which contain the random environmental variance, the dominance variance, three-fourths of the additive genetic variance and most of the epistatic variance.[1]

---

[1] σ_s^2 also includes a small amount of the epistatic variance due to the interactions of additive effects of the genes on different loci. These are usually considered to be so small that they are not considered when heritabilities are estimated.

The mean square estimates of variance from our analysis were used according to the following partition of the variance to solve for $\hat{\sigma}_s^2$ and $\hat{\sigma}_w^2$

Source of Variation	E[MS]
Between Sires	$\sigma_w^2 + k_o \sigma_s^2$
Within Sires	σ_w^2

$$\hat{\sigma}_s^2 = \left(\frac{MS_B - MS_W}{K_o} \right)$$

where:

k_o = Coefficient for Unequal Number of Progeny per Sire calculated as described by Snedecor (1967)

$$k_o = \frac{1}{s-1} \left(n. - \frac{\Sigma n_i}{n.} \right)$$

where:

s = number of sires

n. = total number of individuals

n_i = number of individuals with ith sire.

The approximate value for standard error of heritability was calculated as suggested by Swiger et al. (1964). Normality of the intraclass correlation t was assumed.

$$t = \frac{\hat{\sigma}_s^2}{\hat{\sigma}_s^2 + \hat{\sigma}_w^2}$$

$$S.E.\ (h_s^2) = 4 \sqrt{\frac{2(n.-1)\ (1-t)^2\ [1+(k_o-1)\ t]^2}{k_o^2\ (n.-s)\ (s-1)}}$$

RESULTS AND DISCUSSION

Factors Affecting Production Traits

The analysis of variance for all the factors considered are shown in Table 6. All the sources of variation were significant for most traits. The influence of each independent variable on the dependent variable is presented and discussed individually.

Sex of Calf

The effect of sex was highly significant on all the traits studied. Least squares means for sex are shown in Table 7. This is in agreement with the findings of all the studies of this nature. The difference between sexes tended to increase during the lifetime; this has also been found in other studies.

The greater growth of males when compared to females can be attributed to the genetic differences with respect to sex chromosomes. This genetic difference directly affects the physiological and biochemical functions of the animal which are related to growth.

TABLE 6

ANALYSIS OF VARIANCE FOR FACTORS INFLUENCING VARIOUS BEEF PRODUCTION TRAITS[a]

SOURCE	MEAN SQUARE							
	d.f.	BW	WW	YW	TYW	ADW	ADY	ADT
Sex	1	326.8**	73386.4**	213642.7**	772713.6**	.73**	2.33**	2.23**
Age of dam	9	24.7**	3971.2**	3335.3**	2468.0[n.s.]	.09**	.003[n.s.]	.008[n.s.]
Years	12	99.4**	3341.4**	13543.7**	3244.0**	.18**	.50**	.18**
Month	11	9.0[n.s.]	3124.8**	4548.9**	5963.0**	.05**	.13**	.01**
Sires	26	27.6**	3079.7**	4318.7**	6137.0**	5.44**	3.06**	1.90**
Age[b]	1(0)	-	49043.5**	48828.7**	299472.0**	-	-	-
Error[b] (1069)	(1070)	7.0	472.8	725.9	1468.0	.013	.014	.005

[a]The symbols for the traits are: BW=birth weight; WW=weaning weight; YW=yearling weight; TYW=Two-year weight; ADW=average daily gain to weaning; ADY=average daily gain to yearling; ADT=average daily gain to two-year old. All weights are in kg.

[b]Age at weaning one year and two years was fit as a covariable for weight at these times.

**Each source of variation was significant at $P < .01$.

[n.s.]Nonsignificant.

TABLE 7

LEAST SQUARE ESTIMATES OF THE MEAN PERFORMANCE FOR SEX[a]

	TRAIT[b]						
Sex	BW	WW	YW	TYW	ADW	ADY	ADT
Female	25.4	174.2	214.7	307.2	.684	.278	.324
Male	26.7	189.9	245.5	366.2	.742	.384	.425

[a]All weights are in kg.

[b]Traits symbols as in Table 6.

Age of Dam

The age of dam had a highly significant effect on BW, WW, YW, and ADG to weaning. Least square means for age of dam effect are shown in Table 8. The mean values of all the traits in general increased with age of dam until 7 to 8 years of age. This is in general in agreement with the reports in the literature.

We notice a non-significant effect of age of dam on post-weaning growth. This is also in accordance with the reports of Swiger *et al*. (1963) and Brinks *et al*. (1962). However, the age of dam effect could still be

TABLE 8

LEAST SQUARE ESTIMATES OF THE MEAN PERFORMANCE FOR AGE OF DAM[a]

	TRAIT[b]						
Age of Dam	BW	WW	YW	TYW	ADW	ADY	ADT
2	26.2	180.8	230.1	339.9	.747	.347	.389
3	25.1	169.3	218.8	330.6	.649	.339	.391
4	25.9	176.7	224.4	331.6	.680	.322	.375
5	26.6	184.3	231.8	337.0	.727	.329	.370
6	26.2	186.0	232.4	334.7	.723	.319	.361
7	26.4	187.4	235.2	337.0	.736	.329	.362
8	26.0	188.4	236.7	345.6	.743	.328	.376
9	26.0	185.5	232.8	339.8	.725	.334	.371
10	26.4	184.2	232.2	339.2	.710	.329	.377
>10	26.5	177.8	226.0	331.2	.693	.328	.374

[a]All weights are in kg.

[b]Trait symbols as in Table 6.

noticed on yearling weight. The higher value found for the 2-years old age of dam class is unusual. There is no report on this condition in the literature. Warnick et al. (1956) and Reynolds et al. (1963) reported that first estrus occurred later in Brahman cattle than in British origin breeds or their crossbreds in the Gulf Coast area of the United States. Plasse et al. (1968) in a thorough study on the reproductive behavior of Brahman cattle in Florida reported an average age at puberty of 19.4 months with a range of 14 to 24 months. In this study also was reported a correlation between 205-day weaning weight and age of puberty of -.45. This indicates that just the fastest growing heifers would be able to calve by the 2-years old age, hence they form a selected group of cows. Apparently this select group of cows has the genetic potential and size and development for the mothering ability as two-year-olds to produce heavier calves at that age than all the cows to produce calves as three-year-olds.

Month of Birth

The effect of month of birth was highly significant in all but one of the traits studied. Birth weight was not affected by month of birth. This is contrary to what has been indicated in the literature. Most of these reports, however, are from studies of herds with a defined calving season. It was our interest to find out the better months for calving with the purpose of recommending a herd management change. Further study is recommended. Grouping the months in seasons would be a possible way to detect a broader influence.

For all the other traits the influence of month of birth was in general the same. Calves dropped during the rainy season (May through August) made the lowest gains and had the lowest weights. This indicates that those calves born before favorable summer grazing conditions had a better environment during their lifetime. Least square means for month of birth effect are presented in Table 9. Rollings and Guilbert (1954); Lehman *et al*. (1961) and Marlowe *et al*. (1965) in studies of preweaning growth also reported a similar month of birth effect indicating that calves born in the early spring made fastest gains. Waught and Marlowe (1970) reported a non-significant influence of month of birth on postweaning growth which is not in agreement with what we found. Marlowe *et al*. (1965) in a study on preweaning growth reported that creep feeding tended to decrease the magnitude of the differences of the

TABLE 9

LEAST SQUARE ESTIMATES OF THE MEAN PERFORMANCE FOR MONTH OF BIRTH[a]

MONTH	TRAIT[b]						
	BW	WW	YW	TYW	ADW	ADY	ADT
J	26.1	184.3	227.1	339.8	.749	.304	.371
F	26.8	196.6	242.0	358.3	.792	.338	.388
MR	25.8	186.9	227.3	341.3	.748	.274	.376
AP	26.2	185.0	220.4	331.8	.732	.244	.357
MY	26.4	181.1	219.4	327.8	.741	.270	.358
JN	26.2	176.6	219.3	334.8	.706	.287	.378
JY	26.5	170.6	219.8	324.4	.684	.339	.369
AU	25.6	166.8	210.6	316.9	.671	.319	.361
S	25.3	166.3	264.1	348.6	.629	.599	.459
O	26.7	197.5	249.7	353.2	.682	.361	.375
N	25.2	182.9	225.4	320.0	.697	.313	.351
D	25.8	174.5	224.6	330.1	.692	.348	.494

[a]All weights are in kg.

[b]Trait symbols as in Table 6.

effect of month of birth on weaning weight. The range conditions of the animals in this study may be the reason why the month of birth may have a higher effect on post-weaning growth.

Year of Birth

The influence of year of birth was highly significant on all the traits studied. This study covers data from a 13 -year period. It is logical to suppose a greater influence of the climatic conditions on rage cattle without supplementation. Few studies are found in the literature on the influence of year because most of them are being done on a within-year basis, reducing the source of variation represented by year. The estimation of specific year constants is not of any practical use for future data analysis since these years will not occur again. The important point is that the specific years involved in any study will probably be an important source of variation.

Age of Animal

The age of animal used as covariate on weaning, yearling and two-year weight had highly significant effect.

Linear regression coefficients of .337, .295, and .323 kg per day for weaning yearling and two-year-old weight were found based on 216, 363, and 640 days respectively. These values are in general smaller than those reported for other breeds in the literature.

Heritability Estimates

The paternal half-sib heritability estimates computed in this study are shown in Table 10.

TABLE 10

PATERNAL HALF-SIB HERITABILITY ESTIMATES AND STANDARD DEVIATIONS

Trait[a]	Estimate
BW	.27 ± .10
WW	.48 ± .14
YW	.44 ± .13
TYW	.29 ± .10
ADW	.40 ± .12
ADY	.19 ± .07
ADT	.09 ± .05

[a]Symbols as in Table 6.

All the values but two-year weight and average daily gain to two years old agree reasonably well with the average estimates summarized and presented in the Literature Review. The values found for TYW and ADT are smaller than those reported for feed lot gain and final weight. A major cause of this difference is due to maintaining the animals on pasture with minimum supplementation. Other heritability estimates obtained on Brahman cattle are very similar to those of this study. The birth weight heritability value is lower than previously reported by Berruecos and Robison (1968) in Mexico and Beltran (1975) in Venezuela but higher than reported by Miquel and Cartwright (1963) in Texas.

SUMMARY

The data included records on 1130 Brahman calves born over a 13-year period, 1961 to 1973 inclusive, at a ranch on the gulf coast of Mexico (Huasteca Potosina). The animals were kept under range conditions to two years of age. Traits studied were birth, weaning, yearling, and two-year weight, as well as average daily gain to weaning, weaning to yearling, and yearling to two-year old. The influences of age and sex of calf, age of dam and year and month of birth on the traits studied were analyzed.

All the factors were shown to have highly significant influences ($P < .01$) on the traits studied except age of dam did not have a significant influence on post-weaning growth and two-year weight and month of birth did not have a significant effect on birth weight.

Least square estimates of the mean performance for each of the factor trait combinations was calculated. The mean values found for age of dam effect on influenced traits increased with age of dam from 3 to 8 years of age

and slightly declined after 10 years of age. An unusually high value was found for effect of the two-years-old age of dam class. The later onset of puberty in Brahman cattle is a major reason. The least square means for sex showed that bulls were heavier by 1.2, 15.6, 30.8, 59 kg for birth, weaning, yearling, and two-year weight respectively. Month of birth mean values indicated that calves born before summer grazing conditions had the highest weights and gains, calves born during the rainy season (May through August) had the lowest. There was not a defined trend over the rest of the year.

Linear regression coefficients of .337, .295, and .323 kg per day were calculated for weaning, yearling and two-years-old weight based on a mean of 216, 363, and 640 days, respectively.

Paternal half-sib heritability estimates were: birth weight, .27; weaning weight, .48; yearling weight, .44; two-year weight, .29; average daily gain to weaning, .40; ADG to yearling, .19, only, and ADG to two years, .09.

BIBLIOGRAPHY

BIBLIOGRAPHY

Alexander, G. I. and R. Bogart. 1961. Effect of inbreeding and selection on performance characteristics of beef cattle. J. Anim. Sci. 20:702.

Beef Improvement Federation Recommendation. 1974. Guidelines for uniform beef improvement programs. Extension Service, USDA. Wash. D.C.

Beltran, J., D. E. Franke, D. Plasse and O. Verde. 1975. Influence on early Brahman calf growth. J. Anim. Sci. 33:245. (Abstr.)

Berrvecos, J. M. and O. W. Robinson, 1968. Preweaning Growth in Brahmans. J. Anim. Sci. 27:1124. (Abstr.)

Botkin, M. P. and J. A. Whatley, Jr. 1953. Repeatability of production in range beef cows. J. Anim. Sci. 12:552.

Brinks, J. S., R. T. Clark, F. J. Rice and N. M. Kieffer. 1961. Adjusting birth weight, weaning weight and preweaning gain for sex of calf in range Hereford cattle. J. Anim. Sci. 20:363.

Brinks, J. S., R. T. Clark, N. M. Kieffer and J. R. Quesenberry. 1962. Genetic and environmental factors affecting performance tracts of Hereford bulls. J. Anim. Sci. 21:777.

Brown, C. J., M. L. Ray, W. Gifford and R. S. Hornea. 1956a. Growth and development of Hereford cattle. Ark. Agr. Expt. Sta. Bull. 570.

Brown, C. J., M. L. Ray, W. Gifford and R. S. Hornea. 1956b. Growth and development of Aberdeen-Angus cattle. Ark. Agr. Expt. Sta. Bull. 571.

Brown, C. J. 1958. Heritability of weight and certain body dimensions of beef cattle at weaning. Ark. Agr. Exp. Sta. Bull. 597.

Brown, C. J. 1960. Influence of year and season of birth, sex, size, and age of dam on weight of beef calves at 60, 120, 180 and 240 days of age. J. Anim. Sci. 19:1062.

Brown, C. J. and V. Galvez, M. 1969. Maternal and other effects on birthweight of beef calves. J. Anim. Sci. 28:162.

Burgess, J. B., N. L. Landblom and H. H. Stonaker. 1954. Weaning weights of Hereford calves as affected by inbreeding, sex, and age. J. Anim. Sci. 13:843.

Burris, M. J. and C. T. Blunn. 1952. Some factors affecting gestation length and birth weight of beef cattle. J. Anim. Sci. 11:34.

Cardellino, R. and R. R. Frahm. 1971. Evaluation of two types of age of dam correction factors for weaning weight in beef cattle. J. Anim. Sci. 32:1078.

Clark, R. T., J. S. Brinks, R. Bogart, L. A. Holland, C. B. Roubicek, O. F. Panish, J. A. Bennet and R. E. Christian. 1963. Beef cattle breeding research in the western region. Ore. Agr. Exp. Sta. Res. Bull. 73.

Cundiff, L. V., R. L. Willham and C. A. Pratt. 1966. Effects of certain factors and their two-way interactions on weaning weight in beef cattle. J. Anim. Sci. 25:972.

Cunningham, E. P. and C. R. Henderson. 1965. Estimation of genetic and phenotypic parameters of weaning traits in beef cattle. J. Anim. Sci. 24:182.

Dahmen, J. J. and R. Bogart. 1952. Some factors affecting rate and economy of gains in beef cattle. Ore. Agr. Exp. Sta. Tech. Bull. 26.

Dawson, W. M., R. W. Phillips and W. H. Block. 1947. Birth weight as a criteria of selection in beef cattle. J. Anim. Sci. 6:247.

Dunn, R. J. 1968. Genetic parameters in straightbred and crossbred beef cattle populations. Ph.D. Thesis, Michigan State University Library, East Lansing.

Everett, R. W. and W. T. Magee. 1965. Maternal ability and genetic ability on birthweight and gestation length. J. Dairy Sci. 48:957.

Francoise, J. J., D. W. Vogt and J. C. Nolan. 1973. Heritabilities of and genetic and phenotypic correlations among some economically important traits of beef cattle. J. Anim. Sci. 36:635.

Gregory, K. E., C. T. Blunn and M. L. Baker. 1950. A study of some of the factors affecting the birth and weaning weight of beef cattle. J. Anim. Sci. 9:338.

Gregory, K. E. 1961. Improvement of beef cattle through breeding methods. North Central Regional Publ. 120. Neb. Agr. Exp. Sta. Res. Bull. 196.

Guilbert, H. R. and P. W. Gregory. 1952. Some features of growth and development of Hereford cattle. J. Anim. Sci. 11:3.

Harwin, G. O., J. S. Brinks and H. H. Stonaker. 1966. Genetic and environmental interactions affecting weaning weights of Hereford calves. J. Anim. Sci. 25:779.

Harvey, W. R. 1960. Least squares analysis of data with unequal subclass numbers. USDA, ARS. 20-8.

Hitchcock, G. H., W. A. Sawyer, R. Bogart and L. Calvin. 1955. Rate and efficiency of gains in beef cattle. III. Factors affecting weight and effectiveness of selection for gains in weight. Ore. Agr. Expt. Sta. Tech. Bull. 34.

Johnson, L. E. and C. A. Dinkel, 1951. Correction factors for adjusting weaning weight of range calves to the constant age of 190 days. J. Anim. Sci. 10:371.

Koch, R. M. 1951. Size of calves at weaning as a permanent characteristic of range Hereford cows. J. Anim. Sci. 10:768.

Koch, R. M. and R. T. Clark. 1955. Influence of sex, season of birth and age of dam on economic traits in range beef cattle. J. Anim. Sci. 14:386.

Koch, R. M., K. E. Gregory, J. E. Ingalls and R. L. Arthaud. 1959. Evaluating the influence of sex on birth weight and preweaning gain in beef cattle. J. Anim. Sci. 18:738.

Koger, M. and J. H. Knox. 1945a. The effect of sex on weaning weight of range calves. J. Anim. Sci. 4:15.

Koger, M. and J. H. Knox. 1945b. A method for estimating weaning weights of range calves at a constant age. J. Anim. Sci. 4:285.

Landblom, N. L. 1954. Adjusting beef cattle weaning weights for certain environmental variables by the fitting of constants. Colo. Agr. Exp. Sta. Mimeo.

Lasley, J. F., B. N. Day and J. E. Comfort. 1961. Some genetic aspects of gestation length and birth and weaning weights in Hereford cattle. J. Anim. Sci. 20:737.

Lehmann, R. P., J. A. Gaines, R. C. Carter, K. P. Bovard and C. M. Kincaid. 1961. Selection indexes for weaning traits in beef calves. J. Anim. Sci. 20:53.

Lush, J. L. 1948. The genetics of populations. Mimeo Publ.

Lush, J. L. and R. R. Schrode. 1950. Changes in milk production with age and milking frequency. J. Dairy Sci. 33:338.

Marlowe, T. J. and J. A. Gaines. 1958. The influence of age, sex, season of birth of calf and age of dam on preweaning growth rate and type score of beef calves. J. Anim. Sci. 17:706.

Marlowe, T. J. 1962. Weights and grades of beef cattle and their relationship to performance. Va. Agr. Exp. Sta. Bull. 537.

Marlowe, T. J., C. C. Mast and R. R. Schalles. 1965. Some nongenetic influences on calf performance. J. Anim. Sci. 24:494.

Mattoso, J. 1959. Estudio sobre o crecimento em peso de Zebus, na fazenda experimental de criaco de Uberaba. Tese mimeografiada. Vicosa, Minas Gerais. Escola Superior de Agricultura.

Miquel, C. and T. C. Cartwright. 1963. Comparison of heritabilities in crossbred and purepred cattle. J. Anim. Sci. 22:821. (Abstr.)

Nelms, G. E. and R. Bogart. 1956. The effect of birth weight, age of dam and time of birth on suckling gains of beef calves. J. Anim. Sci. 15:662.

Pahnish, O. F., E. B. Stanley, R. Bogart and C. B. Roubicek. 1961. Influence of sex and size on weaning weight of Southwestern range calves. J. Anim. Sci. 20:454.

Plasse, D., A. C. Warnick and M. Koger. 1968. Reproductive behavior of _Bos indicus_ females in a subtropical environment. I. Puberty and ovulation frequency in Brahman and Brahman X British heifers. J. Anim. Sci. 27:94.

Petty, R. R., Jr. and T. C. Cartwright. 1966. A summary of genetic and environmental statistics for growth and conformation traits of young beef cattle. Dept. Tech. Rep. Tex. Agr. Expt. Sta., No. 5. (Mimeo.)

Reynolds, W. L., T. M. De Rouen and J. W. High Jr. 1963. The age and weight at puberty of Angus, Brahman and Zebu cross heifers. J. Anim. Sci. 22:243. (Abstr.)

Rollins, W. C. and H. R. Guilbert. 1954. Factors affecting the growth of beef calves during the suckling period. J. Anim. Sci. 13:517.

Rollins, W. C. and K. A. Wagnor. 1956. A genetic analysis of weaning weights in a range beef herd operated under optimum and sub-optimum nutritional regimes. J. Anim. Sci. 15:125.

Schaeffer, L. R. and J. W. Wilton. 1974. Age of dam, sex and environmental interactions affecting preweaning average daily gains of beef cattle. Can. J. Anim. Sci. 54:183.

Shalles, R. R. and T. J. Marlowe. 1967. Factors affecting test performance of beef bulls. J. Anim. Sci. 26:21.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods (6th Ed.) Iowa State University Press. Ames.

Swiger, L. A. 1961. Genetic and environmental influences on gain of beef cattle during various periods of life. J. Anim. Sci. 20:183.

Swiger, L. A., R. M. Koch, K. E. Gregory, V. H. Arthaud, W. W. Rowden and J. E. Ingalls. 1962. Evaluating preweaning growth of beef calves. J. Anim. Sci. 21:781.

Swiger, L. A. K. E. Gregory, R. M. Koch, W. W. Rowden, V. H. Arthaud and J. E. Ingalls. 1963. Evaluating post-weaning gain of beef calves. J. Anim. Sci. 22:514.

Swiger, L. A., W. R. Harvey, D. O. Everson and K. E. Gregory. 1964. The variance of intraclass correlation involving groups with one observation. Biometrics 20:818.

Taylor, B. R. 1967. The Hereford cattle recording scheme 1963 to 1967. Beef recording association (U.K.) Ltd. Reading, England. Tech. Rpt. No. 6.

Vernon, E. H., W. R. Harvey and E. J. Warwick. 1964. Factors affecting weight and score of crossbred type calves. J. Anim. Sci. 23:21.

Warnick, A. C., W. C. Burns, M. Koger and M. W. Hazen. 1956. Puberty in English, Brahman and crossbred breeds of beef heifers. Proc. Assc. South Agr. Workers.

Warwick, E. J. 1958. Fifty years of progress in breeding beef cattle. J. Anim. Sci. 17:922.

Waugh, G. A. and T. J. Marlowe. 1970. Environmental influences on growth rate and grade of yearling beef cattle. J. Anim. Sci. 29:541.