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# Comparison of various methods for adjusting weaning weights of calves to an age-constant basis

Charles Wallace Robertson

To the Graduate Council:

I am submitting herewith a dissertation written by Charles Wallace Robertson entitled "Comparison of various methods for adjusting weaning weights of calves to an age-constant basis." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

James B. McLaren, Major Professor

We have read this dissertation and recommend its acceptance:

R.L. Murphee, Don Richardson, Robert Dotson, Haley Jamison

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

February 25, 1974

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J B McLaren

James B. McLaren, Major Professor

We have read this dissertation and recommend its acceptance:

Haley M. Jamison

R L Murphree

Don O. Richardson

Robert R Shrode

Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

COMPARISON OF VARIOUS METHODS FOR ADJUSTING WEANING WEIGHTS OF CALVES TO AN AGE-CONSTANT BASIS

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ABSTRACT

Weaning records of 18,393 calves from 395 Angus and Hereford herds participating in The Tennessee Beef Cattle Improvement Program were analyzed statistically to estimate the effects of age and sex of calf, age of dam, season of birth, management, breed and year of birth on pre-weaning rate of gain and weaning type score. Four methods of adjusting weaning weight to an age-constant basis were compared.

The statistical analyses revealed that including unadjusted average daily gain alone in an equation predicting 205-day weight did not effectively remove the dependency of this weight on age. Weights of calves in the extreme age groups were overadjusted when 205-day weights were calculated as the product of unadjusted average daily gain multiplied by 205 plus birth weight. Adjustment of calculated 205-day weight using the coefficient of regression of this weight on weaning age and the calculation of 205-day weight by the intraclass regression or age-intercept methods reduce the dependency of this weight on weaning age.

Adjustment of age-constant weights of calves within each management group with constants estimated within the groups was more effective in removing environmental variation than a single set of factors.

Bull calves were heavier at weaning than heifer calves and steer calves were intermediate. Creep-fed calves born in March, April and May and non-creep-fed calves born between December and May weaned heavier than calves of the two groups, respectively, born in other months.

Probably the most practical procedure for adjusting weaning weight for environmental effects was to use separate adjustment factors for creep- and non-creep-fed calves and to adjust the calculated 205-day weight using the coefficient of regression of that weight on weaning age.

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# INTRODUCTION

The primary goal of beef cattle producers is to obtain maximum production from available resources. This is dependent upon accurate estimates of the most probable producing ability and genetic merit of animals to be saved as herd replacements in a cow-calf operation. It would be desirable to base selection on genetic merit alone. However, it is impossible to exclude all of the variation due to environmental effects. The accuracy of estimates of genetic merit can be increased by adjusting individual values to remove average environmental effects. Some of the major environmental factors which influence weaning weight and grade in beef calves are age of dam, season of birth, sex of calf, age of calf and supplemental feeding programs (creep-feeding).

Since heritability is defined as the regression of breeding value on phenotype or the square of the correlation between phenotype and breeding value, a higher estimate of heritability should result when adjustments are made for these environmental influences. Therefore, greater improvement in weaning weight and grade should be obtained with constant selection differentials and higher heritabilities.

The researcher is faced with the problem of deriving the best adjustment factors for these environmental effects. It is apparent from a review of the literature that the magnitude of these adjustment factors varies for different sections of the country. It is generally recommended that selection should be carried out under the environmental conditions in which the improved breed is destined to live (Falconer, 1952).

Therefore, it was the purpose of this study to (1) determine adjustment factors to be used in adjusting weaning weights for non-genetic effects (age of dam, sex of calf and season of birth) and (2) compare various methods of adjusting weaning weight to an age constant basis.

## CHAPTER II

## REVIEW OF LITERATURE

### I. AGE OF CALF

Since birth dates vary, it would be necessary to secure weights daily over a period of time to obtain actual weights at a constant age. In practice, especially under farm conditions, this procedure is not feasible and all calves in a herd are, generally, weighed at the same time regardless of age.

Calculation of 205-day weights necessitates some adjustment for variation with respect to age of calf at actual weaning since older calves are generally heavier than younger calves. However, younger calves tend to have a higher rate of gain per day of age than older calves since growth in individual calves in non-linear. Variation in age at weaning accounts for a larger fraction of the variation in weaning weight than any other variable (McLaren, 1970).

A review of the literature indicates that weaning age of beef calves varied from one section of the United States to another section. In the northern half of the United States calves were weaned at a younger age, approximately 180 days (Brinks et al., 1961; Dawson et al., 1954; Hohenboken and Brinks, 1969; Koch, 1951; Koch and Clark, 1955b; Minyard and Dinkel, 1960; Shelby, Clark and Woodward, 1955) than in the southern half of the nation where calves are generally weaned at 240 days of age (Brown, 1958; High, 1968; Marlowe, Mast and Schalles, 1965;

McLaren, 1970; McGuire, 1969; Neville, 1962; Rollins and Wagnon, 1956).

In experimental herds, variation in weaning age does not usually exceed 90 to 120 days (Reynolds et al., 1963); however, in commercial beef herds weaning age may vary as much as 290 days (Barker, 1964; Marlowe and Gaines, 1958).

## Effect of Age on Weaning Weight

A five-year study was conducted by Marlowe, Mast and Schalles (1965) using Virginia Beef Cattle Improvement Association data collected in 111 Angus and 82 Hereford herds. Weaning records were arbitrarily divided into seven groups on the basis of weaning age. The individual groups included equal periods of 30 days each from 90 through 299 days of age. In general, as calves increased in age, their gains per day decreased, but their type scores (grades) increased. It was shown also that when seasonal influences were removed, growth of non-creep-fed calves was essentially linear from 120 days to weaning.

Other workers (Brinks et al., 1962; Koch, Schleicher and Arthand, 1955; Marlowe and Gaines, 1958; Swiger et al., 1962) noted a linear relationship between rate of gain and age of calf when the breeding season was limited to 90 to 120 days and the age of weaning was from 180 to 210 days. Barker (1964), Brown (1960) and Rollins and Guilbert (1954) found that when average weaning age was 240 days or more, adjustments are necessary to compensate for variation in age when comparing the rate of gain of early and late calves.

The influence of calf age on preweaning growth rate of Hereford calves was studied by Rollins, Guilbert and Gregory (1952). They reported a coefficient of regression of weaning weight on age of 1.90 lb. for calves weaned younger than four months of age. This regression was 1.81 lb. per day for calves weaned between four and eight months of age.

In a study of 1,737 purebred and grade Hereford calves, Evans et al. (1955) found that the regression of weaning weight on weaning age was significantly different ($P < .05$) for purebred and grade herds. The coefficients of regression were 0.908 and 1.080 lb. per day for the two groups, respectively. Mahmud and Cobb (1963) reported a similar value for the regression of weaning weight on weaning age (0.71 lb. per day). Koch and Clark (1955a) found the regression of average daily gain from birth to weaning on weaning age to be -.04 lb. per day. This regression was considered to be small enough that any adjustments using this value would be of no practical significance. They concluded further that the difference in growth rate between early and late calves was less important than previously indicated. In other studies, Minyard and Dinkel (1965), Sawyer, Bogart and Oloufa (1949), Koger and Knox (1945b), Botkin and Whatley (1953), Burgess, Landblom and Stonaker (1954) and Koch (1951) found that weaning weight of calves increased with increased weaning age at the rate of 1.20 lb., 1.28 lb., 1.33 lb., 1.43 lb., 1.67 lb. and 2.27 lb. per day, respectively.

Hoover et al. (1956) reported that the regression of weaning weight on weaning age was approvimately the same at 112 and 210 days of age. Chambers et al. (1956) reported a rather high correlation between the 112- and 210-day weight in beef calves; however, they did not suggest that the results would support the substitution of 112-day weight records for 210-day weight. Brown (1960) indicated a need for consideration of age of calf, in addition to sex, season of birth and age of dam, when standardizing weaning weight.

Effect of Age on Rate of Gain

A very high positive relationship between average daily gain and weight per day of age was reported by Berg (1961). He suggested that if calves were weaned at approximately the same age the two measures should be essentially equal in appraising preweaning gain. Similar results were reported by Cooper et al. (1965). They found that the regression of weaning weight on age and the regression on weight per day of age were both highly significant and reduced error variance of weaning weight at the mean age to about equal levels.

Since the relationship between weaning weight and weaning age has been shown to be quite variable, adjustment of weaning weight to an age-constant basis is difficult. Warren, Thrift and Cannon (1965) reported that the increase in weight for each increment of age was not constant. A negative value was obtained for the quadratic component of age indicating that rate of gain increased as age increased up to a point and then declined as age increased beyond that point.

Marlowe and Gaines (1958) found no significant differences in growth rate of non-creep-fed calves from 90 to 210 days of age. However, there was a slight decline in growth rate between 211 and 240 days and a rather sharp decline after 240 days. A decrease in average daily gain of non-creep-fed calves as age increased from 60 to 300 days was observed by Marlowe (1962). Even within the normal range in weaning age, 120 to 240 days, the difference in growth rate between calves in the extreme age groups was approximately 0.1 lb. per day.

The validity of the assumption of linearity between growth rate and age has been examined in several other studies. Cunningham and Henderson (1965b) divided age of calf into 10-day intervals from 120 to 250 days and plotted the unadjusted means of the records for each interval. The response appeared to be linear. When unadjusted weaning weights were regressed on weaning age, coefficients of regression were 1.67 for Angus and 1.49 for Hereford calves. Deviations from linear regression were not significant and average daily gain from birth to weaning was considered to be an unbiased estimate of rate of growth.

In order to evaluate pre-weaning growth, Swiger et al. (1962) calculated coefficients of partial regression for rate of gain from birth to 130 days and from 130 to 200 days on weaning age. The curvilinear effect during the early growth period was only slight and could be ignored. However, curvilinear correlation between age and gain from 130 to 200 days was significant. It was concluded that when calves were weaned between 130 and 200 days of age, the most accurate appraisal of weaning weight was obtained by adjusting gains for variation in age of calf. Calf ages were divided arbitrarily into seven equal periods of 30 days each (90 to 299 days) by Marlowe, Mast and Schalles (1965). In general average daily gain was not significantly different between adjacent groups among non-creep-fed calves but age had a significant effect on average daily gain over the entire age range. These results were similar to those reported by Swiger et al. (1962).

Methods of Adjusting Weaning Weight

Several linear functions have been used to compute weaning weight (WW) at a constant or standard age (SA). The most frequently used method is:

$$\text{Age-Constant Weight} = \frac{WW - BW}{WA} \times SA + BW.$$

Where: BW represents birth weight and WA represents actual weaning age in days.

When actual birth weight is not available, Anderson and Dinkel (1969) compared the use of a standard 70-lb. birth weight to the actual birth weight of the calves. They used the following formula:

$$\text{Age-Constant Weight} = \frac{WW - 70}{WA} \times SA + 70.$$

Other investigators (McLaren, 1970; Cunningham and Henderson, 1965a; Lehmann et al., 1961; and Barker, 1964) suggested that when birth weight is not available a constant within each breed-sex group was a satisfactory estimate. When rate of gain is evaluated as weight per day of age (WDA), it is expressed as:

$$WDA = \frac{WW}{WA}.$$

Individual weaning records were adjusted to a 205-day basis by McLaren (1970) using standard procedures in which 205-day weight was defined as the product of average daily gain multiplied by 205 plus birth weight. Variation in the age-constant weaning weight due to variation in weaning age was not completely removed by this adjustment. Values of the coefficients of determination indicated that either the adjustment of weaning weight to an age-constant basis was not efficient or that another source of variation had been introduced. The difference in the relationships of weaning weight and 205-day weight with weaning age and the negative coefficients of regression of 205-day weight on weaning age, reported by McLaren (1970), indicated that the 205-day weight calculated by this method was a biased estimate of weaning weight. He suggested that the standard method of adjusting weaning weight to an age-constant basis tended to overadjust the weights of calves in the extreme age groups. When 205-day weight calculated by the standard procedure was adjusted by the following procedure, the effects of these overadjustments were removed.

$$WT5_2 = WT5_1 - b_2 (WA - 205).$$

Where:

$WT5_1$ = 205-day weight calculated by standard procedures;

$b_2$ = regression of $WT5_1$ on WA.

Another method of adjusting weaning weight was used by Bywaters and Willham (1935) and Whatley and Quaife (1937) in pigs and by Minyard and Dinkel (1965) in calves. This age adjustment employed multiplicative factors computed by linear regression. The appropriate factor for each age was considered to be:

$$\frac{\text{Standard Age-Age Intercept}}{\text{Actual Age-Age Intercept}}.$$

Age intercept was the intercept of the regression line on the age axis. Minyard and Dinkel (1965) compared weaning weights adjusted to a constant age by intraclass regression and by age-intercept factors. They found that the age intercept method resulted in a greater reduction of dependency between age and adjusted weight. It was suggested that the intraclass regression method appeared to overadjust the extreme age groups. Adjusted weight of the youngest calves tended to exceed the weight of the calves when they were grown normally to the constant age; whereas, the adjusted weight of the oldest calves appeared to be smaller than would be expected if the weights were taken at 190 days of age. Johnson and Dinkel (1951) and McLaren (1970) reported similar effects of adjustment on the weights of calves in the extreme age groups.

Adjustments of the calculated 205-day weights by intraclass regression of 205-day weight on weaning age made by McLaren (1970) removed the effect of the overadjustment.

## II. AGE OF DAM

Age of dam has been shown to have an important effect on the weaning weight of beef calves. The cow's influence on calf performance comes from at least two sources, the genes she transmits and the maternal environment she provides her calf. The age of the dam significantly influences maternal factors such as birth weight and the amount of milk she will produce for her calf (Marlowe, Mast and Sheehan, 1964).

Studies by many workers (Botkin and Whatley, 1953; Lacy, 1957; Roubicek et al., 1957; Marlowe, Mast and Sheehan, 1964; Christian et al., 1965; Marlowe, Mast and Schalles, 1965; Cundiff, Wilham and Pratt, 1966) indicated that 2- and 3-year-old cows produced lighter calves than older cows. Most research workers reported that the effects of age of dam on weaning weight tended to peak at 5 or 6 years of age (Burgess, Landblom and Stonaker, 1954; Cunningham and Henderson, 1965b; Mahmud and

Cobb, 1961; Berg, 1961; Swiger, 1961; Knapp et al., 1942; McLaren, 1970; Brown, 1960; Koger and Knox, 1945b) and remained constant through 9 or 10 years of age (Harricharan, Bratton and Henderson, 1967; Minyard and Dinkel, 1965; Sawyer, Bogart and Oloufa, 1949; Vernon et al., 1964; Koch and Clark, 1955a; Nelms and Bogart, 1956; Sawyer et al., 1949; Minyard and Dinkel, 1960; Clark et al., 1958; Vernon, Harvey and Warwick, 1964). A uniform decline between the ages of 9 and 13 years is indicated in several studies conducted by Botkin and Whatley (1958), Rollins and Gilbert (1954), Evans et al. (1955), McCormick, Southwell and Warwick (1956), Brown (1958), Lindley et al. (1958), and Raynolds et al. (1958). Calves from cows over 13 years of age were found to be the lightest of any mature-cow-age group (Clum, Kidder and Koger, 1956; McCormick, Southwell and Warwick, 1956; Minyard and Dinkel, 1960).

One of the most important aspects of the total performance of the dam is the amount of milk she produces for her calf. Melton et al. (1966) studied milk yield data from Angus, Charolais and Hereford Cows. They found that milk yield of 2-, 3- and 4- or 5-year-old cows was 13.5, 16 and 19 lb., respectively. In a similar study, Melton et al. (1967) reported that differences in milk and total solid yields due to variation in age of dam were highly significant.

Regression procedures were used by Neville (1962) to study the influence of milk production of grade Hereford cows on 120- and 240-day weight and on gain from birth to 240-days of age. He concluded that the variation in the growth rate of calves attributable to age-of-dam effects was largely due to differences in milk production of the dams.

Similar work conducted by Hamann, Wearden and Smith (1963) and Christian, Hauser and Chapman (1965) suggested that the large difference in weaning weight between calves of 2-year-old cows and calves of older cows was probably due to factors other than the difference in milk production. They suggested also that the larger calves dropped by the older cows may have been more aggressive, and these heavier calves may have been less dependent on the milk production of their dams.

Studies by O'Mary and Ament (1961) suggested that adding 75, 44, 19, 7, and 0 lb. to the weights of calves from 2, 3, 4, 5, and 6 to 10-year-old cows, respectively, corrected weaning weight for variation in age of dam. Lacy (1957) found that calves weaned by 2- and 3-year-old dams were considerably lighter than those weaned by cows 6 years old or older. He suggested the addition of 55 lb. to the weaning weight of calves from 2-year-old cows, and 10 lb. for calves weaned by 4-year-old cows.

A study in Georgia by Warren, Thrift and Cannon (1965) involving 37,000 weaning records and indicated that calves from cows 12 years old and older were comparable to those from 5- and 6-year-old cows, while 8, 9, 10 and 11-year-old cows produced calves of comparable weaning weights. Therefore, 8-year-old cows were selected as the base for calculating the age of dam adjustment factors. Multiplicative adjustment factors for cows 2 to 11 and 12-year-olds and over were 1.17, 1.12, 1.07, 1.04, 1.03, 1.02, 1.00, 1.00, 1.01, 1.01 and 1.03, respectively. Clum et al. (1956) found the most productive ages of dam were from 5 to 10 years of age. Calf weights were adjusted to mature dam equivalents by adding 63, 35, 12, 5, 3, 8, 18, 34, 53 and 53 lb. to calves from cows 1, 2, 3, 4, 11, 12, 13, 14, 15 and 16 years old, respectively. Harvin, Brinks and Stonaker (1966), using the same base for mature dam (5 years) as Clum, Kidder and Koger (1956), found that weaning weights of calves from 2-year-old dams averaged 47 pounds lighter than calves from mature dams. Evans et al. (1955) found that cows reached maximum production, as measured by calf weights, at 5 through 8 years of age. Mature-cow-equivalent-calf weights were obtained by adding 106, 20, 14, and 43 lbs. to the weaning weight of calves from 2, 4, 9 and 10-year-old cows, respectively.

Adjustment factors may be either additive or multiplicative. The type of correction adjustment used (additive or multiplicative) tends to vary from worker to worker. Brinks et al. (1961) gives the most complete explanation as to which method of adjustment is appropriate. An additive adjustment is appropriate if the standard deviation among the groups in equal, whereas, a multiplicative adjustment is appropriate if the coefficients of variation for the trait is equal within various groups. Therefore, examination of the data should determine the appropriate adjustments to use (additive or multiplicative).

## III. SEX OF CALF

Most of the published results indicate a significant effect of sex of calf on weaning weight. In general, bull calves grow faster than steers and steers grow faster than heifers.

As early as 1930, Lush et al. noted that steers consistently grew faster than heifers. Morrison (1936) observed also that bulls grew faster with respect to both weight and height than heifers. Knapp and

Black (1941) found that the heaviest calves were bulls and were from cows giving the largest amount of milk.

Cunningham and Henderson (1965a) observed that the difference between bulls and steers were, in part, attributable to the effects of selection. Purebred breeders tended to save the heavier calves as bulls and to castrate the remainder.

Both Bogart et al. (1963) and Melton et al. (1967) found that males grow at a more rapid rate than females during both the nursing and post-weaning feeding periods. The ratio of mean age-constant weaning weight of bulls to that of heifers was reported to be 1.064, 1.075 and 1.082 by Swiger et al. (1962), Koch et al. (1959) and Minyard and Dinkel (1965), respectively. Least-squares estimates for weight per day of age (Brinks et al., 1961; Rollins and Guilbert, 1954; Taylor et al., 1960; Berg, 1961; Barker, 1964; Dunbar and Albaugh, 1966) indicated males gained approximately 0.1 to 0.3 lb. more per day from birth to weaning than females from birth to weaning. In contrast, Knapp and Phillips (1942) and Gregory, Blunn and Baker (1950) reported that there was no significant difference in weaning weight due to sex. Burgess, Landblom and Stonaker (1954), Evans et al. (1955), Marlowe and Gaines (1958), Brinks et al. (1961) and Marlowe (1962) found that the growth rate of steers was intermediate to that of bulls and heifers.

In addition, a number of comparisons between weaning weight of males and female calves are presented in Table 1. Smith and Warwick (1954), Bovard, Priode and Harvey (1963), Vernon, Harvey and Warwick (1964) and McLaren (1970) noted that the male calves of all breeds or breed crosses outweighed heifers at weaning.

TABLE 1

DIFFERENCE IN WEANING WEIGHT OF MALE AND FEMALE CALVES

| Reference | Weight Difference lb. | Day Weight | Status of Males[a] |
|---|---|---|---|
| Knapp et al. (1942) | 20 | 210 | S |
| Evans et al. (1955) | 22 | 210 | B |
| Brown (1960) | 22 | 240 | B |
| Koch (1951) | 23 | 176 | B, S |
| Botkin and Whatley (1953) | 25 | 210 | B, S |
| Clum, Kidder and Koger (1956) | 25 | 180 | B, S |
| Koch and Clark (1955a) | 26 | 180 | B, S |
| Marlowe, Mast and Schalles | 27 | 210 | S |
| Mahmud and Cobb (1963) | 27.5 | 240 | B |
| Marlowe and Gaines (1958) | 30 | 210 | B |
| Rice, Kelley and Lasley (1954) | 29 | 205 | B |
| Koger and Knox (1945a) | 32 | 240 | B, S |
| Reynolds et al. (1958) | 34 | 205 | S |
| McCormick, Southwell and Warwick (1956) | 38 | 210 | B |
| Warren, Thrift and Cannon (1956) | 44 | 205 | B |
| Koch (1951) | 44 | 180 | B |
| Lacy (1957) | 49 | 225 | B |
| Brown (1961) | 57 | 240 | B |
| Rollins and Guilbert (1954) | 68 | 240 | B |

[a]B = intact males; S = castrated males.

The influence of sex of calf on weaning type score was found to be negligible by Koch and Clark (1955a). However, several studies suggested that the effect of age on weaning type was significantly affected (Marlowe, Mast and Schalles, 1965) by sex of the calf. Males graded slightly higher in tests conducted by Barker (1964) and High (1968), while Lehmann et al. (1961) found the type score at weaning to favor heifers. It was generally agreed by most researchers (Marlowe and Gaines, 1958; Taylor et al., 1960; Marlowe, 1962; Cunningham and Henderson, 1965b) that type score was higher in favor of heifers over steers at weaning.

## IV. SEASON OF BIRTH

In a beef cow-calf operation the selection of the season in which calves are born presents three important considerations for the cattleman. First, the producer must consider conception rate of breeding females in various seasons of the year. Secondly, he must plan the calving season to coincide with maximum growth and maximum utilization of available forages and grains, and thirdly, he must select the calving season which will result in a marketable calf at a point in the price cycle where maximum income will result. Since some months appear to have an advantage over others with respect to weaning weights, month of birth becomes a major concern.

Calves born in January through March were heavier at weaning than those born in other months according to Rollins and Guilbert (1954), Clum, Kidder and Koger (1956), Marlowe, Kincaid and Litton (1958), Reynolds et al. (1958) and Dinkel, Minyard and Ray (1963). Most research reports agree that weaning weights generally are maximum for calves born in March and tend to decrease for calves born later in the year with a minimum weaning weight observed for calves born in mid-fall (Barker, 1964; Warren, Thrift and Cannon, 1965; McGuire, 1969; and McLaren, 1970). Marlowe (1962) noted a decrease of 0.1 lb. per month in the average daily gain of calves born from March to September. Nelms and Bogart (1956) suggested that season-of-birth effect on rate of gain was equal to if not greater than the age-of-dam effect.

Marlowe and Vogt (1965) noted that calves born between June and September scored approximately one-third of a grade lower than calves born in other seasons. Koch and Clark (1955a) found the regression of weaning type score on weaning age to be 0.01 ± 0.005 units per day, indicating that early born calves tended to score a little higher than those born later in the year. According to Burris and Priode (1956) selection for early calving dates would result in an immediate increase in calving percentage when the breeding season is limited to approximately 90 days.

# CHAPTER III

# EXPERIMENTAL PROCEDURE

## I. SOURCE OF DATA

Data used in this study were taken from weaning records of 36,521 calves collected in 395 herds during the nine-year period between 1964 and 1972 by The Tennessee Beef Cattle Improvement Association Program (TBCIP). The TBCIP began in 1956 as a joint project between the Tennessee Agricultural Experiment Station (Animal Husbandry-Veterinary Science Department) and The University of Tennessee Extension Service. The Extension Service assumed the responsibility for administration of the program and collection of the data, and the Experiment Station was responsible for processing and analyzing the data.

Data were collected in 201 Angus, 138 Hereford, 8 Shorthorn, 25 Charolais, 1 Red Polled, 2 Santa Gertrudis herds, and 28 herds with other breeds. These 395 farms were located throughout the State of Tennessee and the climatic conditions and management practices under which the calves were produced varied widely. Calves were born throughout the year; however, the smallest number were born in June, July, August, and September and the largest number were born in January, February, and March (Table 2). Most Tennessee producers practiced a restricted calving season (90 to 120 days), but some producers practiced year-round calving.

TABLE 2

DISTRIBUTION OF CALVES BY SEX, AGE OF DAM AND MONTH OF BIRTH WITHIN MANAGEMENT GROUPS

| Source | Number of Calves | | |
|---|---|---|---|
| | Creep | Non-Creep | Combined |
| Sex | | | |
| Bull | 2599 | 3523 | 6122 |
| Steer | 789 | 2444 | 3233 |
| Heifer | 2682 | 6356 | 9038 |
| Age of Dam | | | |
| 2 | 420 | 970 | 1390 |
| 3 | 826 | 1748 | 2574 |
| 4 | 895 | 1805 | 2700 |
| 5 | 768 | 1608 | 2376 |
| 6 | 724 | 1363 | 2087 |
| 7 | 571 | 1195 | 1766 |
| 8 | 524 | 920 | 1444 |
| 9 | 442 | 767 | 1209 |
| 10 | 328 | 656 | 984 |
| 11 and over | 572 | 1291 | 1863 |
| Month of Birth | | | |
| January | 1005 | 2591 | 3596 |
| February | 775 | 2597 | 3372 |
| March | 756 | 2075 | 2831 |
| April | 511 | 1219 | 1730 |
| May | 430 | 660 | 1090 |
| June | 196 | 179 | 375 |
| July | 103 | 128 | 231 |
| August | 69 | 75 | 144 |
| September | 541 | 507 | 1048 |
| October | 572 | 504 | 1076 |
| November | 511 | 638 | 1149 |
| December | 601 | 1150 | 1751 |

Weaning records for each calf include parentage, breed, birth date, age of dam, weaning weight, and weaning age of calf. In addition to weaning weight, type or conformation score, condition grade of calf and feed management practice were recorded for each calf. Birth weights were not required, but cows were required to be registered in the program before calving. Weaning weights were adjusted to an age-constant basis using the birth-weight constants in Table 3. The breed of the calf was designated from the breed of the sire and the dam. The TBCIP system for coding breed classified Horned and Polled Hereford separately. However, the calves of the two breeds were designated by a single breed code (Hereford) in this study. All breeds and breed crosses, except registered Hereford (horned and Polled), registered Angus, grade Hereford and grade Angus, were eliminated from this study due to the small number of calves represented by these breeds or because these animals did not express specific breed characteristics.

Weaning weights of calves were generally taken when the calves are between 120 and 300 days of age. At the time weaning weights are taken, an official TBCIP grader or a member of Cooperative Extension Service assigned a conformation score to each calf. The scoring system used by the TBCIP conformed to the system recommended by S-10 Beef Cattle Breeding Committee. The scoring system is shown in Table 4.

A total of 18,128 or 49.6 percent of the 36,521 weaning records were eliminated for failure to conform to one or more of the restrictions imposed on records to be included in the study. If weaning weight, birth date, sire number, breed of sire, age of dam, breed of dam, or conformation score of calf was missing the record was deleted. If

TABLE 3

AVERAGE BIRTH WEIGHTS ASSUMED FOR ANGUS AND HEREFORD CALVES

| Breed | Birth Weight | |
|---|---|---|
| | Males | Females |
| Angus | 65 | 60 |
| Hereford | 70 | 65 |

TABLE 4

CODING OF CONFORMATION SCORE

| | Prime | Choice | Good | Standard | Common |
|---|---|---|---|---|---|
| High | 17 | 14 | 11 | 8 | 5 |
| Average | 16 | 13 | 10 | 7 | 4 |
| Low | 15 | 12 | 9 | 6 | 3 |

management practice code (creep or non-creep) were missing the calf was likewise eliminated. All calves weaned at less than 120 days of age or over 300 days of age were omitted from this study. Any farm with less than two sires within one year and any sire with less than three calves were not included. On farms were multiple-sire groups were used during a breeding season and the sire of individual calves could not be determined, records of these calves were also discarded.

Preweaning performance records of 8,320 Angus and 10,073 Hereford calves weaned during the years 1964 through 1972 were used to compute adjustment constants for environmental effects and various other factors necessary to adjust weaning weight to an age-constant basis. In the preliminary analyses, weaning records were divided into four breed-feed-management groups. They included creep-fed Hereford, non-creep-fed Hereford, creep-fed Angus and non-creep-fed Angus as shown in Table 5.

In the preliminary analysis preweaning growth was evaluated as weaning weight (WW), average daily gain (ADG), weight per day of age (WDA) and 205-day weight ($WT_5$). Coefficients of correlation between members of pairs of these various measures of growth rate were greater than 0.98 which indicated they were equally effective in expressing the trait. Weaning weight, adjusted for environmental factors and adjusted to 205-days of age, was the measure of preweaning growth rate used in the TBCIP for comparative reporting; therefore, these standards were selected for this study.

TABLE 5

DISTRIBUTION OF CALVES USED IN THE ANALYSES BY BREED, MANAGEMENT AND YEAR

| | BREED | | | |
|---|---|---|---|---|
| | Angus | | Angus | |
| Year | Creep | Non-Creep | Creep | Non-Creep |
| 1964 | 105 | 111 | 69 | 61 |
| 1965 | 156 | 407 | 240 | 616 |
| 1966 | 331 | 690 | 320 | 721 |
| 1967 | 158 | 688 | 435 | 784 |
| 1968 | 303 | 939 | 627 | 1021 |
| 1969 | 571 | 733 | 524 | 999 |
| 1970 | 267 | 791 | 366 | 807 |
| 1971 | 307 | 862 | 385 | 939 |
| 1972 | 356 | 545 | 541 | 609 |
| TOTAL | 2554 | 5766 | 3516 | 6557 |

Method of Analysis

Varying reports of the magnitude of the effects of various environmental factors which influence weaning type score and preweaning growth rate, reported in the literature, indicated the need for evaluating these average effects. The effect of four independent variables and selected interactions on three dependent variables measuring performance was of primary interest in this study. Weaning weight, type score at weaning and 205-day weight are the three dependent variables and the four independent variables include age of dam, sex of calf, age at weaning, season of birth, and various two-way interactions between these variables.

Creep feeding was thought to influence growth rate and conformation score of calves, therefore, these data were divided into separate analyses for creep and non-creep fed calves because unbiased comparisons of creep and non-creep feeding were not possible on an intra-herd basis.

Calves were born in each of the 12 months of the year. Therefore, in the preliminary analysis date of birth was coded as 12 discrete levels which coincided with the 12 months of the year. Age of calf and month of birth were not completely confounded and as a result independent estimates of these effects on both average daily gain and conformation score were possible. Age of dam was divided into 11 discrete levels. Age-of-dam subclasses represented age in years of cow from 2 through 12 years of age. According to previous research (Cunningham and Henderson, 1965a; Minyard and Dinkel, 1965; McLaren, 1970), age of dam effects on weaning weight of calves reaches peak performance at 5 or 6 years of age and this performance is maintained through 9 or 10 years of age and decreases thereafter. Therefore, the 6, 7, 8, 9, and 10-year-old cows were classified as a single group in subsequent analyses. Since cows 11 years of age and older were rare in these data and undoubtedly were highly selected, cows 11 years old and older were also grouped as one age of dam classification.

The reduction in sum of squares due to fitting constants for month of birth was not significantly reduced when adjacent months of birth were grouped into seasons. Therefore, month of birth was grouped into one of four discrete seasons. Seasons were classified as Winter (January, February and March), Spring (April, May and June), Summer (July, August and September), and Fall (October, November and December).

In order to fit a model including breed, year, and herd, it was necessary to assume that they were independent of each other and that they can be combined in an additive manner. Each herd/year subclasses was considered a separate herd group due to the fact that herd was completely confounded with breed and year. Some farms were included in this study in only one year. Feed management was confounded with farm, but variation due to creep feeding could be removed as part of the farm effect. A nested analysis of variance was done to access the effects of breed, year within breed, and herd within breed-year subclasses on the four dependent variables.

Herd, year, feed management and breed was absorbed in all subsequent analyses. Calculating sum of squares and cross products on a within-subclass basis (herd/year-breed) and summing over all subclasses accomplished this absorption. Similar analysis were used by Minyard and Dinkel (1965), High (1968) and McLaren (1970). The four management-breed subclasses were tested using Bartlett's test for homogeneity of variance as described by Snedecor (1956) and breeds were pooled within management.

The fraction of the variation in weaning weight, type score, average daily gain and 205-day weight explained by the four dependent variables was calculated by sequentially adding elements to the model in a stepwise fashion. Linear regression for these dependent variables on weaning age was the first element considered. The order of incorporation of other variables following weaning age was: sex of calf, age of dam, season of birth and the quadratic and cubic elements of the weaning age polynomial. The fraction of the total variation ($\Delta R^2$) associated with each element was calculated as the difference in the $R^2$ value of the analysis in which the element was included and the preceding analysis in which it was not included.

When weaning weight was adjusted to a constant age, correlations between other elements of the model and weaning age was reduced. No significant increase in $R^2$ was observed when the quadratic and cubic terms of the weaning-age polynomial and various two-way interactions were included in the model. Therefore, these elements were assumed to be negligible with respect to adjustments for fixed environmental effects.

An individual observation (Y) was assumed to be composed of six components in the final analysis. The model was as follows:

1. A constant ($\mu$) common to all observations;
2. The partial regression of Y on weaning age (linear);
3. Sex expressed as three discrete levels;
4. Age of dam expressed as six discrete levels;
5. Season of birth expressed as four discrete levels; and

6. Random variation.

## Adjusting for Fixed Environmental Effects

Individual weaning weights were adjusted to an age-constant basis by the following methods:

(1) $$WT5_1 = \frac{WW - BW}{WA} \times 205 + BW;$$

(2) $$WT5_2 = WW - b_1 (WA - 205);$$

where:

$b_1$ coefficient of regression of weaning weight on weaning age.

(3) $$WT5_3 = WT5_1 - b_2 (WA - 205);$$

where:

$b_2$ = regression of $WT5_1$ on age.

(4) $$WT5_4 = WW \times \left(\frac{\text{Standard Age} - \text{Age Intercept}}{\text{Actual Age} - \text{Age Intercept}}\right)$$

These four methods of adjusting weaning weight to an age constant basis will be referred to as the standard, regression ($b_1$), standard + $b_2$ and age intercept method, respectively, in subsequent discussions.

Constants used to adjust weaning weight for variation in sex of calf, age of dam and season of birth were as follows:

(1) Weaning records of all calves (creep- and non-creep-fed) were pooled and one set of factors were derived from the single analysis of these data. The single set of factors and the single $b_1$ value were used to adjust the weight both creep- and non-creep-fed to a 205-day, steer, mature dam and average season of birth basis.

(2) Weaning records of creep-fed and non-creep-fed calves were analyzed separately and the resulting two sets of adjustment factors were used to adjust the weaning weight of creep-fed and non-creep-fed calves, respectively.

(3) Adjustment factors currently used by The Tennessee Beef Cattle Improvement Program were used to adjust weaning records in this study.

These three methods of adjusting weaning weight for sex of calf, age of dam and season of birth will be referred to as (1) single set of factors, (2) by management, and (3) TBCIP factors, respectively, in subsequent discussions. It should be noted that the methods of calculating the b values used in the regression ($b_1$) and standard + $b_2$ procedure for adjusting weaning weight to an age-constant basis will be designated as one value and by management, respectively.

Nine combinations of the four methods of adjusting weaning weight to an age-constant basis and the four methods of adjusting age-constant weights for fixed environmental effects were used to generate nine sets of adjusted 205-day weights. The combinations of these methods used to develop each set of adjusted 205-day weights are shown in Table 6. The nine sets of adjusted 205-day weights were analyzed using the model previously described for analysis of the original data.

Stepwise regression procedures, described earlier, were used to evaluate the various methods of adjusting for fixed environmental effects. The $R^2$ values were used as indices of relative efficiency of the various adjustment procedures to remove environmental variation. These values of $R^2$ actually reflect the fraction of the original variation in weaning

TABLE 6

METHODS OF ADJUSTING FOR AGE OF CALF, SEX OF CALF, AGE OF DAM AND SEASON OF BIRTH

| Dataset Number | Method of Adjusting for Age of Calf | Method of Adjusting for Sex, Age of Dam and Season of Birth |
|---|---|---|
| W1 | Standard Method[a] | One Set of Factors[b] |
| W2 | Standard Method[a] | By Management[c] (Creep and Non-Creep) |
| W3 | Standard Method[a] | TBCIP Factors[d] |
| W4 | $b_1$ (One Value)[b,e] | One Set of Factors[b] |
| W5 | $b_1$ (By Management)[c,e] | By Management[c] (Creep and Non-Creep) |
| W6 | Standard + $b_2$ (One Value)[a,b,f] | One Set of Factors[b] |
| W7 | Standard + $b_2$ (By Management)[a,c,f] | By Management[c] (Creep and Non-Creep) |
| W8 | Age Intercept, (One Value)[b] | One Set of Factors[b] |
| W9 | Age Intercept, (By Management)[c] | By Management[c] (Creep and Non-Creep) |

[a]Standard method = (Weaning Weight-Birth Weight)/(Weaning Age) X 205 + Birth Weight = Calculated 205-day weight.

[b]One $b_i$ value and one set of factors were calculated from the analysis of the combined records of creep- and non-creep-fed calves and used to adjust records of both management groups.

[c]Separate $b_i$ values and separate adjustment factors were calculated for creep- and non-creep-fed calves and used to adjust records of calves in the respective management groups.

[d]Adjustment factors currently used by The Tennessee Beef Cattle Improvement Association.

[e]$n_1$ = Coefficient of regression of weaning weight on weaning age.

[f]$b_1$ = Coefficient of regression of calculated 205-day weight on weaning age.

weight remaining after the data were adjusted to an age-constant basis and for environmental effects.

CHAPTER IV

# RESULTS AND DISCUSSION

## I. ENVIRONMENTAL FACTORS

Comparison of residual mean squares from preliminary analyses of the four breed-management groups indicated that the creep- and non-creep-fed Hereford and Angus calves could be pooled. Therefore, a single estimate for each of the genetic parameters and environmental constants for each group would be valid. However, differences in magnitude of the means for various performance traits, especially those measuring rate of gain, suggested that the degree of pooling could possibly affect the efficiency with which resulting adjustment factors removed environmental variation. Since there was no significant difference due to breed of calf with respect to weaning weight, type score, average daily gain and calculated 205-day weight, separate analyses of variance was done for creep-, non-creep-fed calves. The efficiency of the resulting constants, as adjustment factors, was compared to those from a single analysis of the performance records of all calves (creep- and non-creep-fed combined).

Analysis of variance for the effect of various environmental factors on weaning weight, average daily gain, conformation score and calculated 205-day weight for all calves is shown in Table 7. The separate analyses of these effects on the performance of creep- and non-creep-fed calves are shown in the Appendix, Tables 21 and 22, respectively. Year, herd, age of calf, sex of calf, age of dam and season significantly

TABLE 7

ANALYSIS OF VARIANCE OF PREWEANING PERFORMANCE OF ALL CALVES

| | | MEAN SQUARE | | | |
|---|---|---|---|---|---|
| Source | df | Weaning Weight | Type | Calculated[a] 205-Day Weight | Average Daily Gain |
| Year | 8 | 99350.0** | 279.21** | 77723.1** | 1.8428** |
| Breed/Year | 18 | 74097.5 | 39.84 | 48562.6 | 1.0685 |
| Herd/Year-Breed | 608 | 209074.8** | 45.45** | 147022.5** | 3.4599** |
| Age | 1 | 22879696.0** | 390.1** | 767544.8** | 18.5** |
| Sex | 2 | 4322408.0** | 196.9** | 3757585,9** | 72.3** |
| Age of Dam | 5 | 856625.1** | 119.4** | 806567.8** | 17.2** |
| Season | 3 | 110952.0** | 21.1** | 96139.5** | 2.2** |
| Residual | 17737 | 2739.7 | .0130 | 2382.2 | .0566 |

**P <.01.

[a]Calculated 205-day weight = (((weaning weight-birth weight) ÷ weaning age) X 205) + birth weight.

affected ($P < .01$) weaning weight, weaning type score and average daily gain of both creep- and non-creed-fed calves. However, breed influenced only type score among creep-fed calves. Results were similar when the feed-management groups were considered separately and when they were pooled and a single analysis was performed.

The magnitude of the influence of the environmental factors on weaning weight was emphasized by the extremely large F-values. In order to determine the relative magnitude of the various environmental factors on the preweaning performance traits, stepwise regression analyses were performed. The results of the stepwise regression analyses were expressed as change in $R^2$ ($\Delta R^2$) or the fraction of the variation of the performance trait attributable to the independent variable after variation due to previously included fixed environmental effects had been considered. The order of incorporation of the environmental factors is important if any pair of the elements are correlated. In this analysis, the practical sequence of adjusting performance records for environmental variation and reported contribution of the various environmental factors on variation in performance traits were considered when establishing the order of incorporation of elements in the model. Adjusted records are generally used for comparisons of animals within a herd and variation due to individual herd management practices would be difficult to measure. Therefore, the $R^2$ values reported in Table 8 represent the fraction of the variation within herds which can be attributed to specific environmental factors. The four independent variables, season of birth, age of dam, sex of calf and weaning age, included in the analysis accounted for 47.2, 21.0, 6.3 and 23.6 percent of the variation in weaning weight, average

TABLE 8

VARIATION IN WEANING WEIGHT, AVERAGE DAILY GAIN, TYPE SCORE AND 205-DAY WEIGHT OF ALL CALVES EXPLAINED BY SEQUENTIALLY ADDING ELEMENTS TO THE MODEL

| | | | | | | $\Delta R^2$ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age[a] | Age[b] | Age[c] | Sex | Age of Dam | Season | Weaning Weight | Average Daily Gain | Type Score | Calculated 205-Day Weight[d] |
| X | | | | | | .322 | .018 | .018 | .017 |
| X | X | | | | | .003 | .001 | .001 | .001 |
| X | X | X | | | | .001 | .001 | .001 | .001 |
| X | X | X | X | | | .097 | .119 | .017 | .141 |
| X | X | X | X | X | | .046 | .066 | .023 | .072 |
| X | X | X | X | X | X | .003 | .005 | .003 | .004 |
| TOTAL $R^2$ | | | | | | .472 | .210 | .063 | .236 |

[a]Linear.

[b]Quadratic.

[c]Cubic regression of WW on WA.

[d]Calculated 205-day weight = (((Weaning weight-birth weight) ÷ Weaning age) X 205) + birth weight.

daily gain (ADG), conformation score and calculated 205-day weight, respectively. The influences of these environmental factors on weaning weight was further emphasized by the F-values which ranged from 40 for season of birth to 8351 for weaning age. The extremely large F-value for weaning age indicates the importance of an effective method of adjusting the weaning weight to an age-constant basis. These mean squares and F-values were very similar to that reported by McLaren (1970) who evaluated similar data collected by the Alabama Beef Cattle Improvement Association.

The quadratic and cubic term of the weaning age polynomial explained only 0.3 and 0.1 percent, respectively, of the variation in weaning weight. In addition, these terms explained less than 1 percent of the variation in ADG, conformation score and calculated 205-day weight. Age of dam accounted for 9.7, 11.9, 1.7 and 14.1 percent of the variation in the four performance traits, respectively, when weaning age was held constant. The amount of variation explained by season of birth was less than that explained by the other independent variables.

The influence of these four independent variables on the performance of creep- and non-creep-fed calves is shown in the Appendix, Tables 23 and 24, respectively. The percentages of the variation in weaning weight and conformation score of both creep-fed and non-creep-fed calves attributable to age of calf, sex of calf, age of dam and season of birth were similar to those found in the combined analysis of all calves. However, about 5 percent more variation was attributable to these dependent variables in non-creep-fed than in creep-fed calves. This larger $R^2$ value was probably due to the failure of the procedure used to calculate

205-day weight to completely remove the dependancy between this age-constant weight and weaning age in non-creep-fed calves.

Variation in sex of calf accounted for 1.6 to 1.7 percent of the variation in type score among creep- and non-creep-fed calves. The residual mean squares were similar for creep- and non-creep-fed calves and indicated some pooling was in order. These findings were in close agreement with those reported by McLaren (1970), but were in direct contrast to research conducted by Marlowe, Mast and Schalles (1965).

The mean age, weight, conformation score and average daily gain of the 18,393 calves included in this study were 221.1 days, 424.7 lb., 12.5 units and 1.63 lb. per day, respectively, as shown in Table 9. These values were 222.6 days, 456.8 lb., 13.0 units and 1.76 lb. per head per day, respectively, for the 6,070 creep-fed calves. The results of the analysis of variance of the creep-fed calves are summarized in the Appendix, Table 22. All the main sources of variation in weaning weight and conformation score were found to be highly significant ($P<.01$). Year and breed/year had no significant effect on average daily gain. However, all other sources of variation were highly significant ($P<.01$). In the analysis involving all calves, management had the greatest influence on weight and type score of the factors studied. Also, the effect of year on average daily gain was less for creep-fed calves than for non-creep-fed calves.

The mean age, weaning weight, type score and average daily gain of the 12,323 non-creep-fed calves were 220.3 days, 408.9 pounds, 12.2 grade and 1.57 pounds per day, respectively. As in the two previous analyses, all the main sources of variation for weaning weight, type

TABLE 9

OVERALL MEANS[a] AND THEIR STANDARD ERRORS FOR AGE, WEANING WEIGHT, TYPE SCORE, AVERAGE DAILY GAIN AND 205-DAY WEIGHT

| Source | Non-Creep | Creep | Creep & Non-Creep Combined |
|---|---|---|---|
| Age | 220.3 ± .272 | 222.6 ± .380 | 221.1 ± .310 |
| Weaning Weight | 408.9 ± .605 | 456.8 ± 1.029 | 424.7 ± .740 |
| Type Score | 12.2 ± .011 | 13.0 ± .014 | 12.5 ± .011 |
| Average Daily Gain | 1.57 ± .002 | 1.76 ± .004 | 1.63 ± .003 |
| 205-Day Weight | 387.1 ± .476 | 426.5 ± .783 | 400.1 ± .577 |

[a]Means are based on 12,323 non-creep-fed calves and 6,070 creep-fed calves.

score and average daily gain except for breed/year were found to be significant ($P < .05$).

It was noted from a study of the $R^2$ values, that only a small variation in weaning weight was due to the quadratic and cubic terms of the age polynomial and to the various two-way interactions among sex, age of dam, and season of birth. The growth rate between 120 and 300 days of age was found to have a near linear relationship with weaning age. This was in close agreement with Cunningham and Henderson (1965 a) and in the neighboring state of Alabama by McLaren (1970). However, two studies in the neighboring state of Georgia (Warren, Thrift and Cannon, 1965; and Rhodes, 1970) reported a curvilinear relationship between age and weight.

Adjustment of Weaning Weight to an Age-Constant Basis

Individual weaning records were adjusted to a 205-day basis by the standard method described in Table 6, page 30. The mean calculated 205-day weight for non-creep-fed, creep-fed and combined calves were 387.1 pounds, 426.5 pounds and 400.1 pounds, respectively (Table 9). Results of the analysis of variance showed that all main sources in the model, except breed/year, had a significant effect ($P < .01$) on calculated 205-day weight. Weaning age was the first element included in the model and the $R^2$ value for this regression of weaning weight on weaning age was 0.322 on a within-herd basis. When creep- and non-creep-fed calves were considered separately the values were 0.334 and 0.320, respectively. The $R^2$ value for the regression of calculated 205-day weight on weaning age was 0.017 for the combined analysis and 0.007 and 0.025 for creep-and non-creep calves separately. These $R^2$ values indicate that the standard method of adjusting weaning weight to an age-constant basis was not completely effective. When the coefficients of regression were examined, it was observed that the coefficient for the regression of weaning weight on age was positive and the coefficient for regression of calculated 205-day weight on weaning weight on weaning age was negative. These coefficients further emphasized the inefficiency of the standard method of adjusting weaning weight to an age-constant basis and suggested that another source of variation had been introduced. These values show that the standard method of adjustment resulted in a biased estimate of 205-day weight.

The majority of calves in this study were born in the winter and the spring (Table 10) and were weaned at different ages between July to September. This study agrees closely with work by McLaren (1970) who studied the age-weight relationship in a similar group of calves between 120 to 300 days of age. He observed that an overadjustment of the weaning weight of calves in the extreme age groups was evident due to the change in the direction of the weight-age regression lines before and after adjustment. Work conducted by Minyard and Dinkel (1965) agrees with this study and suggested that the standard method of adjusting weaning weight to an age-constant basis tended to overadjust the weight of calves in the extreme age groups. Results of this study are partially supported by the summary of the Virginia BCIA data reported by Marlowe, Kincaid and Litton (1958). They found that the type score of calves increased as age increased from 120 to 270 days of age but their gains decreased in a curvilinear fashion. They rationalize that when grade

TABLE 10

LEAST SQUARES CONSTANT AND THEIR STANDARD ERROR FOR WEANING WEIGHT, TYPE SCORE, 205-DAY WEIGHT AND AVERAGE DAILY GAIN OF ALL CALVES

| Source | No. of Calves | Weaning Weight | Type Score | 205-Day Weight | Average Daily Gain |
|---|---|---|---|---|---|
| Sex of Calf | | | | | |
| Bulls | 6122 | 30.2 ± .69 | .259 ± .015 | 28.4 ± .64 | .131 ± .003 |
| Steers | 3233 | -7.4 ± .82 | -.258 ± .018 | -7.3 ± .76 | -.044 ± .004 |
| Heifers | 9038 | -22.8 ± .83 | -.001 ± .017 | -21.1 ± .89 | -.087 ± .006 |
| Age of Dam[a] | | | | | |
| 2 | 1390 | -33.0 ± 1.33 | -.405 ± .029 | -33.1 ± 1.24 | -.141 ± .006 |
| 3 | 2574 | -14.6 ± 1.00 | -.071 ± .022 | -13.8 ± .93 | -.071 ± .005 |
| 4 | 2700 | -.2 ± .99 | .020 ± .022 | 4 ± .92 | -.003 ± .005 |
| 5 | 2376 | 11.2 ± 1.03 | .167 ± .022 | 10.9 ± .96 | .049 ± .005 |
| 6[b] | 7490 | 21.0 ± 2.12 | .280 ± .027 | 20.1 ± 1.23 | .094 ± .006 |
| 11[c] | 1863 | 15.6 ± 1.15 | .009 ± 0.25 | 15.5 ± 1.07 | .072 ± .005 |
| Season of Birth[d] | | | | | |
| Winter | 9799 | 7.6 ± .77 | .062 ± .017 | 6.5 ± .72 | .031 ± .003 |
| Spring | 3195 | 5.2 ± 1.08 | .134 ± .023 | 6.1 ± 1.01 | .030 ± .005 |
| Summer | 1423 | -9.9 ± 1.32 | -.118 ± .029 | -9.1 ± 1.23 | -.044 ± .006 |
| Fall | 3976 | -2.9 ± 1.23 | -.078 ± .028 | -3.5 ± 1.14 | -.017 ± .004 |
| Regression Y on WA (linear) | | 1.349 ± .015 | .006 ± .0003 | -.247 ± .014 | -.001 ± .00007 |
| Number of Calves | 18,393 | | | | |
| Mean | | 425 ± .740 | 12.5 ± .011 | 400 ± .577 | 1.63 ± .003 |

TABLE 10 (continued)

[a]Age of dam expressed in years.

[b]6-, 7-, 8-, 9-, and 10-year-old dams grouped together.

[c]Eleven-years-old and over.

[d]Winter = January, February and March; Spring = April, May and June; Summer = July, August and September; Fall = October, November and December.

and weight were combined into a single selection index, the increase in grade as age increased was neutralized by the decrease in gain and that the index based on weight and grade was a relatively accurate estimate of genetic net worth.

In contrast, Koch and Clark (1955a) reported that the growth of calves appeared to be linear. However, they suggested that age may be confounded with season and an apparent decrease in growth with increasing age may result when it is truly a seasonal effect. They also reported a negative coefficient (-.04) for the regression age-constant (182-day calculated weight) on weaning age.

The standard method described in Table 6, page 30, will be discussed in more detail in a later section.

<u>The Effect of Age on Other Traits</u>

The effect of weaning age on type score is shown in Figure 1. As age increased from 120 to about 240 days, type score tended to increase. After 240 days of age, types score decreased. This could be an artifact of the confounding of season with calf age since the largest number of calves were weaned between July and late September. The trend was similar in both creep- and non-creep-fed calves; however, the decline in type score tended to start at a slightly younger age in non-creep-fed calves.

As age increased, rate of gain tended to decrease (Figure 2). This decrease appeared to be linear. However, cumulative gain, expressed as weaning weight, increased as age increased and the deviation of this weight age relation from linearity was not statistically significant.

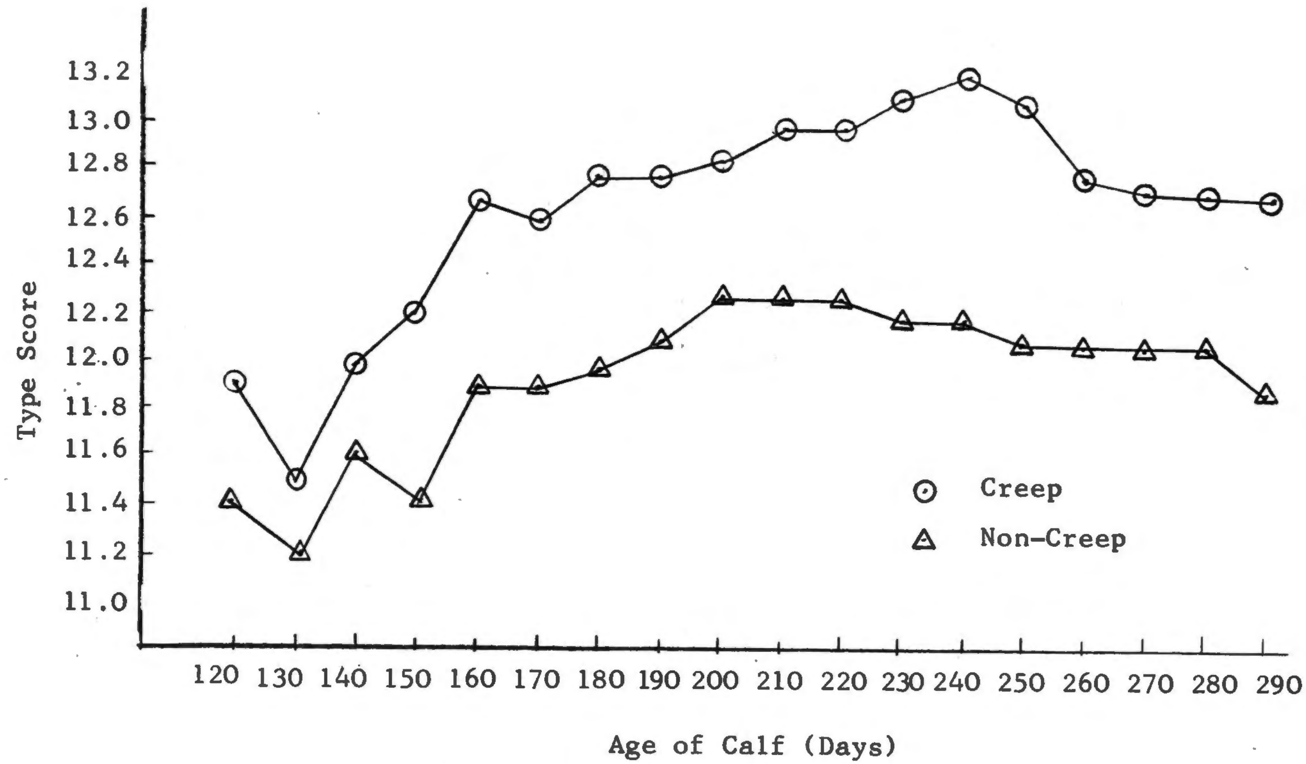


FIGURE 1. Effects of age on type score of calf.

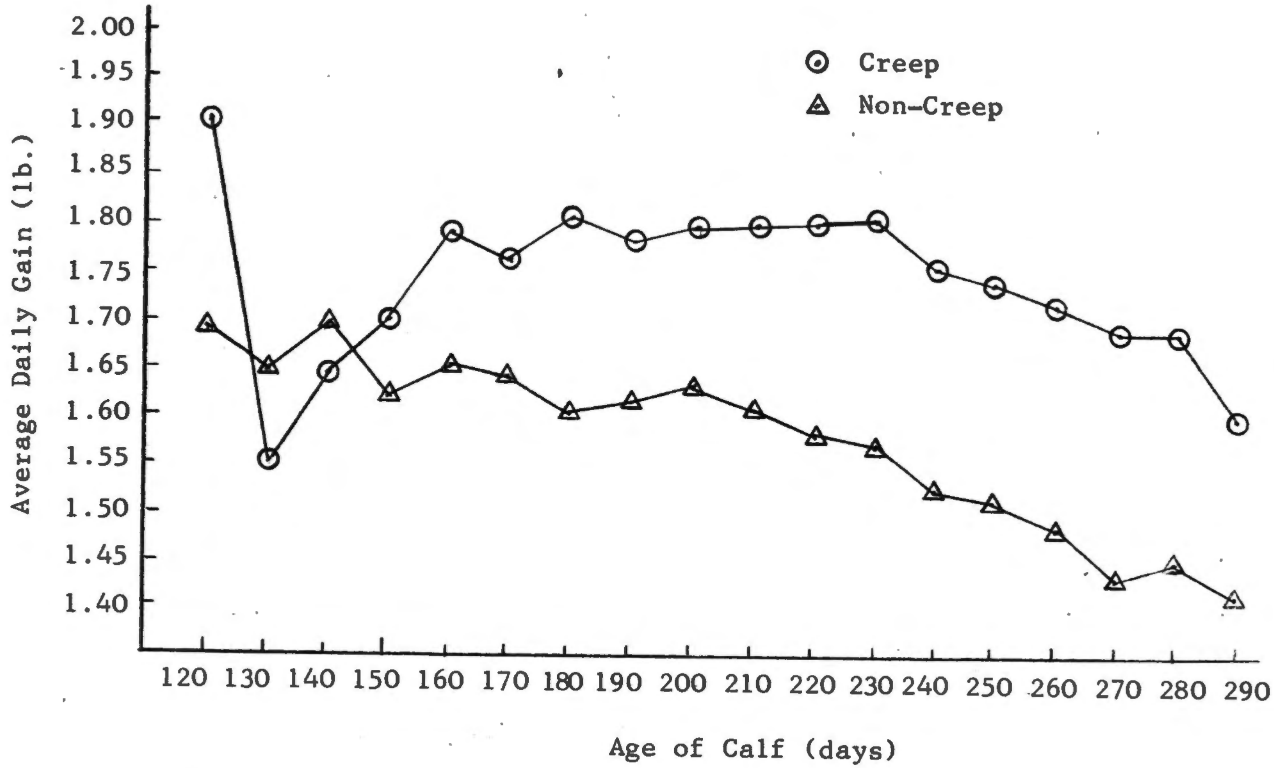


FIGURE 2. Effects of age of calf on average daily gain.

Sex of Calf

This study included 6,122 bulls, 3,233 steers and 9,038 heifers (Table 2, page 19). Least squares constants for the effect of sex on 205-day weight, weaning weight, type score and average daily gain for all calves are shown in Table 10, page 41, and constants from the analysis of creep- and non-creep-fed calves separately are shown in the Appendix, Tables 25 and 26. Results of the analyses of variance indicated that effect of sex on all performance traits were highly significant ($P < .01$) regardless of which management practice was used.

The mean weaning weight of bull calves was 37.6 lb. greater than that of steer calves and 53.0 lb. greater than that of heifer calves. The mean weaning weight of creep-fed bulls was 52.8 lb. heavier than that of creep-fed steers and 65.6 lb. heavier than that of heifers. These differences were not as great among non-creep-fed calves (29.1 and 44.8 lb., respectively). The difference in calculated 205-day weight of bull and steer calves and bull and heifer calves were 49.0 and 60.9 lb., respectively, for the creep-fed calves and 28.8 and 43.0 lb., respectively, for the non-creep calves. Evans et al. (1955) reported that male calves were 22 lb. heavier than females at weaning; whereas, Rollins and Guilbert (1954) found bulls to be 68 lb. heavier at weaning.

When all calves were considered, bull calves graded an average of .4 units higher than heifers and 1.0 unit higher than the steer calves. Marlowe, Kincaid and Litton (1958), McLaren (1970) and Rhodes (1970) also found that bull calves graded higher than steers or heifers. In addition, they reported that heifers graded considerably higher than steers.

It should be noted that at least part of the difference in weaning weight, conformation score and average daily gain attributed to difference in sex was probably due to selection of calves to be castrated. A large number of the calves represented in this study were purebreds and breeders tend to retain the faster gaining, heavier, higher grading calves as bulls and to castrate the remainder. Due to this differential selection, bull calves will grade higher and will be heavier than steer calves at weaning. Therefore, adjustment factors for sex of calf calculated from data including a high percentage of purebred calves may tend to over-adjust the weaning weight of bull calves and under-adjust that of steer calves. The most efficient factors would be those derived from a planned experiment designed to measure the effect of sex in a group of calves where random castration was practiced.

Age of Dam

The results found in this study agree closely with reports of similar work by previous workers. Two-year-old cows produce calves which were inferior with respect to type score and lighter at weaning than those produced by older cows. Maximum weaning weight and type scores were attained by calves from cows between six and ten years of age. In the preliminary analysis where age was classified by year from two to thirteen years of age, no significant differences were noted with respect to weaning weight of calves of cows from six through ten years of age. In subsequent analyses these ages were considered as one group. Cows eleven years and older were also combined in one group due to the small number of cows in this age range.

Least-squares constants for the effect of age of dam on calculated 205-day weight, weaning weight, type grade, and average daily gain from birth to weaning are presented in Table 10, page 41. The anslysis of variance (Table 7, page 33) shows that the effect of age of dam was highly significant ($P < .01$) for these preweaning performance traits. It should be remembered that in commercial herds the older cows would not have been retained if their producing ability was not above the average for the herd and that this probably biased the estimates upward for the older ages. In all three management groups the rank of age of dam with respect to production (weaning weight and type) was the same for the six age groups. The order of these six age-of-dam groups from least productive to most productive is 2, 3, 4, 5, 11 and over and 6, 7, 8, 9, 10 years of age combined. Management significantly affected the difference in productivity among the six age groups. Calves from cows 6 to 10 years old gained faster (Figure 3) and were 68 and 79.4 lb. heavier at weaning and graded 0.5 and 0.7 units higher (Figure 4) than calves from 2-year-old cows in the creep- and non-creep groups, respectively. Work by Marlowe and Gaines (1958), McLaren (1970), Koger and Knox (1945b) Jamison (1966) and Blackwell, Knox and Hurt (1958), was in close agreement with this study with respect to the trends of the age-of-dam constants for 205-day weights. The constants for creep- and non-creep calves reported in this study agrees closely with those reported by McGuire (1969) and Anderson and Dinkel (1969), but smaller constants were reported by Hamann, Wearden and Smith (1960). A curvilinear response in weaning weight as age of dam increased, similar to that reported by Cunningham and Henderson (1965b).

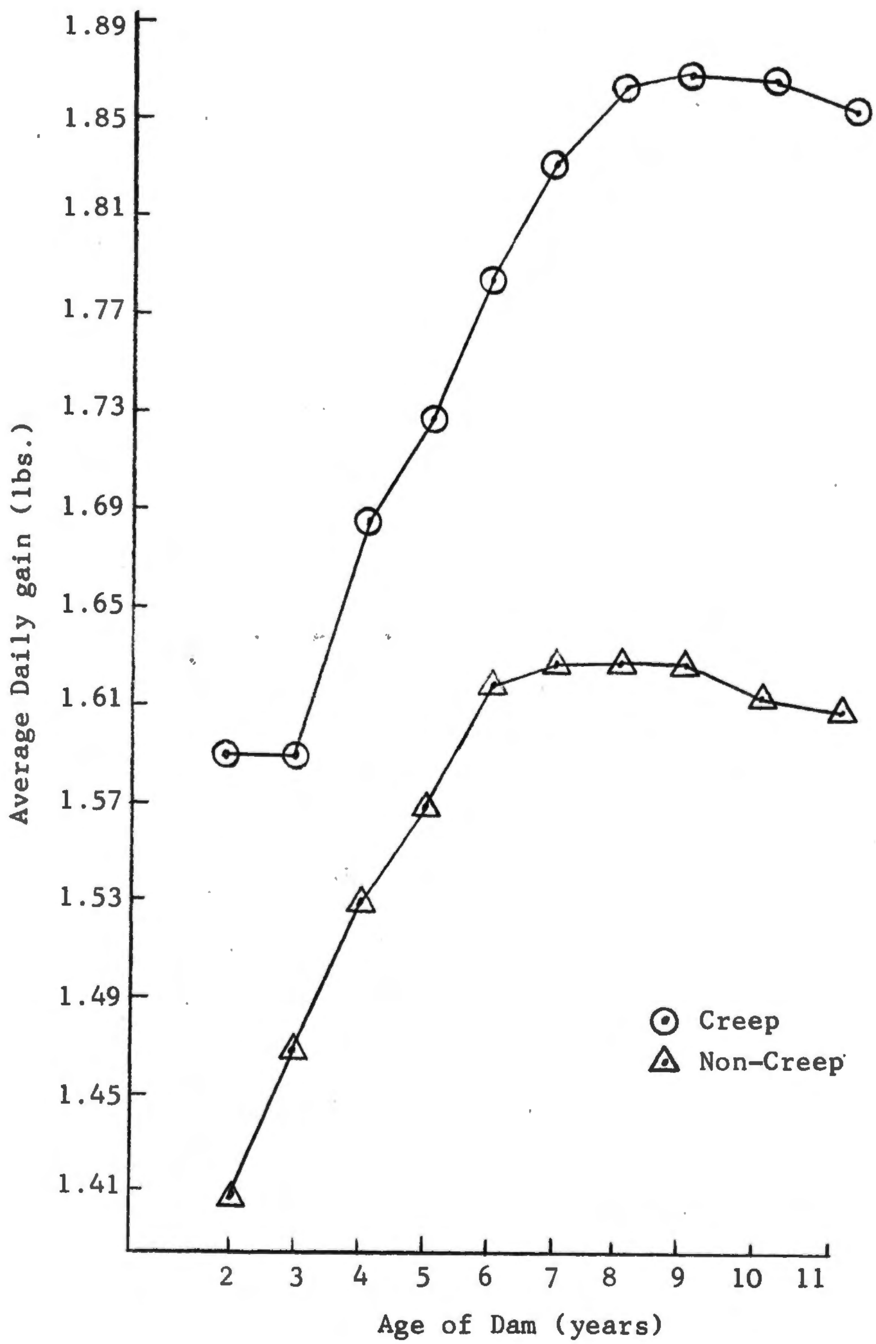


FIGURE 3. Effects of age of dam on average daily gain.

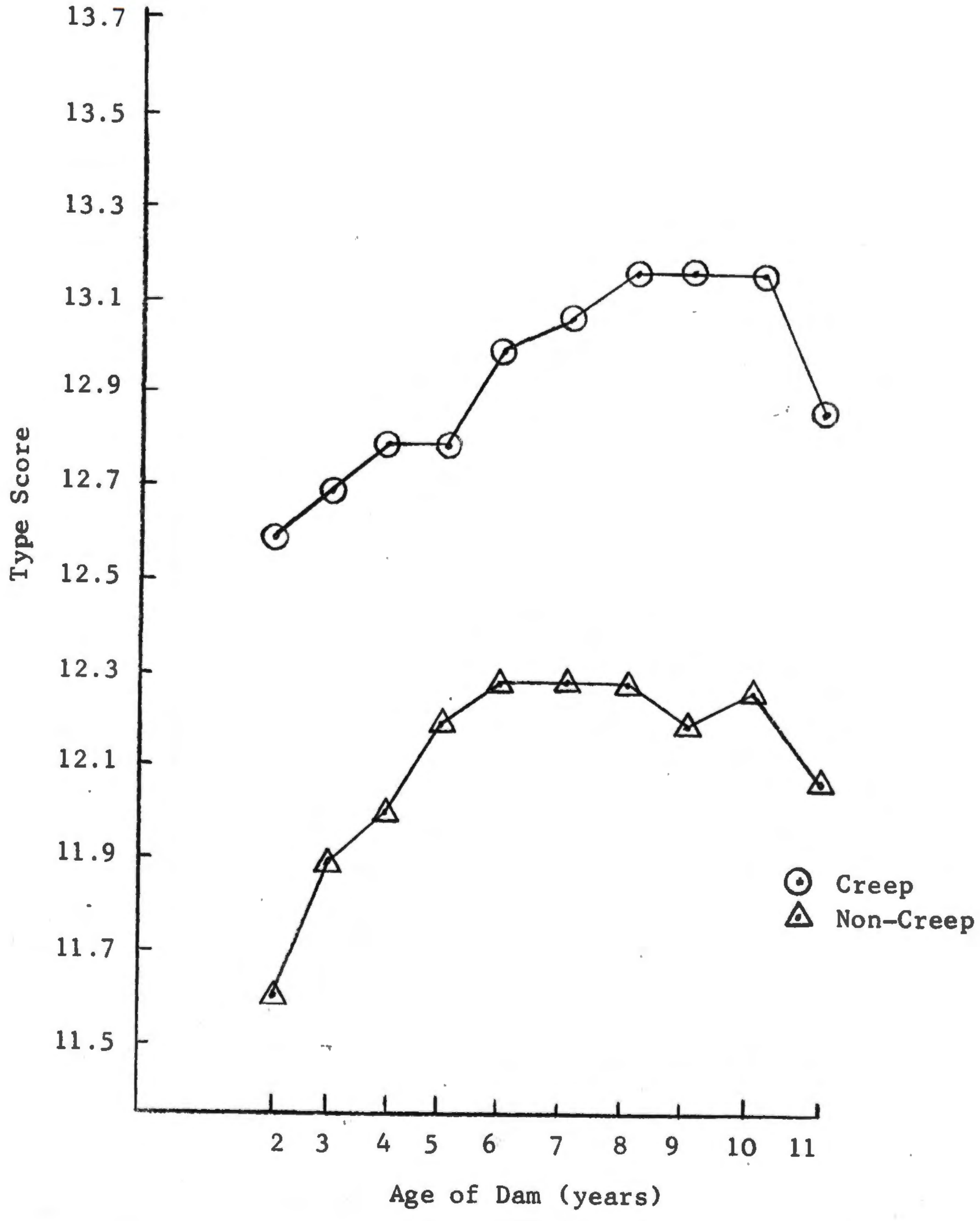


FIGURE 4. Effects of age of dam on type score of calf.

Season of Birth

In the three analyses of variance tables discussed earlier (creep, non-creep and all calves combined) season of birth had a highly significant ($P < .01$) effect on weaning weight, type grade, average daily gain and calculated 205-day weight. McLaren (1970) and Rhodes (1970) found that the most productive months for birth of calves were December and January. It should be noted that these two studies were done in Alabama and Georgia where winter pastures are about one month in advance of the winter pastures of Tennessee. Therefore, trends observed with respect to months of birth effects in TBCIP data would be expected to occur about one month later than those in reports based on data collected in states to the south of Tennessee.

Least-squares constants for the effect of season on 205-day weight (Table 10, page 41) indicate that calves born in July, August and September were lighter at weaning than calves born in other months and calves born in October, November and December were only slightly heavier. These data indicate a significant advantage in growth rate for calves born in the winter and the spring. The heaviest calves at weaning were those born in May and April, respectively. Calves born in August had the lowest average daily gain in both creep- and non-creep-fed calves and those born in October graded the lowest (Figures 5 and 6). This was in close agreement with Loganathan (1962) who reported that calves born in April and May made the fastest gains. Reports of studies involving herds in which year-round calving was practiced tended to substantiate the fact that calves born in these summer and fall months were the lighter and graded lower at weaning than calves born in other months

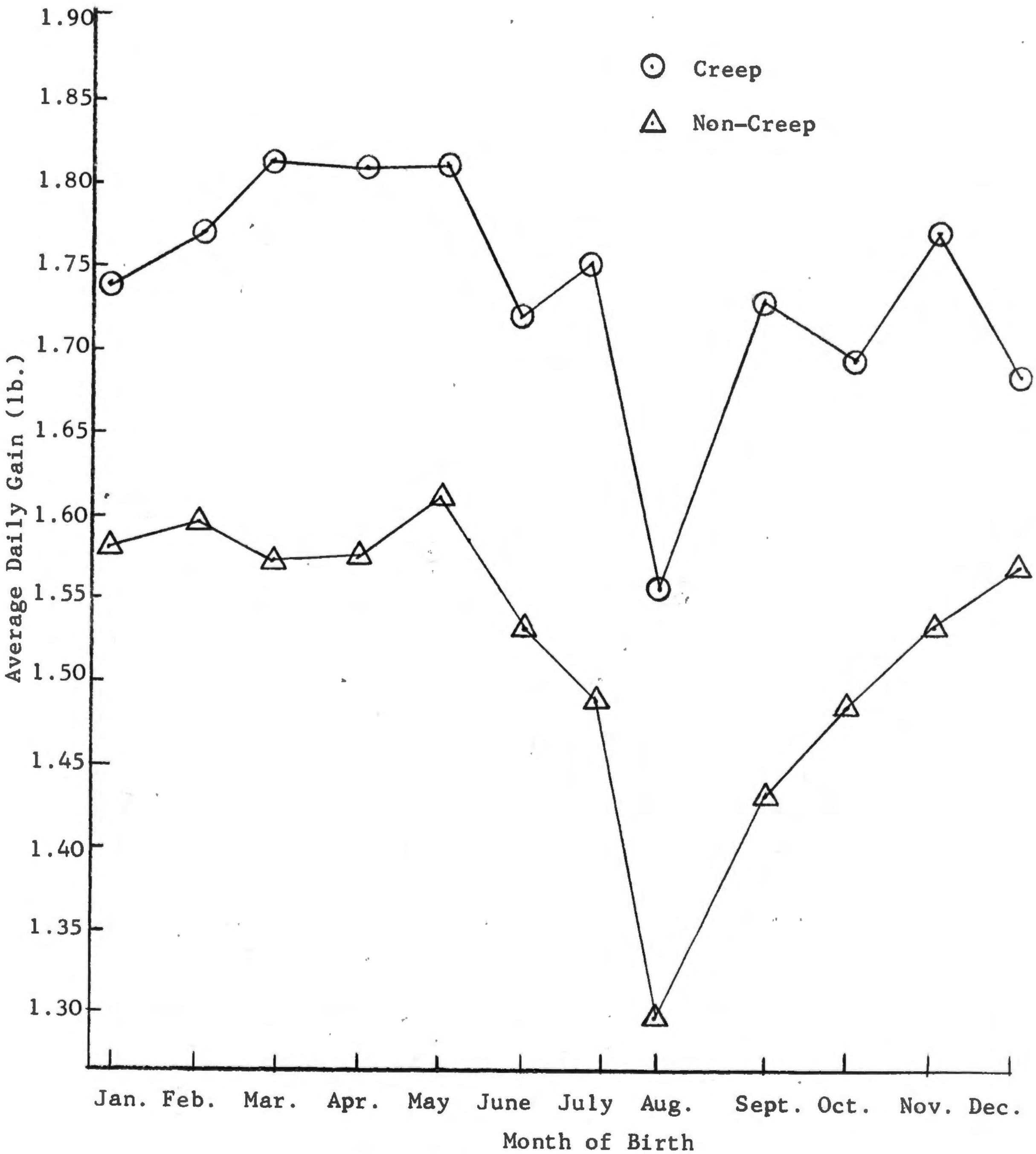


FIGURE 5. Effects of month of birth on average daily gain.

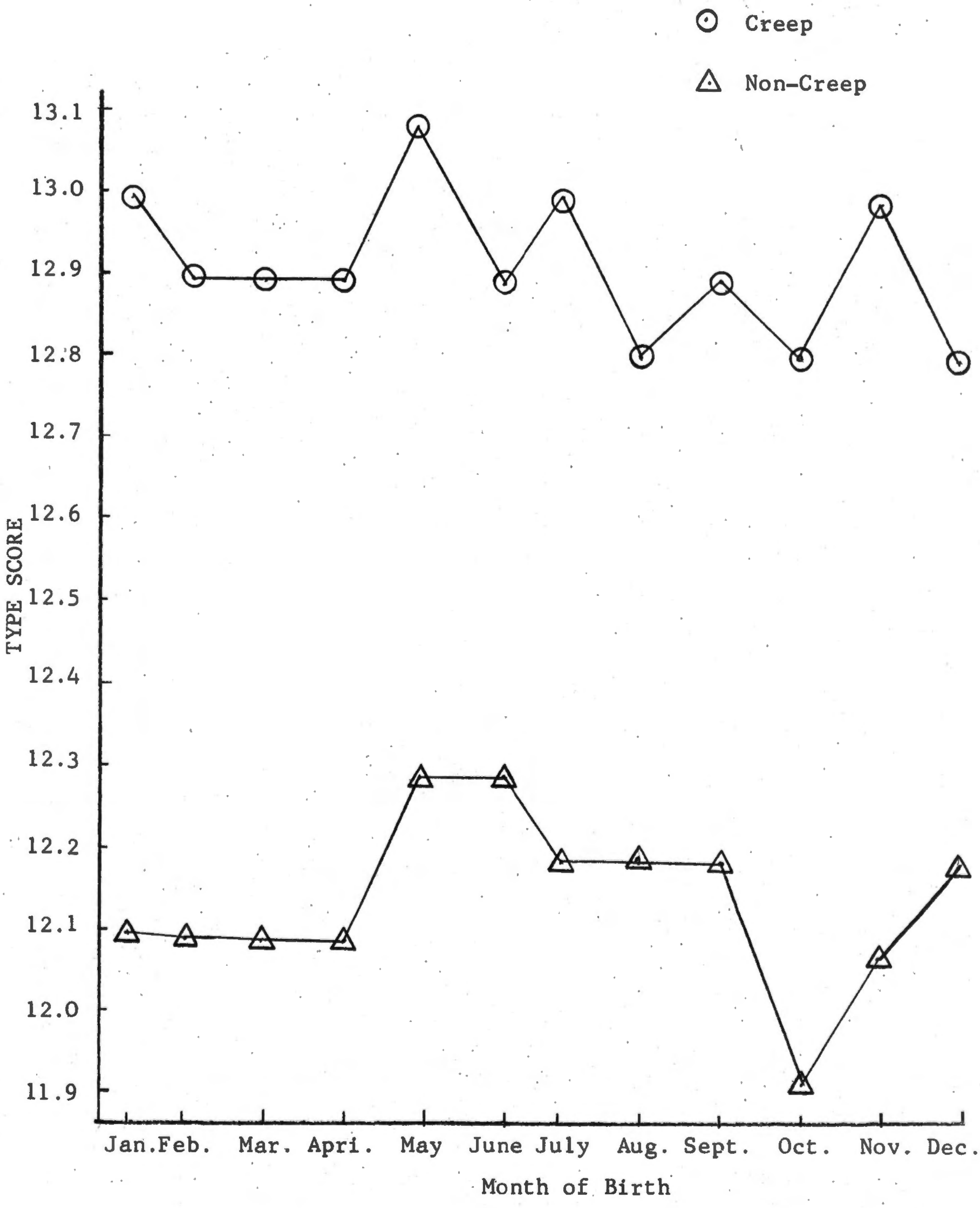


FIGURE 6. Effects of month of birth on type score of calf.

(Reynolds et al., 1958; Marlowe, Mast and Schalles, 1965).

Non-creep-fed calves born in the winter (January, February and March) were 5.0, 24.8, and 10.2 lbs. heavier at weaning than those born in the spring, summer and fall, respectively. Performance of the non-creep-fed calves should more accurately reflect the effect of month of birth on weaning weight since these calves are more dependent on pasture than on supplemental feed. A difference in the magnitude of month of birth effect on weaning weight was noted between the creep-fed and non-creep-fed calves. Creep-fed calves born in the winter were 2.0, 12.7 and 10.7 lbs. heavier at weaning than those born in the three other seasons, respectively. Creep-fed calves born in the winter were 44 lb. heavier at weaning than non-creep-fed calves born during that season. This indicates a need for supplemental feeding during the late summer and fall when pastures are at their lowest level of production.

## II. EVALUATION OF ADJUSTMENT FACTORS

The weight-age relationship at weaning is shown in Figure 7. The regression was calculated from weaning records of 18,393 Angus and Hereford calves. Weaning weight increased 1.58 lb. for each increase of one day in weaning age. It was not practical to show the dispersion of the individual weights about the regression line because of the large number of observations. The $R^2$ values for the quadratic and cubic terms of the weaning weight-age polynomial are shown in Table 8, page 35, and indicate that this relationship was linear.

Age-constant weights were calculated from the individual weaning weights by the standard method described in Table 6, page 30. The

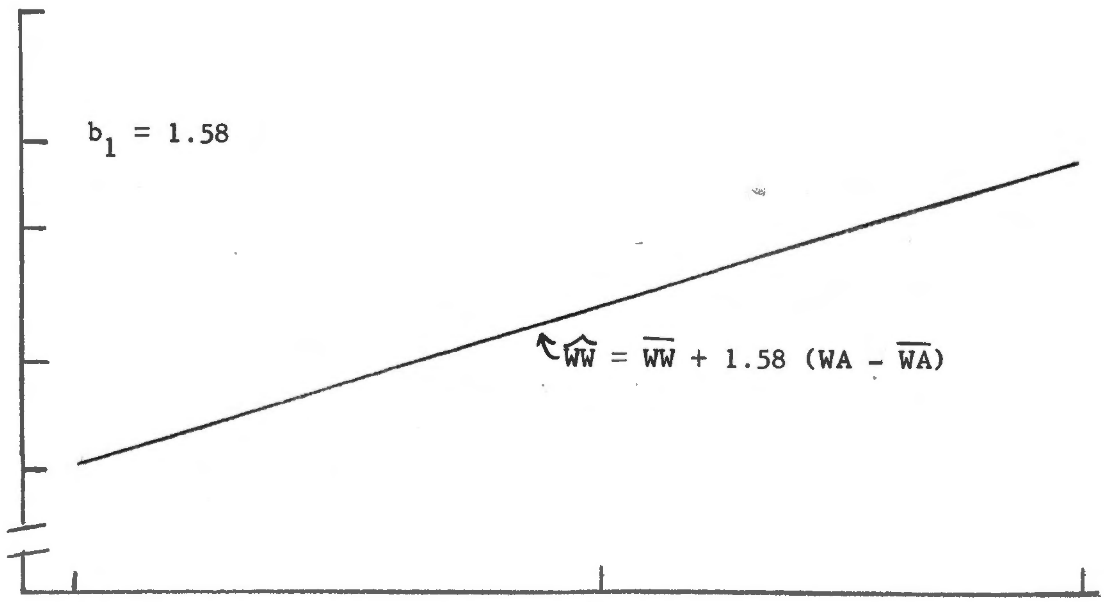


FIGURE 7. Average relationship of actual weaning weight with weaning age within the age range of 120 to 300 days.

regression of 205-day weight, calculated by this method, on weaning weight is presented in Figure 8 and indicates that this adjustment did not remove all of the dependency of weight on weaning age. The fact that calculated 205-day weight decreases 0.247 lb. for each increase of one day in weaning age showed that a new source of variation was introduced. The direction of the regression lines for weaning weight on weaning age and for 205-day weight calculated weight on weaning age was different. This change in direction, positive to negative $b_1$, indicates that the age-constant weights, calculated using unadjusted average daily gain, were too high for the young calves and too low for the older calves.

Weaning weight of each calf was adjusted to a steer, 205-day, average-season and six-year-old-dam basis using each of the nine methods described in Table 6, page 30. These methods included various combinations of four methods for correcting weaning weight to a constant age and three sets of adjustment factors for environmental effect derived from (1) weaning records of creep-fed and non-creep-fed calves analyzed separately, (2) weaning records of all calves combined in a single analysis, and (3) current factors used by the TBCIP. The nine resulting data sets were analyzed to evaluate the relative effectiveness of the various combinations of correction factors to remove environmental variation.

The results of these analyses are shown in Table 11 in terms of $R^2$. The fraction of the variation in weaning weight remaining after adjustment was defined as the $R^2$ value. In each 205-day-weight data set this value included only that fraction attributable to the combined

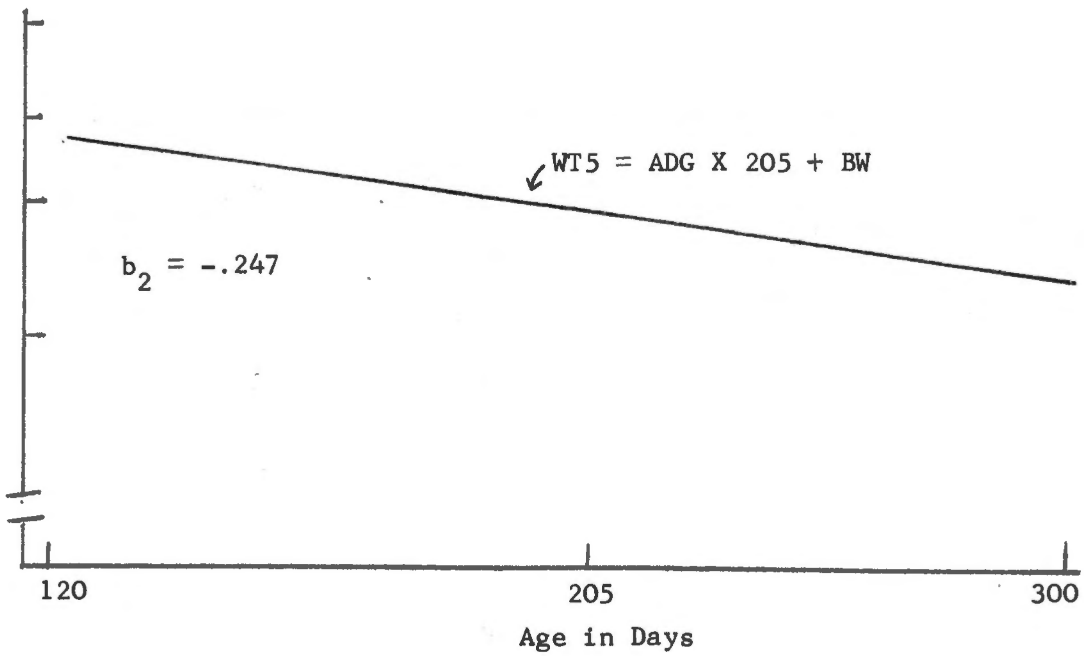


FIGURE 8. Relationship of calculated 205-day weight with weaning age when unadjusted average daily gain alone was considered in the prediction equation.

TABLE 11

EVALUATION[a] OF THE EFFECTIVENESS OF VARIOUS METHODS OF ADJUSTING WEANING WEIGHT TO REMOVE VARIATION DUE TO ENVIRONMENTAL EFFECTS[b]

| Method | Creep | Non-Creep | All Calves |
|---|---|---|---|
| ADJUSTMENT FOR ENVIRONMENTAL EFFECTS | | | |
| One set of factors[c] | 0.0123 | 0.0266 | 0.0069 |
| By management[d] | 0.0091 | 0.0178 | 0.0098 |
| TBCIP FACTORS vs CALCULATED FACTORS[e] | | | |
| One set of factors | 0.0258 | 0.0386 | 0.0226 |
| By management | 0.0183 | 0.0336 | 0.0256 |
| TBCIP[f] | 0.1200 | 0.0926 | 0.0963 |
| AGE-CONSTANT WEIGHT[g] | | | |
| Standard | 0.0307 | 0.0361 | 0.0241 |
| Regression ($b_1$) | 0.0185 | 0.0048 | 0.0020 |
| Standard + $b_2$ | 0.0183 | 0.0031 | 0.0010 |
| Age intercept | 0.0182 | 0.0028 | 0.0012 |

[a]Lower $R^2$ values represent the set of factors most effective in removing environmental variation.

[b]The $R^2$ values are means of four separate analyses where each of the four methods of adjusting to an age-constant weight and the respective set of factors for environmental effects were combined to adjust weaning weight.

[c]One set of factors derived from a single analysis of the combined records.

[d]Different factors were used for creep- and non-creep-fed calves.

[e]Adjustment to an age-constant basis by the standard method only.

[f]Factors currently used by the TBCIP.

[g]Adjustment of weaning weight to an age constant basis. $R^2$ values are an average of two methods of adjusting for environmental factors.

effects of variation in weaning age, age of dam, season of birth and sex of calf on a within herd basis. Therefore, lower $R^2$ values represent greater effectiveness of the adjustment procedures.

The $R^2$ values shown in Table 11 indicate that separate adjustment factors derived within each feed-management group and each set of these factors used to adjust the records of calves in the respective groups was more efficient in removing variation than a single set of adjustment factor. However, the use of one set of adjustment factor may be more practical and the reduced efficiency due to pooling was not serious.

Adjustment factors currently used by the Tennessee Beef Cattle Improvement Program were significantly less effective in removing variation due to sex of calf, age of dam and season of birth than either set of calculated factors (Table 11). The $R^2$ values indicate that 12.0 and 9.26 percent of the variation in age-constants weight of creep- and non-creep-fed calves, respectively, is due to the inefficiency of the TBCIP factors to remove variation due to sex, age of dam and season of birth.

The relative effectiveness of the standard, regression ($b_1$), standard + $b_2$ methods of adjusting weaning records to 205-day weight is shown also in Table 11. Regardless of the degree of pooling of records, the standard method (average daily gain from birth to weaning multiplied by 205 plus birth weight) was significantly less effective than the other three methods. The regression ($b_1$), standard + $b_2$ and age intercept methods were similar with respect to the dependency of the resulting 205-day weight on weaning age. When 205-day weights adjusted by the standard, regression ($b_1$), standard + $b_2$ and age intercept method were analyzed the $R^2$ values were 0.0307, 0.0185, 0.0183 and 0.0182, respectively, in creep-fed calves; 0.0361, 0.0048, 0.0031 and 0.0028, respectively, in non-creep-fed calves; and 0.0241, 0.0020, 0.0010 and 0.0012, respectively, when both groups were combined.

The effectiveness of the nine individual combinations of the four methods of adjusting for age of calf and three methods of adjusting for fixed environmental effects is shown in Table 12. $R^2$ values from the analyses of the 205-day weights indicate that methods W1, W5, W6, W7, W8 and W9 were similar with respect to effectiveness of adjusting weaning weights for creep-fed calves. However, methods W5, W7 and W9 were more effective than the other methods in adjusting weaning weights of non-creep-fed calves. On the other hand, W6 and W8 were more effective in adjusting weaning weights in creep-fed and non-creep-fed calves combined.

The dependence between various adjusted 205-day weights and weaning age in creep- and non-creep-fed calves is emphasized by the coefficients of correlation shown in Tables 13 and 14. These coefficients indicate also that the standard method of adjusting to an age-constant basis and the TBCIP factors for adjusting for fixed environmental effects are inefficient.

The results of the stepwise regression analyses of the various 205-day weight data sets are presented in Tables 15, 16 and 17. They indicate that that most of the variation in 205-day weight on weaning age was due to the fact that age-constant weights calculated by the standard method, were too low for older calves and too high for the younger calves. These results indicate that two procedures may be used to remove the effect of the adjustments of the calculated 205-day

TABLE 12

EVALUATION OF THE EFFECTIVENESS OF VARIOUS COMBINATIONS OF ADJUSTING WEANING WEIGHT IN REMOVING VARIATION DUE TO ENVIRONMENTAL EFFECTS

| Method of Adjustment[a] | Creep Fed | Non-Creep Fed | Creep and Non-Creep Combined |
|---|---|---|---|
| | $R^2$ | | |
| W1 | 0.0183 | 0.0386 | 0.0226 |
| W2 | 0.0258 | 0.0336 | 0.0256 |
| W3 | 0.1200 | 0.0926 | 0.0963 |
| W4 | 0.0353 | 0.0083 | 0.0013 |
| W5 | 0.0188 | 0.0013 | 0.0028 |
| W6 | 0.0146 | 0.0051 | 0.0002 |
| W7 | 0.0219 | 0.0012 | 0.0019 |
| W8 | 0.0203 | 0.0052 | 0.0004 |
| W9 | 0.0194 | 0.0003 | 0.0021 |

[a]Combinations of procedures for adjusting weaning weight to an age constant basis and the origin of the environmental adjustment factors used to calculate each 205-day weight dataset are shown in Table 6, page 30.

TABLE 13

CORRELATION BETWEEN AGE AND 205-DAY ADJUSTED WEIGHTS (BY VARIOUS ADJUSTMENT METHODS) IN CREEP-FED CALVES

| | WA | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 |
|---|---|---|---|---|---|---|---|---|---|---|
| WA | 1.00 | -.085 | -.083 | -.104 | 0.128 | 0.003 | 0.056 | 0.054 | 0.086 | 0.022 |
| W1 | | 1.000 | 0.996 | 0.948 | 0.937 | 0.969 | 0.980 | 0.990 | 0.971 | 0.992 |
| W2 | | | 1.000 | 0.966 | 0.951 | 0.963 | 0.990 | 0.980 | 0.983 | 0.983 |
| W3 | | | | 1.000 | 0.922 | 0.929 | 0.953 | 0.935 | 0.947 | 0.940 |
| W4 | | | | | 1.000 | 0.985 | 0.971 | 0.957 | 0.986 | 0.966 |
| W5 | | | | | | 1.000 | 0.966 | 0.972 | 0.977 | 0.984 |
| W6 | | | | | | | 1.000 | 0.989 | 0.996 | 0.988 |
| W7 | | | | | | | | 1.000 | 0.985 | 0.997 |
| W8 | | | | | | | | | 1.000 | 0.987 |

TABLE 14

CORRELATION BETWEEN AGE AND 205-DAY ADJUSTED WEIGHTS (BY VARIOUS ADJUSTMENT METHODS) IN NON-CREEP-FED CALVES

| | WA | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 |
|---|---|---|---|---|---|---|---|---|---|---|
| WA | 1.00 | -.191 | -.186 | -.200 | -.065 | 0.010 | -.030 | -.035 | -.024 | .005 |
| W1 | | 1.000 | 0.998 | 0.971 | 0.964 | 0.954 | 0.985 | 0.988 | 0.978 | 0.974 |
| W2 | | | 1.000 | 0.960 | 0.967 | 0.952 | 0.988 | 0.986 | 0.981 | 0.973 |
| W3 | | | | 1.000 | 0.930 | 0.927 | 0.945 | 0.957 | 0.939 | 0.944 |
| W4 | | | | | 1.000 | 0.995 | 0.973 | 0.972 | 0.988 | 0.986 |
| W5 | | | | | | 1.000 | 0.970 | 0.973 | 0.986 | 0.900 |
| W6 | | | | | | | 1.000 | 0.998 | 0.994 | 0.991 |
| W7 | | | | | | | | 1.000 | 0.992 | 0.992 |
| W8 | | | | | | | | | 1.000 | 0.997 |

TABLE 15

FACTORS AFFECTING VARIATION IN ADJUSTED 205-DAY WEIGHT OF CREEP-FED CALVES

| | | | | $R^2$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | Sex | Age of Dam | Season | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 |
| X | | | | .0072 | .0069 | .011 | .0164 | .0000068 | .0031 | .0029 | .0074 | .00047 |
| X | X | | | .0258 | .0165 | .107 | .0328 | .0184 | .0118 | .0219 | .0177 | .0194 |
| X | X | X | | .0258 | .0177 | .115 | .0350 | .0156 | .0139 | .0219 | .0199 | .0194 |
| X | X | X | X | .0258 | .0183 | .120 | .0353 | .0188 | .0146 | .0219 | .0203 | .0194 |

TABLE 16

FACTORS AFFECTING VARIATION IN ADJUSTED 205-DAY WEIGHT OF NON-CREEP-FED CALVES

| | | | | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | Sex | Age of Dam | Season | | | | | $R^2$ | | | | |
| X | | | | .0366 | .0346 | .0400 | .0042 | .000093 | .00089 | .00124 | .00056 | .000021 |
| X | X | | | .0366 | .0375 | .0765 | .0058 | .00049 | .00390 | .00125 | .0039 | .000035 |
| X | X | X | | .0366 | .0379 | .0850 | .0062 | .00073 | .00431 | .00125 | .00375 | .000056 |
| X | X | X | X | .0366 | .0386 | .0926 | .0083 | .00127 | .00509 | .00125 | .00519 | .000335 |

TABLE 17

FACTORS AFFECTING VARIATION IN ADJUSTED 205-DAY WEIGHT OF ALL CALVES

| | | | | $R^2$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | Sex | Age of Dam | Season | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 |
| X | | | | .0237 | .0225 | .0276 | .000014 | .000051 | .000000017 | .000016 | .000219 | .000110 |
| X | X | | | .0256 | .0225 | .0831 | .000867 | .00226 | .00000087 | .00190 | .000256 | .00194 |
| X | X | X | | .0256 | .0226 | .0900 | .0012 | .00245 | .0000237 | .00191 | .000304 | .00195 |
| X | X | X | X | .0256 | .0226 | .0963 | .00138 | .00285 | .0000237 | .00194 | .000401 | .00209 |

weights of the older and younger calves. They are:

$$(1)\ WT5_2 = WT5_1 - b_2 (X_i - 205)$$

where:

$WT5_2$, $WT5_1$, $b_2$ and $X_i$ are explained in Table 6, page 30.

$$(2)\ WT5 - WW \times \left(\frac{\text{Standard Age} - \text{Age Intercept}}{\text{Actual Age} - \text{Age Intercept}}\right)$$

where: age-intercept is the intercept of the X-axis and the regression line of weaning weight on weaning age.

The comparison of the $R^2$ values from the analyses of 205-day weight datasets shows that a single set of factors and separate factors for creep- and non-creep-fed calves are similar in effectiveness. However, two sets of factors were slightly more efficient when creep- and non-creep-fed calves were considered separately.

The mean adjusted 205-day weight resulting from the nine methods of adjusting weaning weights to an age-constant basis are shown in Table 18. Weaning weights adjusted by the TBCIP method were at least 19 pounds lighter than those resulting from the other methods of adjustments. Mean weights of all other combinations of adjustment methods were similar.

Analyses of variance of the nine sets of adjusted 205-day weights of creep- and non-creep-fed calves combined are presented in Table 19. Separate analyses for creep-fed and non-creep-fed calves are shown in the Appendix, Tables 30 and 31. The effect of age of calf on 205-day weight was significant when the standard methods of adjustment was used (W1, W2, W3). Other significant effects observed in these analyses were

TABLE 18

MEANS AND STANDARD ERRORS OF 205-DAY WEIGHTS
ADJUSTED BY VARIOUS METHODS

| Method of Adjustment | Creep-Fed[a] | Non-Creep-Fed[b] |
|---|---|---|
| Age (Days) | 223 ± .38 | 220 ± .27 |
| W1 | 473 ± .68 | 432 ± .43 |
| W2 | 470 ± .67 | 436 ± .43 |
| W3 | 451 ± .76 | 412 ± .47 |
| W4 | 477 ± .73 | 437 ± .45 |
| W5 | 475 ± .73 | 435 ± .45 |
| W6 | 475 ± .67 | 440 ± .42 |
| W7 | 477 ± .68 | 435 ± .42 |
| W8 | 475 ± .68 | 438 ± .42 |
| W9 | 475 ± .68 | 434 ± .42 |

[a] 6,070 creep-fed calves.

[b] 12,323 non-creep-fed calves.

TABLE 19

ANALYSIS OF VARIANCE OF ADJUSTED 205-DAY WEIGHTS OF ALL CALVES

| Source | df | MEAN SQUARE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 |
| Age of Calf | 1 | 794947* | 768487* | 883570* | .22288 | 10.28 | .01931 | 227.6 | 5114 | 1817 |
| Sex of Calf | 2 | 40471* | 31.10 | 1453782** | 20245 | 52016** | 16.15 | 39955* | 741.2 | 39100** |
| Age of Dam | 5 | 42.45 | 144.6 | 81599** | 2335 | 1681 | 192.3 | 43.09 | 397.4 | 82.45 |
| Season of Birth | 3 | 348.6 | 16.64 | 112846** | 2586 | 6432 | .018286 | 360.4 | 1396 | 2097 |
| Residual | 17737 | 23.77 | 2381 | 2741 | 2740 | 2705 | 2381 | 2878 | 2426 | 2413 |

*P < .05.

**P < .01.

results of the inefficiency of the TBCIP method of adjustment to remove the environmental variation due to sex of calf, age of dam and season of birth when adjusting weaning weights for creep-fed, non-creep-fed and combined calves.

The various sets of factors shown in Table 20 indicates that the TBCIP factors are based on the assumption that the growth rate of steers and bulls are the same and that heifers are adjusted upward to a steer basis only. These data suggest that correlation factors for sex, age of dam and season of birth currently used in beef cattle testing programs should be re-evaluated.

TABLE 20

WEANING WEIGHT CORRECTION FACTORS USED BY THE BEEF CATTLE IMPROVEMENT PROGRAMS IN ALABAMA, GEORGIA, TENNESSEE AND THE USDA-FES

| Source | Alabama[a] | Georgia[b] | Tennessee[c] | USDA[d] | This Study[e] |
|---|---|---|---|---|---|
| Age of Dam | | | | | |
| 2 | 1.10 | 1.15 | 1.15 | 1.15 | 1.14 |
| 3 | 1.05 | 1.10 | 1.10 | 1.10 | 1.09 |
| 4 | 1.03 | 1.05 | 1.06 | 1.05 | 1.05 |
| 5 | 1.02 | 1.00 | 1.03 | 1.00 | 1.02 |
| 6 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 7 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 8 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 9 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 10 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 11 | 1.00 | 1.05 | 1.02 | 1.05 | 1.01 |
| 12 | 1.03 | 1.05 | 1.05 | 1.05 | 1.01 |
| 13 | 1.06 | 1.05 | 1.08 | 1.05 | 1.01 |
| 14 | 1.09 | 1.05 | 1.08 | 1.05 | 1.01 |
| 15 | 1.15 | 1.05 | 1.08 | 1.05 | 1.01 |
| Sex of Calf | | | | | |
| Bull | .95 | .95 | 1.00 | .95 | .92 |
| Steer | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heifer | 1.07 | 1.05 | 1.07 | 1.05 | 1.06 |

[a]Alabama BCIA Annual Report 1972.

[b]Georgia BCIA Annual Report 1972.

[c]Tennessee Beef Cattle Improvement Program Summary 1972.

[d]Guidelines for Uniform Beef Improvement Programs 1972.

[e]The 205-day weights in this study were adjusted for the over adjustment of weights of older and younger calves and for season of birth.

## CHAPTER V

## SUMMARY

The purpose of this study was to appraise the influence of age and sex of calf, age of dam, season of birth, management, breed and year of birth on the weaning weights and grades of Tennessee beef calves and to compare various methods for adjusting weaning weights of calves to an age-constant basis.

The data used in this study were the Tennessee Beef Cattle Improvement Program weaning records of 18,393 Angus and Hereford accumulated over the nine year period, 1964 through 1972. The calves were classified according to age (within the range of 120 to 300 days inclusive), sex (bulls, heifers, steers), age of dam (by years from 2 to 10 years inclusive and 11 years and over), month of birth, management (creep or non-creep feeded), year and breed.

Age of calf at weaning was found to be highly significant ($P < .01$) for grade in the analysis of all calves. Age of calf has a pronounced effect on average daily gain. Average daily gain was highest during the early stages of growth, and gradually declines to 300 days of age. Creep feeding appeared to stabilize the growth pattern of calves in the 200 to 300 day old age range, but did not appear to affect the relationship at younger ages.

Sex of calf exerted a highly significant influence on calf weaning weight, 205-day weight and weaning grade. Creep-fed bull calves were 52.8 pounds heavier than creep-fed steers and 65.6 pounds heavier than heifers. These differences were not as great among non-creep-fed calves (29.1 and 44.8 lb., respectively). The difference in calculated 205-day weight of bulls and steer calves and bull and heifer calves were 49.0 and 60.9 lb., respectively, for the creep-fed group and 28.8 and 43.0 lb., respectively, for the non-creep fed calves. As for grade, the creep-fed calves graded significantly above the non-creep-fed calves for each sex. Bulls were .259 units above the average, steers -.258 units, and heifers intermediate between bulls and steers.

Age of dam was highly significant ($P < .01$) for these preweaning performance traits. The order of these age of dam group from least productive to most productive is 2, 3, 4, 5, 11 and over and 6, 7, 8, 9 and 10 years of age combined. Management significantly affected the difference in productivity among the six age groups. Calves from 6 to 10 years old gained faster and were 68 and 79.4 lb. heavier at weaning and graded 0.5 and 0.7 units higher than calves from 2-year-old cows in the creep- and non-creep groups, respectively.

Season of birth had a highly significant ($P < .01$) effect on weaning weight, type score, average daily gain and calculated 205-day weight for creep, non-creep and all calves combined. Least-squares constant for the effect of season on 205-day weight indicate that calves born in July, August and September were lighter at weaning and the heaviest calves were those born in May and April, respectively. Calves born in August had the lowest average daily gain in both creep- and non-creep-fed calves and those born in October graded the lowest.

Analyses of the adjusted 205-day weights indicated that methods W5, W6, W7, W8 and W9 were similar with respect to effectiveness of adjusting weaning weights for creep-fed calves. However, methods W5, W7 and W9 were more effective than the other methods in adjusting weaning weights of non-creep-fed calves. On the other hand, W6 and W8 were more effective in adjusting weaning weights in creep-fed and non-creep-fed calves combined.

The results of the stepwise regression analyses of various 205-day weight datasets indicate that most of the dependency of the 205-day weight on environmental weight was due to the fact that these age-constant weights were too low for older calves and too high for the younger calves when the standard method was used. The comparison of the $R^2$ values from the analyses of 205-day weight datasets indicate that a single set of factors and separate factors for creep- and non-creep-fed calves are similar in effectiveness. However, two sets of factors were slightly more efficient when creep- and non-creep-fed calves were considered separately.

Removal of the effect of age of calf was least effective when using the standard method of adjustment (W1, W2, W3). Other significant effects observed in this study were results of the inefficiency of the TBCIP method of adjustment to remove the environmental variation due to sex of calf, age of dam and season of birth when adjusting weaning weights for creep-fed, non-creep-fed and combined calves.

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# APPENDIX

TABLE 21

ANALYSIS OF VARIANCE OF PREWEANING PERFORMANCE OF NON-CREEP-FED CALVES

| | | MEAN SQUARE | | | |
|---|---|---|---|---|---|
| Source | df | Weaning Weight | Type | Calculated 205-day Weight[a] | Average Daily Gain |
| Year | 8 | 113222.6** | 428.17** | 97800.7** | 2.396** |
| Breed/Year | 9 | 71416.9 | 58.76* | 49440.8 | 0.943 |
| Herd/Year-Breed | 311 | 74124.6** | 22.81** | 52343.5** | 1.228** |
| Age | 1 | 11588634.0** | 236.76** | 710333.1** | 17.177** |
| Sex | 2 | 2020250.7** | 140.60** | 1820011.0** | 33.460** |
| Age of Dam | 5 | 584943.8** | 99.40** | 548278.4** | 11.613** |
| Season | 3 | 96327.2** | 13.37** | 71582.9** | 16.518** |
| Residual | 11983 | 2451.59 | 1.387 | 2171.4 | 0.0516 |

*P < .05.

**P < .01.

[a]Calculated 205-day weight = (((weaning weight - birth weight) ÷ weaning age) X 205) + birth weight.

TABLE 22

ANALYSIS OF VARIANCE OF PREWEANING PERFORMANCE OF CREEP-FED CALVES

| | | MEAN SQUARE | | | |
|---|---|---|---|---|---|
| Source | df | Weaning Weight | Type | Calculated 205-day Weight[a] | Average Daily Gain |
| Year | 8 | 85477.5 | 130.24** | 57645.5 | 1.2897 |
| Breed/Year | 9 | 76778.1 | 20.92 | 47684.4 | 1.1939 |
| Herd/Year-Breed | 198 | 134950.2** | 22.64** | 94679.0** | 2.2319** |
| Age | 1 | 11379550.0** | 145.61** | 105652.2** | 2,5014** |
| Sex | 2 | 2440604.1** | 58.28** | 2038265.0** | 41.2066** |
| Age of Dam | 5 | 2913688.4** | 23.90** | 267853.9** | 5.8587** |
| Season | 3 | 3407182.3** | 7.916** | 32039.5** | 0.7615** |
| Residual | 5843 | 3142.5 | 1.085 | 2714.9 | 0.0646 |

**P < 0.01.

[a]Calculated 205-day weight = (((weaning weight-birth weight) ÷ weaning age) X 205) + birth weight.

TABLE 23

VARIATION IN WEANING WEIGHT, AVERAGE DAILY GAIN, TYPE SCORE AND 205-DAY WEIGHT OF CREEP-FED CALVES EXPLAINED BY SEQUENTIALLY ADDING ELEMENTS TO THE MODEL

| | | | | | | $\Delta R^2$ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age[a] | Age[b] | Age[c] | Sex | Age of Dam | Season | Weaning Weight | Average Daily Gain | Type Score | Calculated[d] 205-Day Weight |
| X | | | | | | .334 | .008 | .021 | .007 |
| X | X | | | | | .001 | .000 | .000 | .001 |
| X | X | X | | | | .001 | .001 | .001 | .000 |
| X | X | X | X | | | .137 | .174 | .019 | .199 |
| X | X | X | X | X | | .038 | .058 | .017 | .060 |
| X | X | X | X | X | X | .002 | .004 | .003 | .004 |
| TOTAL $R^2$ | | | | | | .513 | .245 | .061 | .271 |

[a]Linear.

[b]Quadratic.

[c]Cubic regression of WW on WA.

[d]Calculated 205-day weight = (((Weaning weight-birth weight) ÷ Weaning age) X 205) + birth weight.

TABLE 24

VARIATION IN WEANING WEIGHTS, AVERAGE DAILY GAIN, TYPE SCORE AND 205-DAY WEIGHT OF NON-CREEP CALVES EXPLAINED BY SEQUENTIALLY ADDING ELEMENTS TO THE MODEL

| | | | | | | $\Delta R^2$ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age[a] | Age[b] | Age[c] | Sex | Age of Dam | Season | Weaning Weight | Average Daily Gain | Type Score | Calculated[d] 205-Day Weight |
| X | | | | | | .320 | .026 | .018 | .025 |
| X | X | | | | | .005 | .002 | .001 | .001 |
| X | X | X | | | | .000 | .000 | .001 | .001 |
| X | X | X | X | | | .077 | .090 | .016 | .112 |
| X | X | X | X | X | | .054 | .074 | .027 | .080 |
| X | X | X | X | X | X | .003 | .006 | .002 | .003 |
| TOTAL $R^2$ | | | | | | .459 | .198 | .065 | .222 |

[a]Linear.

[b]Quadratic

[c]Cubic regression of WW on WA.

[d]Calculated 205-day weight = (((Weaning weight-birth weight) ÷ Weaning age) X 205) + birth weight.

TABLE 25

LEAST SQUARES CONSTANTS AND STANDARD ERROR FOR WEANING WEIGHT, TYPE SCORE, 205-DAY WEIGHT AND AVERAGE DAILY GAIN OF CREEP-FED CALVES

| Source | No. of Calves | Weaning Weight | Type Score | 205-Day Weight | Average Daily Gain |
|---|---|---|---|---|---|
| Sex of Calf | | | | | |
| Bulls | 2599 | 39.4 ± 1.27 | .242 ± .02 | 36.3 ± 1.18 | .169 ± .006 |
| Steers | 789 | -13.2 ± 1.72 | -.271 ± .03 | -12.7 ± 1.60 | -.070 ± .008 |
| Heifers | 2682 | -26.2 ± 2.00 | .029 ± .03 | -23.6 ± 1.87 | -.099 ± .009 |
| Age of Dam[a] | | | | | |
| 2 | 420 | -29.6 ± 2.57 | -.257 ± .05 | -28.5 ± 2.39 | -.119 ± .012 |
| 3 | 826 | -19.5 ± 1.90 | -.081 ± .04 | -18.6 ± 1.77 | -.095 ± .009 |
| 4 | 895 | -1.5 ± 1.84 | -.016 ± .03 | -1.4 ± 1.71 | -.011 ± .008 |
| 5 | 768 | 12.2 ± 1.94 | .132 ± .04 | 11.5 ± 1.81 | .052 ± .009 |
| 6[b] | 2589 | 20.6 ± 1.97 | .230 ± .03 | 19.7 ± 1.93 | .092 ± .014 |
| 11[c] | 572 | 17.8 ± 2.00 | .008 ± .04 | 17.3 ± 2.05 | .081 ± .010 |
| Season of Birth[d] | | | | | |
| Winter | 2536 | 6.2 ± 1.38 | .007 ± .03 | 5.2 ± 1.28 | .025 ± .006 |
| Spring | 1137 | 4.8 ± 1.80 | .103 ± .03 | 5.9 ± 1.67 | .029 ± .008 |
| Summer | 713 | -6.5 ± 1.98 | -.113 ± .04 | -5.8 ± 1.84 | -.028 ± .009 |
| Fall | 1684 | -4.5 ± 1.83 | .003 ± .04 | -5.3 ± 1.89 | -.026 ± .008 |
| Regression Y on WA (linear) | | 1.59 ± .026 | .006 ± .0005 | -.153 ± .025 | -.001 ± .0001 |
| Number of Calves | 6070 | | | | |
| Mean | | 457 ± 1.03 | 13.0 ± .014 | 427 ± .783 | 1.76 ± .004 |

TABLE 25 (continued)

[a]Age of dam expressed in years.

[b]6-, 7-, 8-, 9-, and 10-year-old dams grouped together.

[c]Eleven-years-old and over.

[d]Winter = January, February and March; Spring = April, May and June; Summer = July, August and September; Fall = October, November and December.

TABLE 26

LEAST SQUARES CONSTANTS AND STANDARD ERROR FOR WEANING WEIGHT, TYPE SCORE, 205-DAY WEIGHT AND AVERAGE DAILY GAIN OF NON-CREEP-FED CALVES

| Source | No. of Calves | Weaning Weight | Type Score | 205-Day Weight | Average Daily Gain |
|---|---|---|---|---|---|
| Sex of Calf | | | | | |
| Bulls | 3523 | 24.8 ± .81 | .27 ± .03 | 23.8 ± .76 | .11 ± .004 |
| Steers | 2444 | -4.3 ± .91 | -.26 ± .02 | -4.6 ± .85 | -.03 ± .004 |
| Heifers | 6356 | -20.5 ± .91 | -.01 ± .02 | -19.2 ± .92 | -.08 ± .005 |
| Age of Dam[a] | | | | | |
| 2 | 970 | -35.3 ± 1.52 | -.47 ± .04 | -35.4 ± 1.43 | -.152 ± .008 |
| 3 | 1748 | -12.3 ± 1.14 | -.07 ± .03 | -11.6 ± 1.07 | -.060 ± .005 |
| 4 | 1805 | .8 ± 1.15 | .04 ± .03 | 1.5 ± 1.08 | .001 ± .005 |
| 5 | 1605 | 11.0 ± 1.19 | .18 ± .03 | 10.7 ± 1.12 | .049 ± .005 |
| 6[b] | 4901 | 21.3 ± 1.26 | .30 ± .03 | 20.3 ± 1.22 | .095 ± .007 |
| 11[c] | 1291 | 14.5 ± 1.31 | .02 ± .03 | 14.5 ± 1.23 | .067 ± .006 |
| Season of Birth[d] | | | | | |
| Winter | 7263 | 9.6 ± .93 | .06 ± .02 | 7.9 ± .87 | .038 ± .004 |
| Spring | 2058 | 4.7 ± 1.36 | .15 ± .03 | 6.2 ± 1.28 | .030 ± .006 |
| Summer | 710 | -15.2 ± 1.78 | .12 ± .04 | -13.3 ± 1.68 | -.064 ± .008 |
| Fall | 2292 | .9 ± .68 | -.09 ± .03 | -.8 ± 1.23 | -.004 ± .005 |
| Regression Y of WA (linear) | | 1.2 ± .02 | .006 ± .0004 | -.30 ± .017 | -.001 ± .00008 |
| Number of Calves | 12,323 | | | | |
| Mean | | 409 ± .61 | 12.2 ± .01 | 387 ± .48 | 1.57 ± .002 |

TABLE 26 (continued)

[a]Age of dam expressed in years.

[b]6-, 7-, 8-, 9-, and 10-year-old dams grouped together.

[c]Eleven-years-old and over.

[d]Winter = January, February and March; Spring = April, May and June; Summer = July, August and September; Fall = October, November and December.

TABLE 27

MEAN WEANING WEIGHTS AND STANDARD DEVIATION OF ALL CALVES AS AFFECTED BY SEX, AGE OF DAM, MONTH OF BIRTH, BREED AND YEAR OF BIRTH

| Source | CREEP | | NON-CREEP | | COMBINED | |
|---|---|---|---|---|---|---|
| | Means | SD | Means | SD | Means | SD |
| Sex | | | | | | |
| Bull | 498.8 | 107.7 | 434.8 | 84.3 | 462.0 | 94.2 |
| Steer | 429.1 | 92.8 | 413.1 | 80.5 | 417.0 | 83.5 |
| Heifer | 424.3 | 88.0 | 393.0 | 73.0 | 402.3 | 77.5 |
| Age of Dam | | | | | | |
| 2 | 412.6 | 90.4 | 351.1 | 72.3 | 369.7 | 77.8 |
| 3 | 419.7 | 95.7 | 380.6 | 74.5 | 393.1 | 81.3 |
| 4 | 438.6 | 98.6 | 398.7 | 75.4 | 411.9 | 83.1 |
| 5 | 450.2 | 108.1 | 408.2 | 77.6 | 421.8 | 87.5 |
| 6 | 463.5 | 99.1 | 425.3 | 76.1 | 438.5 | 84.1 |
| 7 | 482.1 | 105.7 | 432.5 | 73.6 | 448.5 | 84.0 |
| 8 | 489.4 | 102.4 | 435.7 | 75.0 | 456.5 | 85.2 |
| 9 | 484.2 | 100.2 | 430.0 | 78.6 | 450.0 | 86.5 |
| 10 | 484.0 | 110.5 | 429.0 | 76.3 | 447.3 | 87.7 |
| 11 and over | 480.3 | 98.9 | 425.2 | 81.1 | 442.1 | 86.6 |
| Month of Birth | | | | | | |
| January | 470.8 | 96.7 | 436.5 | 72.0 | 446.1 | 78.9 |
| February | 455.8 | 97.4 | 421.6 | 73.8 | 429.5 | 79.2 |
| March | 450.8 | 98.0 | 388.4 | 75.5 | 405.1 | 81.5 |
| April | 441.1 | 103.3 | 362.5 | 69.0 | 385.7 | 79.1 |
| May | 441.2 | 113.6 | 356.2 | 70.9 | 389.7 | 87.7 |
| June | 411.6 | 95.1 | 353.6 | 76.3 | 383.9 | 86.1 |
| July | 436.3 | 119.5 | 374.0 | 89.3 | 401.8 | 102.8 |
| August | 430.6 | 111.1 | 350.7 | 104.0 | 389.0 | 107.4 |
| September | 479.4 | 105.6 | 413.2 | 80.5 | 447.4 | 93.5 |
| October | 462.2 | 111.3 | 414.4 | 82.9 | 439.8 | 98.0 |
| November | 459.0 | 106.9 | 424.1 | 81.4 | 439.6 | 92.7 |
| December | 461.0 | 104.3 | 438.5 | 75.6 | 446.2 | 85.5 |
| Breed | | | | | | |
| Angus | 457.8 | 92.7 | 408.7 | 80.3 | 423.8 | 84.1 |
| Hereford | 456.1 | 111.6 | 409.2 | 79.6 | 425.6 | 90.8 |
| Year | | | | | | |
| 1964 | 464.3 | 83.6 | 416.5 | 78.6 | 440.5 | 81.1 |
| 1965 | 431.7 | 117.5 | 397.4 | 80.8 | 407.2 | 91.2 |
| 1966 | 455.3 | 110.8 | 419.3 | 86.6 | 430.6 | 94.2 |
| 1967 | 451.5 | 111.5 | 398.6 | 81.7 | 413.8 | 90.3 |
| 1968 | 469.4 | 109.0 | 401.0 | 81.5 | 423.0 | 90.3 |
| 1969 | 445.2 | 102.1 | 407.3 | 76.9 | 422.0 | 86.7 |
| 1970 | 459.2 | 103.8 | 415.0 | 73.6 | 427.5 | 72.2 |
| 1971 | 465.6 | 95.8 | 421.0 | 77.2 | 433.4 | 82.4 |
| 1972 | 464.1 | 90.3 | 407.5 | 78.2 | 432.3 | 83.5 |

TABLE 28

MEAN TYPE SCORE AND STANDARD DEVIATIONS OF ALL CALVES AS AFFECTED BY SEX, AGE OF DAM, MONTH OF BIRTH, BREED AND YEAR OF BIRTH

| | CREEP | | NON-CREEP | | COMBINED | |
|---|---|---|---|---|---|---|
| Source | Means | SD | Means | SD | Means | SD |
| Sex | | | | | | |
| Bull | 13.3 | 1.3 | 12.5 | 1.4 | 12.8 | 1.4 |
| Steer | 12.3 | 1.4 | 11.7 | 1.5 | 11.8 | 1.5 |
| Heifer | 12.9 | 1.5 | 12.1 | 1.5 | 12.4 | 1.5 |
| Age of Dam | | | | | | |
| 2 | 12.7 | 1.3 | 11.7 | 1.6 | 12.4 | 1.5 |
| 3 | 12.7 | 1.4 | 12.0 | 1.6 | 12.2 | 1.5 |
| 4 | 12.8 | 1.4 | 12.1 | 1.5 | 12.3 | 1.5 |
| 5 | 12.8 | 1.5 | 12.2 | 1.6 | 12.4 | 1.5 |
| 6 | 13.0 | 1.4 | 12.4 | 1.4 | 12.6 | 1.4 |
| 7 | 13.1 | 1.3 | 12.4 | 1.4 | 12.6 | 1.4 |
| 8 | 13.3 | 1.5 | 12.3 | 1.5 | 12.7 | 1.5 |
| 9 | 13.2 | 1.4 | 12.3 | 1.5 | 12.6 | 1.5 |
| 10 | 13.2 | 1.4 | 12.4 | 1.5 | 12.7 | 1.5 |
| 11 and over | 13.0 | 1.5 | 12.1 | 1.6 | 12.4 | 1.5 |
| Month of Birth | | | | | | |
| January | 13.0 | 1.4 | 12.1 | 1.6 | 12.4 | 1.5 |
| February | 12.9 | 1.3 | 12.1 | 1.5 | 12.3 | 1.5 |
| March | 13.0 | 1.4 | 12.1 | 1.6 | 12.3 | 1.6 |
| April | 13.0 | 1.4 | 12.2 | 1.5 | 12.4 | 1.5 |
| May | 13.1 | 1.6 | 12.3 | 1.5 | 12.6 | 1.5 |
| June | 12.9 | 1.5 | 12.4 | 1.3 | 12.7 | 1.4 |
| July | 13.1 | 1.1 | 13.4 | 1.6 | 12.6 | 1.4 |
| August | 12.8 | 1.5 | 12.2 | 1.4 | 12.5 | 1.5 |
| September | 13.0 | 1.4 | 12.3 | 1.5 | 12.7 | 1.5 |
| October | 12.8 | 1.5 | 12.0 | 1.4 | 12.4 | 1.5 |
| November | 13.0 | 1.4 | 12.2 | 1.6 | 12.6 | 1.5 |
| December | 12.8 | 1.4 | 12.3 | 1.4 | 12.5 | 1.4 |
| Breed | | | | | | |
| Angus | 13.0 | 1.2 | 12.3 | 1.5 | 12.5 | 1.4 |
| Hereford | 12.9 | 1.6 | 12.0 | 1.6 | 12.3 | 1.6 |
| Year | | | | | | |
| 1964 | 12.3 | 1.3 | 12.0 | 1.2 | 12.2 | 1.3 |
| 1965 | 12.3 | 1.6 | 11.3 | 1.6 | 11.6 | 1.6 |
| 1966 | 12.4 | 1.4 | 11.6 | 1.5 | 11.8 | 1.5 |
| 1967 | 12.7 | 1.3 | 11.8 | 1.4 | 12.1 | 1.4 |
| 1968 | 12.9 | 1.3 | 11.8 | 1.6 | 12.2 | 1.5 |
| 1969 | 12.9 | 1.5 | 12.3 | 1.5 | 12.5 | 1.5 |
| 1970 | 13.3 | 1.5 | 12.5 | 1.4 | 12.7 | 1.4 |
| 1971 | 13.5 | 1.3 | 12.9 | 1.3 | 13.0 | 1.3 |
| 1972 | 13.5 | 1.2 | 12.9 | 1.2 | 13.2 | 1.2 |

TABLE 29

MEAN AVERAGE DAILY GAIN AND STANDARD DEVIATIONS OF ALL CALVES AS AFFECTED BY SEX, AGE OF DAM, MONTH OF BIRTH, BREED AND YEAR OF BIRTH

| Source | CREEP | | NON-CREEP | | COMBINED | |
|---|---|---|---|---|---|---|
| | Means | SD | Means | SD | Means | SD |
| Sex | | | | | | |
| Bull | 1.94 | .40 | 1.70 | .34 | 1.80 | .37 |
| Steer | 1.62 | .32 | 1.56 | .29 | 1.58 | .30 |
| Heifer | 1.63 | .34 | 1.50 | .28 | 1.54 | .30 |
| Age of Dam | | | | | | |
| 2 | 1.59 | .34 | 1.42 | .29 | 1.47 | .31 |
| 3 | 1.60 | .35 | 1.47 | .30 | 1.51 | .32 |
| 4 | 1.70 | .38 | 1.54 | .30 | 1.59 | .33 |
| 5 | 1.74 | .40 | 1.59 | .30 | 1.64 | .33 |
| 6 | 1.80 | .40 | 1.62 | .29 | 1.68 | .33 |
| 7 | 1.85 | .39 | 1.65 | .29 | 1.71 | .32 |
| 8 | 1.87 | .39 | 1.65 | .29 | 1.73 | .32 |
| 9 | 1.88 | .40 | 1.64 | .31 | 1.73 | .34 |
| 10 | 1.89 | .42 | 1.62 | .28 | 1.71 | .33 |
| 11 and over | 1.86 | .40 | 1.61 | .33 | 1.69 | .35 |
| Month of Birth | | | | | | |
| January | 1.75 | 36 | 1.58 | .28 | 1.63 | .30 |
| February | 1.78 | .35 | 1.60 | .29 | 1.64 | .30 |
| March | 1.82 | .39 | 1.58 | .32 | 1.64 | .34 |
| April | 1.82 | .43 | 1.59 | .32 | 1.66 | .35 |
| May | 1.83 | .46 | 1.62 | .34 | 1.71 | .39 |
| June | 1.73 | .43 | 1.54 | .37 | 1.64 | .40 |
| July | 1.76 | .45 | 1.49 | .40 | 1.61 | .42 |
| August | 1.56 | .38 | 1.30 | .34 | 1.43 | .36 |
| September | 1.74 | .40 | 1.44 | .33 | 1.59 | .36 |
| October | 1.70 | .42 | 1.49 | .33 | 1.60 | .38 |
| November | 1.78 | .41 | 1.55 | .32 | 1.65 | .36 |
| December | 1.69 | .37 | 1.57 | .27 | 1.61 | .30 |
| Breed | | | | | | |
| Angus | 1.77 | .35 | 1.57 | .30 | 1.63 | .32 |
| Hereford | 1.76 | .43 | 1.57 | .32 | 1.64 | .36 |
| Year | | | | | | |
| 1964 | 1.72 | .29 | 1.58 | .22 | 1.65 | .26 |
| 1965 | 1.68 | .43 | 1.48 | .30 | 1.54 | .34 |
| 1966 | 1.74 | .40 | 1.61 | .30 | 1.65 | .33 |
| 1967 | 1.75 | .41 | 1.61 | .30 | 1.65 | .33 |
| 1968 | 1.80 | .41 | 1.53 | .30 | 1.61 | .34 |
| 1969 | 1.72 | .40 | 1.57 | .31 | 1.63 | .34 |
| 1970 | 1.78 | .42 | 1.57 | .32 | 1.63 | .35 |
| 1971 | 1.78 | .36 | 1.61 | .31 | 1.66 | .32 |
| 1972 | 1.82 | .37 | 1.58 | .33 | 1.68 | .35 |

TABLE 30

ANALYSIS OF VARIANCE OF ADJUSTED 205-DAY WEIGHTS OF NON-CREEP-FED CALVES

| Source | df | MEAN SQUARE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 |
| Age of Calf | 1 | 711921* | 711041* | 821130* | 132696 | .072888 | 23363** | 23421** | 22038** | 34.196 |
| Sex of Calf | 2 | 71.58 | 40126** | 590552** | 24794 | 5708 | 40664** | 22.07 | 38818** | 181.31 |
| Age of Dam | 5 | 12.90 | 2212 | 60471** | 2214 | 1260 | 2186 | .90336 | 1879 | 101.6 |
| Season of Birth | 3 | 19.90 | 6934 | 84986** | 20671 | 5230 | 6718 | 1.320 | 12738 | 2380 |
| Residual | 11983 | 2170 | 2170 | 2522 | 2452 | 2452 | 2170 | 2170 | 2199 | 2206 |

*P <.05.

**P <.01.

TABLE 31

ANALYSIS OF VARIANCE OF ADJUSTED 205-DAY WEIGHTS OF CREEP-FED CALVES

| Source | df | MEAN SQUARE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 |
| Age of Calf | 1 | 105698** | 105810** | 122908** | 257599** | .040917 | 40152** | 39887** | 99673** | 5977 |
| Sex of Calf | 2 | 151342* | 706864** | 952066** | 154623* | 170603* | 70197* | 154005* | 85818* | 154770** |
| Age of Dam | 5 | .5052 | 6837 | 33888** | 8450 | 509 | 6892 | .1408 | 7326 | 7.8598 |
| Season of Birth | 3 | 11.00 | 35.87 | 37363* | 1985 | 1093 | 35.20 | .01576 | 2335 | 131 |
| Residual | 5843 | 2714 | 2715 | 3086 | 3142 | 3141 | 2715 | 2715 | 2776 | 2759 |

*P < .05.

**P < .01.

VITA

Charles Wallace Robertson was born in Hamilton County, Tennessee, January 18, 1940, the son of C. Wallace and Margaret A. Robertson. He attended South St. Elmo Elementary School, Lookout Junior High School and was graduated from Chattanooga High School, Chattanooga, Tennessee, in 1958. He entered Tennessee Polytechnic Institute, Cookeville, Tennessee, in 1958 and received the Bachelor of Science degree in 1962. In September, 1962, he was called to active duty in the United States Marine Corps. He served as an infantry officer and in May, 1963, was honorably released from active duty.

He entered The University of Tennessee in September, 1963. He received the Master of Science degree in Animal Husbandry from The University of Tennessee in December, 1965. He accepted an Assistant County Agent's position with the Tennessee Cooperative Extension Service in Fentress County, Tennessee, after graduation. He worked for two years in this position before accepting a position with the Georgia Cooperative Extension Service as County Agent in Quitman County, Georgia.

In January, 1969, he took study leave to complete the formal requirements for the Doctor of Philosophy degree in Animal Breeding at The University of Tennessee, Knoxville.

In September, 1970, he moved to Early County, Georgia, where he served for three years as County Agent. On February 15, 1973, he was promoted to District Agent--Agriculture and Natural Resources with the Cooperative Extension Service at Tifton, Georgia.

On June 15, 1963, the author married Carol Fraser of Hamilton County, Tennessee, in that county. They have four daughters, Stacey, Jill, Kelli, and Paige, born in 1966, 1968, 1970, and 1973, respectively.

He is a member of the Methodist faith, a Mason, a Shriner, a member of the Georgia County Agents Association, the Georgia Pork Producers Association, and the Georgia Cattlemens Association.