# SOME FACTORS AFFECTING WEANING WEIGHTS OF CALVES IN OKLAHOMA

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## INTRODUCTION

There is opportunity for improving weaning weight of beef cattle by selection depending upon the degree to which differences observed are genetic. Environmental differences among calves tend to reduce the effectiveness of selection. Two methods of reducing environmental variance are available to the breeder. One is to physically control environment by standardizing feeding and management conditions. This allows the proportion of observed variation caused by genetic differences to be maximum. However, there are many factors over which breeders have very little or no managerial control. For some of these it is possible for the breeder to use statistical control. This is done by using appropriate correction factors that correct for the differences among individuals. Statistical control should be applied with discretion since errors may actually be introduced through the use of wrong correction factors. Yet, by proper use of corrections, the breeder will eliminate more environmental than genetic differences and thus improve the effectiveness of selection.

The purposes of this study were: 1) to investigate the effects of age of dam, sex, breed, type of pasture, area of the state, month of birth, and creep- versus noncreep-feeding on weaning weights of calves raised in Oklahoma; 2) to investigate all possibile two-way interactions among these factors; and 3) to derive correction factors appropriate for adjusting weaning weights of calves raised in Oklahoma.

# LITERATURE REVIEW

It is well documented that factors such as age of dam, sex, season of birth, and type of management have a significant influence on weaning weight.

## Age of Dam

Numerous reports indicate that weaning weight increases with increasing age of dam. There is some discrepancy among the reports, however, as to the rate of decline following the age of maximum production. These discrepancies appear to be related to climatological differences.

Table 1 summarizes reports on the effect of age of dam on weaning weights of calves raised under semi-arid conditions. Reports by Knapp et al. (1942) and Koch and Clark (1955) from the Miles City station indicate that maximum production is reached in 6-year-old cows with a gradual increase in weaning weight from 2 to 6 years and a corresponding decrease from 6 to 10 years. Knox and Koger (1945) studied the records of cows ranging in age from 3 to 10 years old maintained on semi-desert grassland in Southern New Mexico. Maximum production was reached at 7 years of age followed by a steady decline. Calves out of 10-year-old cows weighed 32 pounds less than those out of 7-year-old cows.

Burgess et al. (1954), using data from Hereford cattle raised in Southwestern Colorado, observed a strong quadratic age of dam effect on weaning weight. Similar results were observed by Pahnish et al. (1958) in Arizona. Minyard and Dinkel (1960) in South Dakota observed maximum production in 8-year-old cows with a marked increase as cows increased in age from 2 to 3 years, a gradual increase from 3 to 8 years, followed by a corresponding decrease from 8 to 13 years.

Reports from the Midwest (Table 2) and other areas of moderate to high rainfall (Table 3) have not shown a marked decline in production after the eighth year of age. Kieffer (1959) reported that very small corrections were needed to adjust the weaning weights of calves from 8-, 9-, and 10-year-old cows to a 7-year-old basis. Similar results have been observed under Arkansas range conditions (Brown, 1958, 1960).

Marlowe and Gaines (1958) studied the records of calves in the Virginia performance testing program. Their results showed an increase in preweaning average daily gain of calves from cows up to the age of 7 to 8 years followed by only a slight decrease in calves from cows 9 and 10 years old or older. In a later study, Marlowe (1962) observed little or no reduction in the production of cows after the eighth year of age.

Swiger (1961) evaluated the records of a herd of purebred Hereford cattle located in Southern Ohio and observed maximum production in cows ranging in age from 8 to 12 years. The weaning weights of calves from cows ranging from 13 to 17 years of age averaged 18 pounds less than those in the 8- to 12-year-old age group. Koger et al. (1962) suggested that the lack of decline in production of cows over 11 years old observed in their study was likely related to tall grasses and reduced wear on teeth in Florida. Only slight reductions in productivity have been observed in cows exceeding 8 to 10 years of age in studies in Georgia (Thrift, 1964) and in New York (Cunningham and Henderson, 1965).

These reports suggest that the effect of age of dam depends on the type of range land involved. In the relatively arid regions of the West, calf weaning weight appears to decrease with increasing age of dam after reaching a peak in cows 6 to 8 years old. In areas of higher rainfall where the environment is less rigorous and there is more ample forage, the decline following peak production is smaller and more gradual.

Some reports, however, do not clearly support this thesis. Clark et al. (1958) reported that productivity increased markedly from 3 to 5 years of age, increased slowly from 5 to 8 years, and declined very slightly from 8 to 10 years (Table 1) in 2,131 Hereford cows maintained at the Miles City Station from 1926-53. They stated that the fact that average weaning weight remained practically constant as age of dam increased from 6 to 10 years indicates that cows may remain productive longer than had been thought previously. Evans et al. (1955) of the Illinois station reported rather intermediate results. The correction factors they found appropriate for adjusting weaning weight for the effect of age of dam are given in Table 3.

Interactions between age of dam and other factors have not been studied extensively. Pahnish et al. (1958) found the effect of age of dam on weaning weight dependent upon sex of calves in a study of Hereford calves raised in Arizona and weaned at 270 days of age. They recommended separate correction factors for bulls and heifers (Table 1). However, the data of Koch and Clark (1955), Clark et al. (1958), and Cunningham and Henderson (1965) indicated that there was not an important interaction between sex and age of dam. Swiger (1961) tested the interaction between age of dam and sex by treating age of dam as a continuous variable and sex as a discrete variable. He then investigated whether a single quadratic regression of weaning weight on age of dam described the data as well as separate regression for each sex. Since the reduction in variance by the two methods was not significantly different, he concluded that the interaction between age of dam and sex was not significant.

Marlowe and Gaines (1958) studied the effect of age of dam in creep-fed and noncreep-fed calves (Table 3). There was a tendency for the effect of age of dam to be reduced in the 2-year-old and 10- through 18-year-old age group when calves were creep-fed. A similar trend was observed by Marlowe (1962) particularly in older cows.

Marlowe (1962) also studied the effect of age of dam in Herefords and Angus separately. The effect of age of dam was essentially the same in the two breeds. Cunningham and Henderson (1965) reported that estimates for age of dam agreed well in their separate analyses of Herefords and Angus.

These reports indicate that weaning weight increases with increasing age of dam through 6 to 8 years of age after which it declines. The rate of decrease in productivity in cows exceeding 8 years of age appears to be greater in semi-arid regions than in regions of moderate to high rainfall. On the basis of a limited number of reports to date, it appears that interactions of sex, type of management, and breed with age of dam are small and not significant.

TABLE 1

THE EFFECT OF AGE OF DAM ON WEANING WEIGHT IN AREAS OF LOW ANNUAL RAINFALL

| State | Reference[a] | Total no. of obs. | Age of dam 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Montana | | | | | | | | | | | | | | |
| | 1[b] | 770 | 345 | 355 | 370 | 375 | 380 | 375 | 370 | 360 | 345 | 320 | | |
| | 2[c] | 5,952 | | -41 | -18 | -6 | 0 | -3 | -6 | -12 | -24 | | | |
| | 3[c] | 7,434 | | -44 | -19 | -7 | -1 | 0 | 3 | -3 | 1 | | | |
| New Mexico | | | | | | | | | | | | | | |
| | 4[b] | | | 387 | 405 | 429 | 447 | 454 | 450 | 436 | 422 | | | |
| Colorado | | | | | | | | | | | | | | |
| | 5[c] | 546 | -15 | 5 | . . . | 5 | 21 | . . . | 21 | -10 | . . . | . . . | . . . | . . . |
| Arizona | | | | | | | | | | | | | | |
| Bulls | 6[d] | 329 | | 50 | 25 | 0 | . . . | . . . | 0 | 25 | . . . | . . . | . . . | . . . |
| Heifers | | 322 | | 24 | 12 | 0 | . . . | . . . | 0 | 12 | . . . | . . . | . . . | . . . |
| S. Dakota | | | | | | | | | | | | | | |
| | 7[c] | 2,351 | -69 | -33 | -21 | -13 | -4 | -3 | 0 | -9 | -23 | -24 | -38 | -41 |

[a]References

1. Knapp *et al.* (1942)
2. Koch and Clark (1955)
3. Clark *et al.* (1958)
4. Knox and Koger (1945)
5. Burgess *et al.* (1954)
6. Pahnish *et al.* (1958)
7. Minyard and Dinkel (1960)

[b]Means

[c]Least squares constants

[d]Correction factors

TABLE 2

THE EFFECT OF AGE OF DAM ON WEANING WEIGHT IN MIDWESTERN STATES WITH MODERATE RAINFALL

| State | Reference | | Total no. of obs. | Age of dam 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oklahoma | | | | | | | | | | | | |
| | Botkin and Whatley (1953)[a] | | 603 | | 35 | 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Kieffer (1959)[a] | | 657 | 88 | 62 | 32 | 11 | 2 | 0 | 6 | 2 | 0 |
| Arkansas | | | | | | | | | | | | |
| | Brown (1958)[b] | Hereford | 255 | 340 | 347 | 375 | 388 | 390 | 399 | 426 | 390 | 410 |
| | | Angus | 212 | 342 | 391 | 396 | 399 | 408 | 385 | 408 | 436 | 394 |
| | Brown (1960)[c] | Hereford | 253 | | -30 | -35 | -14 | 13 | 0 | 26 | -29 | 18 |
| | | Angus (Herd 1) | 277 | | -11 | 2 | 10 | 6 | 0 | 34 | 33 | 29 |
| | | Angus (Herd 2) | 209 | | -74 | -48 | -18 | -32 | 0 | -11 | 6 | -20 |
| Kansas | | | | | | | | | | | | |
| | Hamann *et al.* (1963)[c] | | 1,861 | -64 | -22 | -1 | 4 | 23 | 27 | 32 | | |

[a]Correction factors

[b]Means

[c]Least squares constants

TABLE 3

THE EFFECT OF AGE OF DAM ON WEANING WEIGHT OR PREWEANING DAILY GAIN IN AREAS OF HIGH TO MODERATE ANNUAL RAINFALL

| State and reference[a] | | Total no. of obs. | Age of dam 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Virginia | | | | | | | | | | | | | | | | |
| 1[b] | (NC)[g] | 4,166 | -.30 | -.17 | -.11 | -.08 | -.04 | 0 | -.06 | -.01 | -.07 | . . . | . . . | . . . | . . . | . . . |
| | (C) | 2,007 | -.25 | -.17 | -.07 | -.05 | -.09 | 0 | .04 | .03 | -.04 | . . . | . . . | . . . | . . . | . . . |
| 2[c] | | 20,057 | 1.51 | 1.64 | 1.68 | 1.75 | 1.77 | 1.80 | 1.80 | 1.81 | 1.81 | 1.78 | 1.76 | 1.83 | 1.87 | 1.86 |
| 3[d] | | 1,987 | -32 | 0 | 20 | 33 | 46 | 32 | 33 | 22 | 22 | 11 | -8 | 26 | 4 | |
| Ohio | | | | | | | | | | | | | | | | |
| 4[d] | | 748 | 0 | 19 | 45 | 93 | . . . | 93 | 102 | . . . | . . . | . . . | 102 | 84 | . . . | . . . |
| Illinois | | | | | | | | | | | | | | | | |
| 5[e] | | 1,737 | 106 | 54 | 20 | 0 | . . . | . . . | 0 | 14 | 43 | | | | | |
| Florida | | | | | | | | | | | | | | | | |
| 6[d] | | 4,729 | -66 | -35 | -19 | 0 | . . . | . . . | . . . | . . . | . . . | 0 | 2 | | | |
| Hawaii | | | | | | | | | | | | | | | | |
| 7[d] | | 1,306 | | -31 | -21 | -10 | -5 | 0 | . . . | 0 | | | | | | |

TABLE 3 (Continued)

| State and reference[a] | Total no. of obs. | Age of dam 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Georgia | | | | | | | | | | | | | | | |
| 8[f] | 28,493 | 360 | 376 | 394 | 405 | 410 | 414 | 421 | 420 | 418 | 419 | 407 | . . . | . . . | . . . |
| New York | | | | | | | | | | | | | | | |
| 9[b] (A)[h] | 3,190 | -.26 | -.16 | -.07 | -.04 | -.02 | 0 | . . . | . . . | 0 | -.03 | . . . | . . . | . . . | . . . |
| (H) | 1,648 | -.26 | -.19 | -.08 | -.03 | -.01 | 0 | . . . | . . . | 0 | -.02 | . . . | . . . | . . . | . . . |

[a]References

1. Marlowe and Gaines (1958)
2. Marlowe (1962)
3. Lehman et al. (1961)
4. Swiger (1961)
5. Evans et al. (1955)
6. Koger et al. (1962)
7. Mahmud and Cobb (1963)
8. Thrift (1964)
9. Cunningham and Henderson (1965)

[b]Least squares constants for preweaning average daily gain

[c]Least squares means for preweaning average daily gain

[d]Least squares constants for weaning weight

[e]Correction factors for weaning weight

[f]Least squares means for weaning weight

[g]Not creep-fed (NC), and creep-fed (C)

[h]Angus (A) and Hereford (H)

## Sex

Sex differences reported in the literature have shown considerable variation. Part of this variation is due to factors such as age of males at castration and age at weaning. As calves get older differences between males and females increase (Lush *et al.*, 1930; Guilbert and Gregory, 1952; Brown *et al.*, 1956; Koger *et al.*, 1962). Therefore, to be consistent with the present study this section will only include studies where calves were weaned at an average age of 205 to 210 days unless otherwise indicated.

In studies including bulls, steers, and heifers least squares constants for weaning weight of 14, -6, and -8 pounds (Burgess *et al.*, 1954) and 23, -3, and -20 pounds (Thirft, 1964) have been reported for the three respective sexes. Marlowe and Gaines (1958) reported least squares constants for preweaning average daily gain of .07, .00, and -.12 in noncreep-fed calves and .10, .00, and -.13 in creep-fed bulls, steers, and heifers, respectively. These results indicate that bulls are heavier than heifers and that steers are intermediate between bulls and heifers or tending toward heifers in weaning weight at 7 months.

Evans *et al.* (1955) reported an average difference of 22 pounds between bulls and heifers in a purebred herd where all male calves were kept as bulls and a difference of 17 pounds between steers and heifers in a separate herd where all males were castrated at birth. Similar results were reported by Brinks *et al.* (1961) where comparisons between bulls and heifers, and steers and heifers were made in separate herds. They observed differences in 180-day adjusted weaning weight of 24 pounds between bulls and heifers and 21 pounds between steers and heifers.

Noting only a small difference between bulls and steers they suggested that the discrepancy between their results and those where data included all three sexes could be due to the effect of selection. If faster growing male calves are retained as bulls and slower growing males are castrated then sex differences between bulls and steers and bulls and heifers would be biased upward. They also noted that the discrepancy could be due in part to the young weaning age of 180 days since the sex differences would tend to increase as calves become older.

In studies comparing just steers and heifers weaned at an average age of 205 to 210 days differences of 20, 32 and 25 pounds in favor of steers have been reported (Lush et al., 1930; Koger and Knox, 1945; Botkin and Whatley, 1953). Kieffer (1959) observed a difference of 46 pounds between bulls and heifers in 210-day adjusted weaning weight.

Reports reviewed in the previous section indicate that the interaction between sex and age of dam is small in calves weaned at 205 days of age. Interactions between sex and other factors have not been studied extensively. Pahnish et al. (1961) detected statistically significant interactions ($P < .05$) between sex and ranch and sex and year. This study included 329 bull and 332 heifer calves raised on two Arizona Hereford ranches over a 6-year period. The calves were weaned at an average of 270 days in both herds. Because of the significant sex by ranch and sex by year interactions, they concluded that the use of a mean sex difference in weaning weight as a sex adjustment factor on various ranches over a period of years or even on the same ranch would be inadequate. These interactions might be more difficult to detect in calves weaned at 205 days of age. One could expect to detect significant effects due to sex, sex by year, and sex by ranch more easily in calves weaned at 270 days than in calves weaned at 205 days since the effect of sex increases with increasing age. In this study, the mean squares for the main effects of sex, year, and ranch were considerably larger and more significant ($P < .01$) than those for the various interactions.

Marlowe (1962) studied the effect of sex on preweaning average daily gain in Hereford and Angus calves separately according to whether they were creep-fed or not creep-fed. His results are given in Table 4. Bull calves grew about 14 percent faster than heifer calves and steer calves about 7 percent faster than heifer calves in both breeds when they were not creep-fed. Creep-feeding did not appear to change this relationship in Angus calves; however, it appeared to widen the difference between bulls and heifers, and bulls and steers among the Herefords. Bull calves gained about 20 percent faster than heifer calves and 16 percent faster than steer calves in creep-fed Herefords. These results suggest a possible sex by type of management by breed interaction on preweaning growth rate.

Reports in the literature indicate that bull calves are heavier than heifer calves at weaning. Some investigations indicate that steers are intermediate between bulls and heifers in weaning weight while others suggest that the difference between bulls and steers is smaller than that between steers and heifers. These discrepancies may be due to varying intensities of selection for growth rate among the males. It appears that the effect of sex may also depend upon whether calves are creep-fed or not creep-fed.

TABLE 4

PREWEANING AVERAGE DAILY GAIN OF ANGUS AND HEREFORD CALVES BY TYPE OF MANAGEMENT AND SEX (MARLOWE, 1962)

| | Hereford | | Angus | |
|---|---|---|---|---|
| Sex | Noncreep-fed | Creep-fed | Noncreep-fed | Creep-fed |
| Bulls | 1.88 | 1.96 | 1.87 | 2.06 |
| Steers | 1.77 | 1.83 | 1.75 | 1.77 |
| Heifers | 1.64 | 1.72 | 1.63 | 1.70 |

## Season of Birth

Beef cattle producers have long been aware that Spring and Fall calving is a more satisfactory practice than calving during the summer months. However, in many herds calves are dropped throughout the year. Thus, correction for season of birth is sometimes needed in order to appraise calves more accurately.

Rollins and Guilbert (1954) classified 159 calves into three seasons and found that additive corrections of 16 and 39 pounds were appropriate for correcting calves dropped in March-May, and August-November to a November-February basis.

Marlowe and Gaines (1958) studied preweaning average daily gains of 4,166 noncreep-fed and 2,007 creep-fed calves in the Virginia performance testing program. They divided the year into four seasons: December 16-March 15, March 16-May 31, June 1-August 31, and September 1-December 15. The least squares constants obtained for the four seasons were .00, .04, -.09, and -.12 for noncreep-fed calves, and .00, .03, -.04, and -.03 for creep-fed calves, respectively. Since the effect of seasons was less in creep-fed calves, they suggested that creep-feeding had an important influence in equalizing the preweaning environment. This was verified further in a later study by Marlowe (1962) where approximately 21,000 calves were classified according to month of birth, breed, and whether they were creep-fed or not creep-fed. The constants obtained in 1958 were not completely adequate in removing variation due to season. The results of this study are summarized in Figure 1. Calves dropped after June 1 were at a decided disadvantage, and calves dropped from August through October were at an even greater

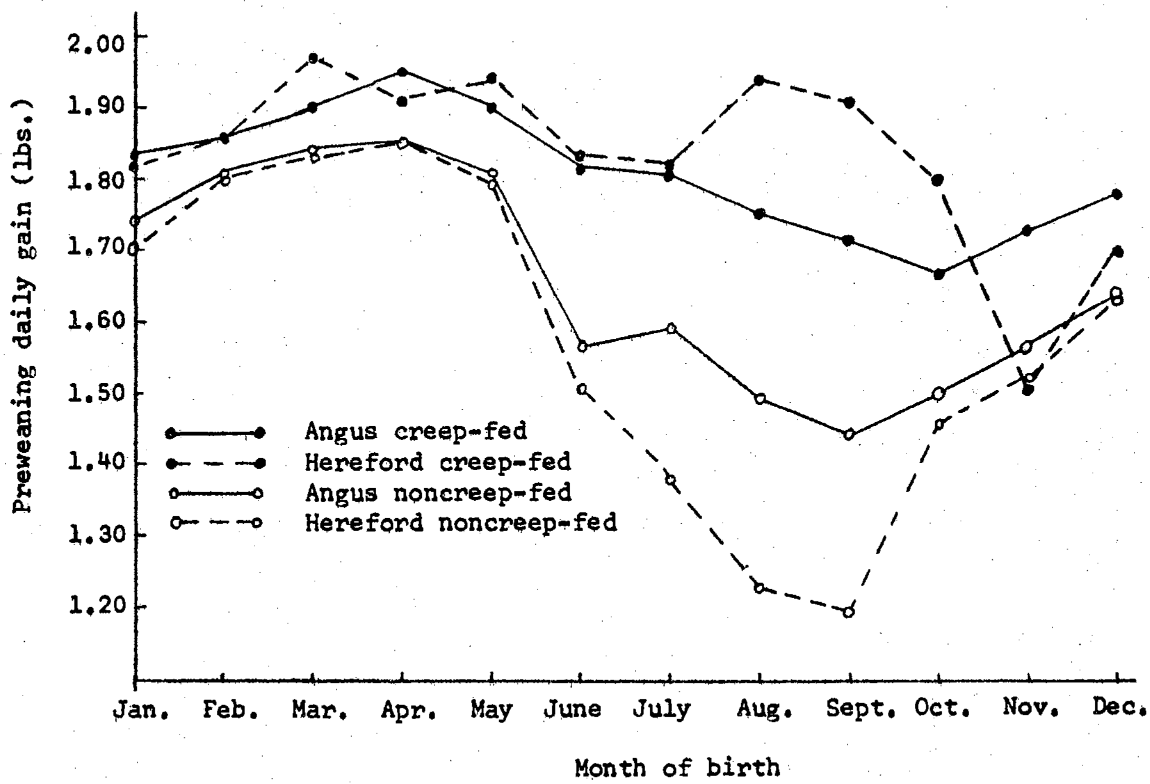


Figure 1. The influence of month of birth on preweaning gains of beef calves. (Marlowe, 1962)

disadvantage. Calves dropped during September had the lowest gains of all among the Angus and Hereford breeds. There was an increase in gains of calves dropped between September and March and a slight additional increase in calves dropped in March and April. This was followed by a decrease in May and a drastic decrease in June.

In a study of 257 Hereford calves at the Arkansas Station, Brown (1958) noted that calves dropped in February, March, and April had heavier weights at 240 days of age than calves dropped during other months. Calves dropped during August, September, October, November, December, and January were intermediate in weight while those dropped in May and July were lightest. In a later report from the same station, Brown (1960) found that in two herds calves dropped in the fall (September-November) weighed 66 and 64 pounds less at 180 days than those dropped in the spring (March-May). In a third herd where cows were on more lush pastures and calves were creep-fed, he found that only slight corrections were needed for season of birth.

Thrift (1964) studied the effect of month of birth on weaning weight in 28,493 calves in the Georgia performance testing program. Least squares means for the nine months considered were as follows:

| Month of Birth | Average Weaning Weight |
|---|---|
| January | 411 |
| February | 414 |
| March | 409 |
| April | 403 |
| May | 394 |
| September | 391 |
| October | 400 |
| November | 410 |
| December | 403 |

These results further support previous findings.

Based on these reports, it appears that calves born in the spring have an advantage in weaning weight at seven months over calves dropped in the fall, which in turn are heavier than calves born during the summer months. Furthermore, creep-feeding is apparently effective in helping to standardize preweaning environment.

## Type of Management

The differences that have been observed in weaning weight of creep-fed and noncreep-fed calves vary considerably. Differential responses to creep-feeding have been attributed to quality and amount of forage and supplementation available to cows and calves (Pope et al., 1955, 1956, 1957; Furr et al., 1959, 1961; Foster et al., 1946) and composition of the creep-feed (Hazen and Comfort, 1943; Duitsman and Kessler, 1956, 1957; Brethour and Duitsman, 1958, McCroskey et al., 1964). Age of dam is another factor that may influence response to creep-feeding. Furr et al. (1960, 1961) reported that creep-feeding considerably increased the weaning weights of October and November calves from 2- and 3-year-old cows. Season of birth may also influence the effect of creep-feeding. In a three-year study to determine the effect of creep-feeding spring calves, Nelson et al. (1955) found that average weaning weights were increased by 30 pounds. Kuhlman (1962) found that creep-fed fall calves gained 64 pounds more than those not creep-fed. The data of Marlowe and Gaines (1958) and Marlowe (1962) show that the effect of creep-feeding is greater when calves are born in the fall than in the spring. In addition, Marlowe (1962) observed that the effect of creep-feeding was greater in bull calves than in steers or heifers.

## MATERIALS AND METHODS

### Data

The data used in this study were the weaning weights of 13,937 Hereford and Angus calves recorded in the Oklahoma Beef Cattle Improvement Program over a four-year period, 1959-1962, inclusive. The weaning weights were adjusted to a constant age of 205 days for each calf by multiplying the preweaning average daily gain times 205 and then adding the birth weight. The birth weight was assumed to be 70 pounds in herds where it was not measured. Reports in the literature indicate that this method of adjusting might bias the adjusted weights of older calves downward (Johnson and Dinkel, 1951; Koch and Clark, 1955; Hoover *et al.*, 1956; Marlowe and Gaines, 1958; Flock *et al.*, 1962; Marlowe, 1962; Swiger *et al.*, 1962). However, the range in weaning age of calves used in this study was restricted to 205 ± 45 days or 160 to 250 days. Thus, the nature of this bias should be small according to Koch and Clark (1955) and Swiger *et al.* (1962).

Figure 2 and Table 5 give the distribution of data into six different areas of the state according to herd and breed. The data were obtained from 66 herds of which 36 were Hereford and 30 Angus. A fairly large sample in terms of number of herds and calves were obtained in area I. Calves in area II were predominantly from Angus herds, while those in area III and V were predominantly Herefords. Only a

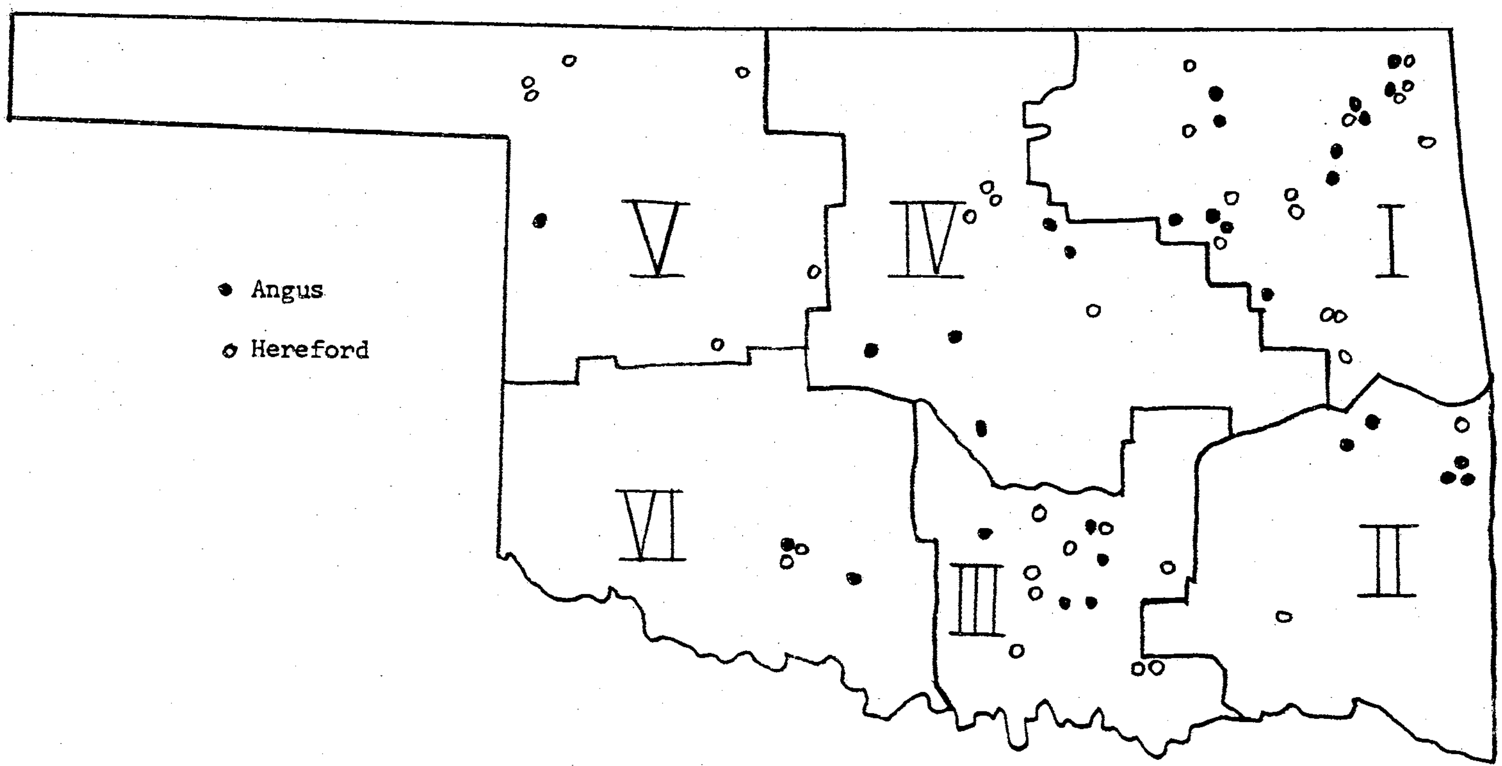


Figure 2. Distribution of herds in six areas by breed.

small sample of 115 calves from two Angus and two Hereford herds were recorded in area VI.

TABLE 5

DISTRIBUTION OF HERDS IN SIX AREAS BY BREED

| Area | Number of herds | | Number of calves | |
|---|---|---|---|---|
| | Hereford | Angus | Hereford | Angus |
| I | 13 | 12 | 3,915 | 2,831 |
| II | 2 | 5 | 266 | 2,306 |
| III | 9 | 5 | 2,004 | 916 |
| IV | 4 | 5 | 436 | 214 |
| V | 6 | 1 | 827 | 107 |
| VI | 2 | 2 | 74 | 41 |
| Breed total | 36 | 30 | 7,522 | 6,415 |
| Total | 66 | | 13,937 | |

Since ranchers have no control over year effects, years were considered random and the data were pooled over years. Each calf was classified according to age of dam, sex, breed, type of pasture, area of the state, month of birth, and type of management (creep versus noncreep). The breakdown for age of dam is given in Table 11. Pastures were divided into three general classes: (1) Native - ranches with predominantly tall and/or short native grasses, (2) Improved - ranches with predominantly cultivated grasses, primarily Fescue and Bermuda, and various temporary pastures such as wheat, rye, and vetch, (3) Mixed - ranches with a predominance of neither grass. The state was divided into the six areas shown in Figure 2. These areas should reflect differences due to gradients in rainfall (east to west) and temperatures (north to south) and any other peculiarities among them. Type of management refers to whether the calves were fed creep-feed or not. The number of calves in each subclass are given in Tables 11, 12, and 13.

## Overall Analysis

The data were analyzed by the method of least squares as outlined by Harvey (1960) according to the following model:

$$Y_{ijklmnop} = \mu + a_i + s_j + b_k + p_l + r_m + m_n + c_o + e_{ijklmnop}$$

where $i = 1, \ldots, 17$; $j = 1, \ldots, 3$; $k = 1, 2$; $l = 1, \ldots, 3$; $m = 1, \ldots, 6$; $n = 1, \ldots, 12$; $o = 1, 2$. In the model $Y_{ijklmnop}$ is the adjusted 205-day weaning weight of a calf, $\mu$ is the mean, $a_i$ is an effect due to the age of dam, $s_j$ is an effect due to the sex, $b_k$ is an effect due to breed, $p_l$ is an effect due to type of pasture, $r_m$ is an effect due to area, $m_n$ is an effect due to month of birth, $c_o$ is an effect due to type of management, and $e_{ijklmnop}$ is a random effect peculiar to each calf. In this model, it is assumed that there were no interactions between effects and that the e values were normally distributed about a mean of zero with a common variance $\sigma^2$.

The normal equations for this model were:

$$[X' X] [\beta] = [X' Y]$$

where

$$[\beta] = \begin{bmatrix} \mu \\ a_1 \\ a_2 \\ \vdots \\ a_{17} \\ s_1 \\ s_2 \\ s_3 \\ b_1 \\ \vdots \\ c_2 \end{bmatrix}$$

and X' X and X' Y are denoted as the coefficient matrix and the right hand side (RHS) in Table 6. Since the normal equations were not independent the restrictions that $\sum_i a_i = \sum_j s_j = \sum_k b_k = \sum_l p_l = \sum_m r_m = \sum_n m_n = \sum_o c_o = 0$ were imposed. Thus, the number of parameters to be estimated for each class were reduced to the number of degrees of freedom available in each class and the least squares constants obtained were expressed as deviations from a zero mean for each class. The normal equations were thus reduced to

$$[X'\,X]^* [\beta]^* = [X'\,Y]^*$$

where

$$[\beta]^* = \begin{bmatrix} \mu \\ a_1 \\ a_2 \\ \vdots \\ a_{16} \\ s_1 \\ s_2 \\ b_1 \\ \vdots \\ c_1 \end{bmatrix}$$

and $[X'\,X]^*$ and $[X'\,Y]^*$ are denoted as the reduced coefficient matrix and the reduced right hand side in Table 7, respectively. The least squares constants were estimated by:

$$[\hat{\beta}]^* = [X'\,X]^{*-1} [X'\,Y]^*$$

where

$$[\beta]^{*} = \begin{bmatrix} \hat{\mu} \\ \hat{a}_1 \\ \hat{a}_2 \\ \vdots \\ \hat{a}_{16} \\ \hat{s}_1 \\ \hat{s}_2 \\ \hat{b}_1 \\ \vdots \\ c_1 \end{bmatrix}$$

and $[X'\ X]^{*-1}$ is the inverse of the reduced coefficient matrix represented in Table 8.

Since the restrictions that $\sum_i a_i = 0$ was imposed $\hat{a}_{17}$ was estimated by

$$\hat{a}_{17} = 0 - (\hat{a}_1 + \hat{a}_2 + \ldots + \hat{a}_{16}).$$

Estimates of the missing elements in the inverse were obtained in the same fashion:

$$c_{1\ 17} = 0 - (c_{1\ 1} + c_{1\ 2} + \ldots + c_{1\ 16}).$$

The constants and inverse elements missing in all other classes due to the restrictions imposed were estimated in the same manner.

The standard errors of the least squares constants were obtained by

$$S_{\hat{\mu}} = \sqrt{c_{\mu\mu}\sigma^2}$$

$$S_{\hat{a}_i} = \sqrt{c_{ii}\sigma^2}$$

$$\vdots$$

$$S_{\hat{c}_{oo}} = \sqrt{c_{oo}\sigma^2}$$

where $\hat{\sigma}^2$ is the error mean square obtained in the analysis of variance

TABLE 6

THE COEFFICIENT MATRIX (X' X) AND THE RIGHT HAND SIDE (X' Y)[1,2]

| | Coefficient matrix | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\mu$ | $a_i$ | $s_j$ | $b_k$ | $p_l$ | $r_m$ | $m_n$ | $c_o$ | RHS |
| $\mu$ | $n_{.......}$ | $n_{i......}$ | $n_{.j.....}$ | $n_{..k....}$ | $n_{...l...}$ | $n_{....m..}$ | $n_{.....n.}$ | $n_{......o}$ | $Y_{.......}$ |
| $a_i$ | $n_{i......}$ | $n_{i......}$ | $n_{ij.....}$ | $n_{i.k....}$ | $n_{i..l...}$ | $n_{i...m..}$ | $n_{i....n.}$ | $n_{i.....o}$ | $Y_{i......}$ |
| $s_j$ | $n_{.j.....}$ | $n_{ij.....}$ | $n_{.j.....}$ | $n_{.jk....}$ | $n_{.j.l...}$ | $n_{.j..m..}$ | $n_{.j...n.}$ | $n_{.j....o}$ | $Y_{.j.....}$ |
| $b_k$ | $n_{..k....}$ | $n_{i.k....}$ | $n_{.jk....}$ | $n_{..k....}$ | $n_{..kl...}$ | $n_{..k.m..}$ | $n_{..k..n.}$ | $n_{..k...o}$ | $Y_{..k....}$ |
| $p_l$ | $n_{...l...}$ | $n_{i..l...}$ | $n_{.j.l...}$ | $n_{..kl...}$ | $n_{...l...}$ | $n_{...lm..}$ | $n_{...l.m.}$ | $n_{...l..o}$ | $Y_{...l...}$ |
| $r_m$ | $n_{....m..}$ | $r_{i...m..}$ | $n_{.j..m..}$ | $n_{..k.m..}$ | $n_{...lm..}$ | $n_{....m..}$ | $n_{....mn.}$ | $n_{....m.o}$ | $Y_{....m..}$ |
| $m_n$ | $n_{.....n.}$ | $n_{i....n.}$ | $n_{.j...n.}$ | $n_{..k..n.}$ | $n_{...l.n.}$ | $n_{....m..}$ | $n_{.....n.}$ | $n_{.....no}$ | $Y_{.....n.}$ |
| $c_o$ | $n_{......o}$ | $n_{i.....o}$ | $n_{.j....o}$ | $n_{..k...o}$ | $n_{...l..o}$ | $n_{....m.o}$ | $n_{.....no}$ | $n_{......o}$ | $Y_{......o}$ |

[1] $n_{.......}$ = Total number of observations,

$n_{i.......}$ = Total number of observations in the $i^{th}$ age of dam class,

$n_{j......}$ = Total number of observations in the $j^{th}$ sex,

$n_{ij.....}$ = Total number of observations in the $i^{th}$ age of dam and $j^{th}$ sex,

$Y_{.......}$ = Total of all weaning weights,

$Y_{i......}$ = Total of all weaning weights in the $i^{th}$ age of dam class.

[2] i = 1, ..., 17; j = 1, 2, 3; k = 1, 2,; l = 1, 2, 3; m = 1, ..., 6; n = 1, ..., 12; o = 1, 2.

TABLE 7

THE REDUCED COEFFICIENT MATRIX $(X' X)^{*}$ AND RIGHT HAND SIDE $(X' Y)^{*1}$

| | $\mu$ | $a_i$ | | | | $s_j$ | | $b_k$ $p_l$ $r_m$ $m_n$ | $c_o$ | RHS |
|---|---|---|---|---|---|---|---|---|---|---|
| $\mu$ | $n_{uu}$ | $n_{u\,1}$ | $n_{u\,2}$ | . . . | $n_{u\,16}$ | $n_{u\,1}$ | $n_{u\,2}$ | . . . . . . . . . . | $n_{u\,1}$ | $Y_u$ |
| | $n_{1\,u}$ | $n_{1\,1}$ | $n_{1\,2}$ | . . . | $n_{1\,16}$ | $n_{1\,1}$ | $n_{1\,2}$ | . . . . . . . . . . | $n_{1\,1}$ | $Y_1$ |
| | $n_{2\,u}$ | $n_{2\,1}$ | $n_{2\,2}$ | . . . | $n_{2\,16}$ | $n_{2\,1}$ | $n_{2\,2}$ | . . . . . . . . . . | $n_{2\,1}$ | $Y_2$ |
| $a_i$ | . | . | . | | . | . | . | . . . . . . . . . . | . | . |
| | . | . | . | | . | . | . | . . . . . . . . . . | . | . |
| | . | . | . | | . | . | . | . . . . . . . . . . | . | . |
| | $n_{16\,u}$ | $n_{16\,1}$ | $n_{16\,2}$ | . . . | $n_{1616}$ | $n_{16\,1}$ | $n_{16\,2}$ | . . . . . . . . . . | $n_{16\,1}$ | $Y_{16}$ |
| | $n_{1\,u}$ | $n_{1\,1}$ | $n_{1\,2}$ | . . . | $n_{1\,16}$ | $n_{1\,1}$ | $n_{1\,2}$ | . . . . . . . . . . | $n_{1\,1}$ | $y_1$ |
| $s_j$ | $n_{2\,u}$ | $n_{2\,1}$ | $n_{2\,2}$ | . . . | $n_{2\,16}$ | $n_{2\,1}$ | $n_{2\,2}$ | . . . . . . . . . . | $n_{2\,1}$ | $Y_2$ |
| $b_k$ | . | . | . | | . | . | . | . . . . . . . . . . | . | . |
| $p_l$ | . | . | . | | . | . | . | . . . . . . . . . . | . | . |
| $r_m$ | . | . | . | | . | . | . | . . . . . . . . . . | . | . |
| $m_n$ | . | . | . | | . | . | . | . . . . . . . . . . | . | . |
| $c_o$ | $n_{1\,u}$ | $n_{1\,1}$ | $n_{1\,2}$ | . . . | $n_{1\,16}$ | $n_{1\,1}$ | $n_{1\,2}$ | . . . . . . . . . . | $n_{1\,1}$ | $Y_1$ |

[1] $i = 1, \ldots, 16$; $j = 1, 2$; $k = 1$; $l = 1, 2$; $m = 1, \ldots, 5$; $n = 1, \ldots, 11$; $0 = 1$

TABLE 8

THE INVERSE MATRIX $(X'\,X)^{-1}$[1]

| | $\mu$ | $a_i$ | | | | $s_j$ | | $b_k$ $p_l$ $r_m$ $m_n$ | $c_o$ |
|---|---|---|---|---|---|---|---|---|---|
| $\mu$ | $c_{u\,u}$ | $c_{u\,1}$ | $c_{u\,2}$ | . . . | $c_{u\,16}$ | $c_{u\,1}$ | $c_{u\,2}$ | . . . . . . . . . . | $c_{u\,1}$ |
| | $c_{1\,u}$ | $c_{1\,1}$ | $c_{1\,2}$ | . . . | $c_{1\,16}$ | $c_{1\,1}$ | $c_{1\,2}$ | . . . . . . . . . . | $c_{1\,1}$ |
| | $c_{2\,u}$ | $c_{2\,1}$ | $c_{2\,2}$ | . . . | $c_{2\,16}$ | $c_{2\,1}$ | $c_{2\,2}$ | . . . . . . . . . . | $c_{2\,1}$ |
| $a_i$ | . | . | . | . . . . | | . | . | . . . . . . . . . . | . |
| | . | . | . | . . . . | | . | . | . . . . . . . . . . | . |
| | . | . | . | . . . . | | . | . | . . . . . . . . . . | . |
| | $c_{16\,u}$ | $c_{16\,1}$ | $c_{16\,2}$ | . . . | $c_{1616}$ | $c_{16\,1}$ | $c_{16\,2}$ | . . . . . . . . . . | $c_{16\,1}$ |
| | $c_{1\,u}$ | $c_{1\,1}$ | $c_{1\,2}$ | . . . | $c_{1\,16}$ | $c_{1\,1}$ | $c_{1\,2}$ | . . . . . . . . . . | $c_{1\,1}$ |
| $s_j$ | $c_{2\,u}$ | $c_{2\,1}$ | $c_{2\,2}$ | . . . | $c_{2\,16}$ | $c_{2\,1}$ | $c_{2\,2}$ | . . . . . . . . . . | $c_{2\,1}$ |
| $b_k$ | . | . | . | . . . . | | . | . | . . . . . . . . . . | . |
| $p_l$ | . | . | . | . . . . | | . | . | . . . . . . . . . . | . |
| $r_m$ | . | . | . | . . . . | | . | . | . . . . . . . . . . | . |
| $m_n$ | . | . | . | . . . . | | . | . | . . . . . . . . . . | . |
| $c_o$ | $c_{1\,u}$ | $c_{1\,1}$ | $c_{1\,2}$ | . . . | $c_{1\,16}$ | $c_{1\,1}$ | $c_{1\,2}$ | . . . . . . . . . . | $c_{1\,1}$ |

[1] $i = 1, \ldots, 16$; $j = 1, 2$; $k = 1$; $l = 1, 2$; $m = 1, \ldots, 5$; $n = 1, \ldots, 11$; $o = 1$.

and $c_{\mu\mu}$, $c_{ii}$ ..., $c_{oo}$ are taken from the diagonal of the inverse. The means were calculated by $\hat{\mu} + \hat{a}_i$ ; $\hat{\mu} + \hat{s}_j$ ; ...; $\hat{\mu} + \hat{c}_o$, and the standard errors of the means by

$$S_{\mu+a_i} = \sqrt{(c_{\mu\mu} + c_{ii} + 2c_{\mu i})\ \sigma^2}$$

$$\vdots$$

$$S_{\mu+c_o} = \sqrt{(c_{\mu\mu} + c_{oo} + 2c_{\mu o})\ \sigma^2}$$

The analysis of variance used to test the hypothesis that each of the effects listed in the model was zero is given in Table 9. The total sum of squares was computed in the usual manner

$$\sum_i \sum_j \sum_k \sum_l \sum_m \sum_n \sum_o Y^2_{ijklmno}$$

The total reduction due to fitting the mean and all constants, R(μ, a, s, b, p, r, m, c) was computed by multiplying the vector of constants, $[\hat{\beta}]^*$, times the right hand side, $[X'\ Y]^*$. The sum of squares of direct effects were obtained as shown below for age of dam.

$$SS_a = [A'] [Z_A^{-1}] [A]$$

where [A'] is the row vector of the $a_i$ constants; $[Z_A^{-1}]$ is the inverse of the segment of the inverse corresponding by row and by column to the age of dam constants and [A] is the column vector of the set of constants. The sum of squares obtained in this manner was the sum of squares due to fitting all constants except the set being considered. That is, $SS_A$ = R(μ, a, s, b, p, r, m, c) - R(μ, s, b, p, r, m, c).

Estimates of the sum of squares of fixed effects for age of dam ($\hat{\sigma}_a^2$), sex ($\hat{\sigma}_s^2$), breed ($\hat{\sigma}_b^2$), pasture ($\hat{\sigma}_p^2$), area ($\hat{\sigma}_r^2$), month ($\hat{\sigma}_m^2$),

TABLE 9

THE ANALYSIS OF VARIANCE

| Source of variation | Degrees of freedom[1] | Sum of squares | Mean squares | Expected mean squares[2,3] |
|---|---|---|---|---|
| Total | N | SS | | |
| Total reduction R(u,a,s,b,p,r,m,c) | (i+j+k+...+s) | $SS_{tr}$ | | |
| Direct effects | | | | |
| Age of dam | i - 1 | $SS_a$ | $MS_a$ | $\sigma^2 + K_a\sigma^2 a$ |
| Sex | j - 1 | $SS_s$ | $MS_s$ | $\sigma^2 + K_s\sigma^2 s$ |
| Breed | k - 1 | $SS_b$ | $MS_b$ | $\sigma^2 + K_b\sigma^2 b$ |
| Pasture | l - 1 | $SS_p$ | $MS_p$ | $\sigma^2 + K_p\sigma^2 p$ |
| Area | m - 1 | $SS_r$ | $MS_r$ | $\sigma^2 + K_r\sigma^2 r$ |
| Month | n - 1 | $SS_m$ | $MS_m$ | $\sigma^2 + K_m\sigma^2 m$ |
| Management | o - 1 | $SS_c$ | $MS_c$ | $\sigma^2 + K_c\sigma^2 c$ |
| Error (residual) | N-(1+I+J+...+0) | $SS-SS_{tr}$ | MS | $\sigma^2$ |

[1]N is the total number of observations; i the number of age of dam groups; j the number of sex groups, k the number of breed groups; l the number of pasture groups; m the number of areas; n the number of months; o the number of production groups.

[2]$K_a$, $K_s$, $K_b$, $K_r$, $K_m$, $K_c$ are approximately the average number of observations per subgroup, computed by

$$K_i = \frac{1}{d.f.} \left(n.. - \frac{\sum_i n_{i.}^2}{n..}\right)$$

where n.. is the total number of observations, $n_i$ the total number of observations in each subgroup, and d.f. is the respective degrees of freedom.

[3]$\sigma_a^2, \sigma_s^2, \sigma_b^2, \sigma_p^2, \sigma_r^2, \sigma_m^2, \sigma_c^2$, represents the sum of squares of the fixed effects of levels for the respective factors divided by the degrees of freedom.

management ($\hat{\sigma}_c^2$), and the variance component for error ($\hat{\sigma}^2$) were then made by equating the expected mean squares given in Table 9 to the observed mean squares given in Table 10. The importance of each effect was assessed by taking the ratio of each component to the total of all components and expressing it as a percent of total variance (Table 10).

## Interactions

It was not possible to obtain estimates of the effects of interaction directly because the dimensions of the matrices required were too large. To investigate the effects of interaction least squares analyses were computed as above for each sex, breed, pasture, type of management, and season. The twelve months were divided into four seasons: February-April; May-July; August-October; and November-January; inclusive. These seasons were chosen on the basis of the overall analysis which indicated that variation within these seasons would be minimum, while that between them would be maximum. It was necessary to drop areas from all of these analyses because of linear dependencies. Thus, the models for the least squares analyses using the previous notation were:

$Y_{iklmno} = \mu + a_i + b_k + p_l + m_m + c_n + e_{iklmno}$, for the three sexes;

$Y_{ijlmno} = \mu + a_i + s_j + p_l + m_m + c_n + e_{ijlmno}$, for the two breeds;

$Y_{ijkmno} = \mu + a_i + s_j + b_k + m_m + c_n + e_{ijkmno}$, for native and improved pastures (mixed was eliminated since there were few in this division and interpretation would be difficult;

$Y_{ijklno} = \mu + a_i + s_j + b_k + p_l + c_n + e_{ijklno}$, for the four seasons

and

$Y_{ijklmo} = \mu + a_i + s_j + b_k + p_l + m_m + e_{ijklmo}$ for the two types of management

where

$i = 1, \ldots, 17$ in the models for sex, breed, and management, and $i = 1, \ldots, 16$ in the models for pastures and seasons because ages 16 and 17 had to be combined to avoid linear dependency.

$j = 1, \ldots 3$ sexes

$k = 1, 2$ breeds

$l = 1, \ldots 3$ pastures

$m = 1, \ldots, 12$ months except in the model for sex where $m = 1, \ldots 4$ seasons because of linear dependency.

$n = 1, 2$ types of management.

To solve these equations, the restrictions that $\sum_i a_i = \sum_j s_j = \sum_k b_k = \sum_l p_l = \sum_m m_m = \sum_n c_n = 0$ were imposed.

All possible two-way interactions were examined by comparing least squares constants computed for a given level of one factor within different levels of another factor. The interaction between age of dam and sex, for example, was studied by comparing the least squares constants for age of dam computed in the three separate sex analyses. The failure of the least squares constants for age of dam to be the same in the three sexes was considered indicative of interaction between sex and age of dam. This seems justified because interaction is by definition the failure of the effect of one factor to be the same in different levels of another factor (Snedecor, 1956). Errors could result from the use of this technique due to disproportionality in numbers of observations for other factors not included in the models. However, this procedure seemed to be the best available to study the two-way interactions. The criterion for assessing the significance of interaction was whether or not 95% confidence intervals on the least squares constants overlapped. This is probably a suitable criterion since it becomes more and more sensitive in detecting interaction as the number of observations increases, as does the direct method of analysis of variance. The approximate 95 percent confidence intervals for the least squares constants were obtained by doubling their standard errors rather than using t = 1.97.

Analyses of variance on least squares means was another method available for assessing the effects of the various two-way interactions. There was no error term to use for a test, but the relative importance of each effect was assessable by comparing the size of the mean square for interaction with those for the main effects. These estimates are in error to the extent that means are estimated with unequal precision. However, the small standard errors obtained for most of the means indicate that this was small.

## Method of Adjustment

Koch et al. (1959) and Brinks et al. (1961) showed that if coefficients of variation for bulls and heifers were equal a multiplicative correction obtained as a ratio of means of the two sexes was most appropriate. On the other hand, an additive correction computed by taking the difference between two sexes was more appropriate when the standard deviations were equal. Standard deviations and coefficients of variation were obtained for each age of dam, sex, season, and type of management to determine the method of correction most appropriate for their effects.

Variances within each age of dam, sex, season, and type of management were estimated by arranging the data into age of dam by sex by type of pasture by season by type of management subclasses, pooling the appropriate corrected sum of squares, and dividing by the appropriate degrees of freedom. Standard deviations were obtained by extracting the square root of each estimate of variance. The coefficients of variation were computed in the usual manner using the standard deviation and the least squares mean computed in the overall analysis for each respective age of dam, sex, or type of management subclass.

The 12 months had to be grouped into four seasons: February-April, May-July, August-October, and November-January; and the six areas dropped in this analysis to maintain degrees of freedom for estimating variances in certain subclasses. Season of birth means were computed by taking the weighted average of the least squares means for the months in each season.

## RESULTS AND DISCUSSION

### Overall Analysis

The overall analysis of variance is given in Table 10. All factors were statistically significant sources of variation ($P < .005$) largely because of the large numbers involved. However, breed and pasture differences were of little practical significance as they accounted for less than one percent of the total variation in weaning weight. Age of dam, sex, area, month of birth, and type of management were important sources of variation. Each accounted for more than five percent of the total variation.

#### Age of dam

The least squares constants and means obtained for age of dam are given in Table 11. The constants represent the average deviation (in pounds) of each age of dam group from the overall mean adjusted for differences due to sex, breed, pasture, area, month of birth, and type of management. The least squares means are interpreted as the average weaning weights for the various age of dam groups adjusted for the other effects.

The effect of age of dam is shown graphically in Figure 3. Weaning weights increased 46 pounds as dams increased in age from 24 months to 45 months. These estimates indicate that increases in age of only 3-month increments have an important influence on weaning weights of

TABLE 10

THE OVERALL ANALYSIS OF VARIANCE

| Source of variation | Degrees of freedom | Sum of squares | Mean squares | Variance components | % of variance |
|---|---|---|---|---|---|
| Total | | | | | |
| Total reduction | | | | | |
| Direct effects | | | | | |
| Age of dam | 16 | 5,315,129 | 332,196* | 410 | 7.1 |
| Sex | 2 | 8,548,508 | 4,274,254* | 999 | 17.3 |
| Breed | 1 | 59,183 | 59,183* | 8 | 0.1 |
| Pasture | 2 | 369,252 | 184,626* | 41 | 0.7 |
| Area | 5 | 2,890,952 | 578,190* | 303 | 5.3 |
| Month | 11 | 4,702,708 | 427,519* | 376 | 6.5 |
| Management | 1 | 2,154,933 | 2,154,933* | 314 | 5.4 |
| Error | 13,897 | 45,988,882 | 3,309 | 3,309 | 57.4 |

*P < .005

TABLE 11

LEAST SQUARES CONSTANTS AND MEANS FOR AGES OF DAM FROM THE OVERALL ANALYSIS

| Item | No. calves | Least squares constants[1] | Least squares means[1] |
|---|---|---|---|
| General mean (μ) | 13,937 | 417.6 ± 1.4 | 417.6 ± 1.4 |
| Age of dam | | | |
| - 27 mo. ($a_1$) | 843 | -49.0 ± 2.0 | 368.6 ± 2.3 |
| 28 - 30 mo. ($a_2$) | 690 | -36.2 ± 2.2 | 381.4 ± 2.6 |
| 31 - 33 mo. ($a_3$) | 454 | -28.3 ± 2.7 | 389.3 ± 3.0 |
| 34 - 39 mo. ($a_4$) | 1,059 | -19.8 ± 1.8 | 397.8 ± 2.1 |
| 40 - 45 mo. ($a_5$) | 1,005 | -4.4 ± 1.9 | 413.2 ± 2.2 |
| 4 yr. ($a_6$) | 1,863 | 0.7 ± 1.5 | 418.3 ± 1.8 |
| 5 yr. ($a_7$) | 1,538 | 7.0 ± 1.6 | 424.6 ± 1.9 |
| 6 ur. ($a_8$) | 1,339 | 13.3 ± 1.6 | 430.9 ± 2.0 |
| 7 yr. ($a_9$) | 1,122 | 15.9 ± 1.8 | 433.5 ± 2.1 |
| 8 yr. ($a_{10}$) | 1,043 | 18.4 ± 1.8 | 436.0 ± 2.2 |
| 9 yr. ($a_{11}$) | 984 | 18.2 ± 1.9 | 435.8 ± 2.2 |
| 10 yr. ($a_{12}$) | 751 | 15.7 ± 2.1 | 433.3 ± 2.4 |
| 11 yr. ($a_{13}$) | 538 | 16.2 ± 2.4 | 433.8 ± 2.8 |
| 12 yr. ($a_{14}$) | 308 | 12.6 ± 3.2 | 430.2 ± 3.5 |
| 13 yr. ($a_{15}$) | 218 | 14.8 ± 3.7 | 432.4 ± 4.1 |
| 14 yr. ($a_{16}$) | 106 | 9.8 ± 5.3 | 427.4 ± 5.7 |
| 15 yr. ($a_{17}$) | 76 | -4.9 ± 6.2 | 412.7 ± 6.7 |

[1] ± standard errors

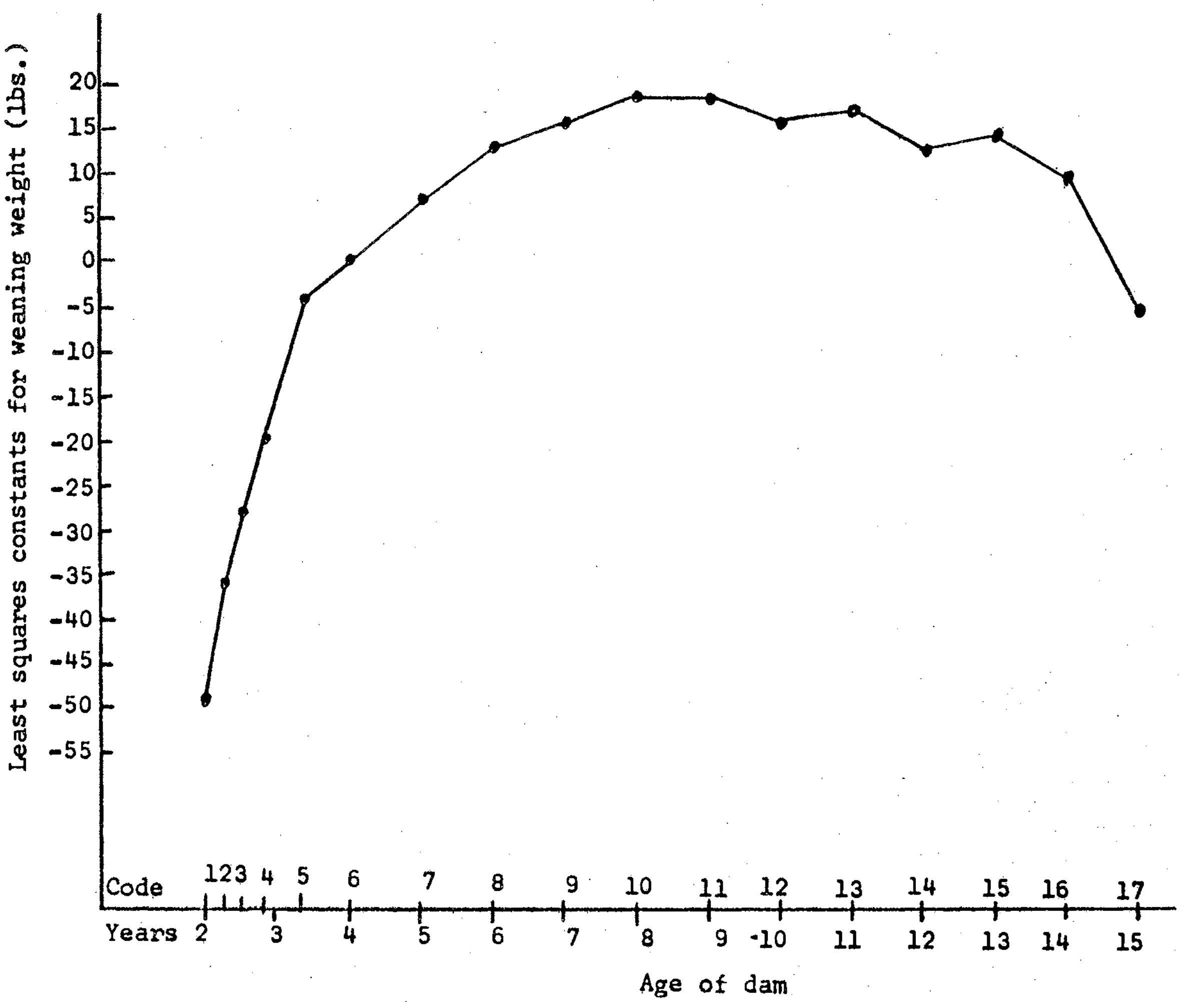


Figure 3. The effect of age of dam.

calves out of 2- and 3-year-old cows. It appears that classifying cows into 3- to 5-month increments between 2 and 4 years of age would result in more accurate corrections than classifying into yearly increments. Weaning weights continued to increase at a diminishing rate as cows increased in age up to 8 years. The weaning weights were essentially the same for calves out of cows between 6 and 13 years old, ranging from 431 pounds to 436 pounds. Weights dropped off slightly to 426 pounds in 14-year-old cows, and decreased to 413 pounds in 15-year-olds. These results agree closely with earlier reports from the Midwest (Botkin and Whatley, 1953; Brown, 1958, 1960; Kieffer, 1959; Hamann et al., 1963) and other areas with relatively high rainfall (Marlowe and Gaines, 1958; Marlowe, 1962; Swiger, 1961; Koger et al., 1962; Thrift, 1964; Cunningham and Henderson, 1965). They do not show the marked decline in production after 8 years seen in the more arid regions of the West (Knapp et al., 1942; Knox and Koger, 1945; Koch and Clark, 1955).

It is possible that the age of dam estimates for the older cows are biased in these data. Lush and Shrode (1950) have shown that corrections may be biased when computed by comparing averages of records made at each age of dam. They showed that culling low producing cows at each age will result in a larger proportion of high producing cows and a smaller proportion of low producing cows to be contained in succeeding age groups. As a result, correction factors computed by comparing averages of age groups will be biased upward from the true effect in older cows.

The magnitude of the bias caused by selection has been studied by Koch and Clark (1955). They calculated correction factors for age of dam in beef cattle using the two methods described by Lush and Shrode in 1950 for dairy cattle: 1) by comparing records made by all cows at each age, as in the present study, and 2) by comparing records made by the same cow at different ages. As discussed above the first method was expected to bias the effect of age of dam upward in older age groups. The second method was expected to bias the effect of age of dam downward in older age groups due to incomplete repeatability of records by the same cow or the tendency for cows selected in one year to regress to the mean in the next year. Unbiased estimates of the effect of age of dam were obtained by proportioning the differences between Methods 1 and 2 by the ratio of the biases p/1-p (after Lush and Shrode) where p, the repeatability of adjacent weaning weights, was estimated as .46. Their results indicated that the use of correction factors obtained by Method 1 would result in a slight over-correction in cows of younger ages (5 pounds in 3-year-old cows, 3 pounds in 4-year-olds) and an under-correction in cows of older ages (5 pounds in 9-year-old cows, and 9 pounds in 10-year-old cows). Marlowe _et al._ (1964) applied the two methods to records of 15,436 calves in the Virginia performance testing program and found only small discrepancies between age of dam correction factors for preweaning gain. They concluded that either little selection was made for cow productivity or that selection was not very effective.

In view of these findings no attempt was made to adjust the age of dam estimates in the present study for the effect of selection. Also the results of the present study agree with those of Botkin and Whatley (1953), Brown (1958), and Kieffer (1959) who indicated that in their data such a bias was small.

Influence of sex

The least squares constants and means given in Table 12 indicate that bulls were 56 pounds heavier than heifers and 44 pounds heavier than steers at weaning. These differences are larger than those that have been reported previously ranging from 22 to 46 pounds between bulls and heifers (Burgess et al., 1954; Evans et al., 1955; Kieffer, 1959; Thrift, 1964) and from 11 to 26 pounds between bulls and steers (Burgess et al., 1954; Thrift, 1964). The difference between steers and heifers of 11 pounds in favor of steers is larger than that of 2 pounds observed by Burgess et al. (1954) but smaller than those ranging from 17 to 32 pounds in other reports (Lush et al., 1930; Koger and Knox, 1945; Botkin and Whatley, 1953; Evans et al., 1955; Thrift, 1964).

These discrepancies have probably resulted since the effect of castration in the males is confounded with the effect of selection for size. A tendency for producers to keep the faster growing, more thrifty calves as bulls, and to castrate the slower growing male calves has apparently caused the differences between bulls and steers and bulls and heifers to be biased upward and the difference between steers and heifers to be biased downward. Thus, means obtained in this study are not good estimates of the effect of sex.

Area

There was a significant difference between weaning weights of calves raised in different areas of the state. These differences are of no concern to ranchers adjusting weaning weights of calves, however, since they would be comparing calves raised in the same area. Areas were included in this analysis only to remove their effects from the

TABLE 12

LEAST SQUARES CONSTANTS AND MEANS FOR SEXES, BREEDS, PASTURES, AND AREAS FROM THE OVERALL ANALYSIS

| Item | | No. calves | Least squares constants[1] | Least squares means[1] |
|---|---|---|---|---|
| Sex | | | | |
| Bulls | $(s_1)$ | 4,665 | 33.4 ± 0.8 | 451.0 ± 1.5 |
| Heifers | $(s_2)$ | 6,904 | -22.4 ± 0.7 | 395.2 ± 1.5 |
| Steers | $(s_3)$ | 2,368 | -11.0 ± 0.9 | 406.6 ± 1.8 |
| Breed | | | | |
| Hereford | $(b_1)$ | 7,522 | -2.4 ± 0.6 | 415.2 ± 1.5 |
| Angus | $(b_2)$ | 6,415 | 2.4 ± 0.6 | 420.0 ± 1.6 |
| Pasture | | | | |
| Native | $(p_1)$ | 6,002 | 4.2 ± 0.9 | 421.8 ± 1.7 |
| Improved | $(p_2)$ | 5,102 | 5.8 ± 1.0 | 423.4 ± 1.8 |
| Mixed | $(p_3)$ | 2,833 | -10.0 ± 1.0 | 407.6 ± 1.7 |
| Area | | | | |
| NE | $(r_1)$ | 6,746 | -1.3 ± 1.3 | 416.3 ± 1.1 |
| SE | $(r_2)$ | 2,572 | -32.6 ± 1.9 | 385.0 ± 1.8 |
| SC | $(r_3)$ | 2,920 | 18.8 ± 1.6 | 436.4 ± 1.6 |
| NC | $(r_4)$ | 650 | -35.4 ± 2.2 | 382.2 ± 2.5 |
| NW | $(r_5)$ | 934 | 19.7 ± 2.0 | 437.2 ± 2.3 |
| SW | $(r_6)$ | 115 | 30.8 ± 4.6 | 448.4 ± 5.6 |

[1]± standard errors

effects of age of dam, sex, breed, pasture, month of birth, and type of management. These estimates of area effects are completely inadequate and should not be used to compare calves raised by a rancher in one area to calves raised by another rancher in another area.

Month of birth

Month of birth had an important influence on weaning weights (See Table 13 and Figure 4). These data indicate that calves born in February, March, and April had an advantage in 205-day weaning weights over those born in any other season of the year. Those born in May were intermediate to those born in early spring and summer. Calves born in August, September, and October were at the greatest disadvantage. There was a steady increase in weights of calves born from November through March. These results are in agreement with those that have been reported previously (Rollins and Guilbert, 1954; Brown, 1958, 1960; Marlowe and Gaines, 1958, Marlowe, 1962; Thrift, 1964).

Type of management

The least squares means given in Table 13 show that on the average creep-fed calves were 28 pounds heavier at weaning than noncreep-fed calves. However, the addition of 28 pounds to weaning weights of noncreep-fed calves would be inadequate in adjusting for creep-feeding in most herds. As pointed out in the literature review, the effect of creep-feeding varies considerably depending on numerous factors such as the amount and quality of forage available, level of supplementation, composition of creep ration, etc.

TABLE 13

LEAST SQUARES CONSTANTS AND MEANS FOR MONTHS OF BIRTH AND TYPES OF MANAGEMENT FROM THE OVERALL ANALYSIS

| Item | | No. calves | Least squares constants[1] | Least squares means[1] |
|---|---|---|---|---|
| Month of birth | | | | |
| Jan. | ($m_1$) | 1,399 | 15.2 ± 1.6 | 432.8 ± 1.9 |
| Feb. | ($m_2$) | 1,319 | 23.0 ± 1.7 | 440.6 ± 2.0 |
| Mar. | ($m_3$) | 1,935 | 29.9 ± 1.5 | 447.5 ± 1.7 |
| Apr. | ($m_4$) | 1,346 | 24.2 ± 1.7 | 441.8 ± 1.9 |
| May | ($m_5$) | 791 | 5.0 ± 2.1 | 422.6 ± 2.4 |
| June | ($m_6$) | 292 | -9.8 ± 3.2 | 407.8 ± 3.6 |
| Jul. | ($m_7$) | 130 | -9.1 ± 4.7 | 408.5 ± 5.2 |
| Aug. | ($m_8$) | 88 | -20.1 ± 5.7 | 397.5 ± 6.3 |
| Sept. | ($m_9$) | 1,254 | -18.8 ± 1.7 | 398.8 ± 2.1 |
| Oct. | ($m_{10}$) | 1,815 | -22.9 ± 1.5 | 394.7 ± 1.8 |
| Nov. | ($m_{11}$) | 1,989 | -12.0 ± 1.5 | 405.6 ± 1.8 |
| Dec. | ($m_{12}$) | 1,579 | -4.6 ± 1.6 | 413.0 ± 1.9 |
| Type of management | | | | |
| Noncreep-fed | ($c_1$) | 7,881 | -14.1 ± 0.6 | 403.5 ± 1.5 |
| Creep-fed | ($c_2$) | 6,056 | 14.1 ± 0.6 | 431.7 ± 1.6 |

[1] ± standard errors

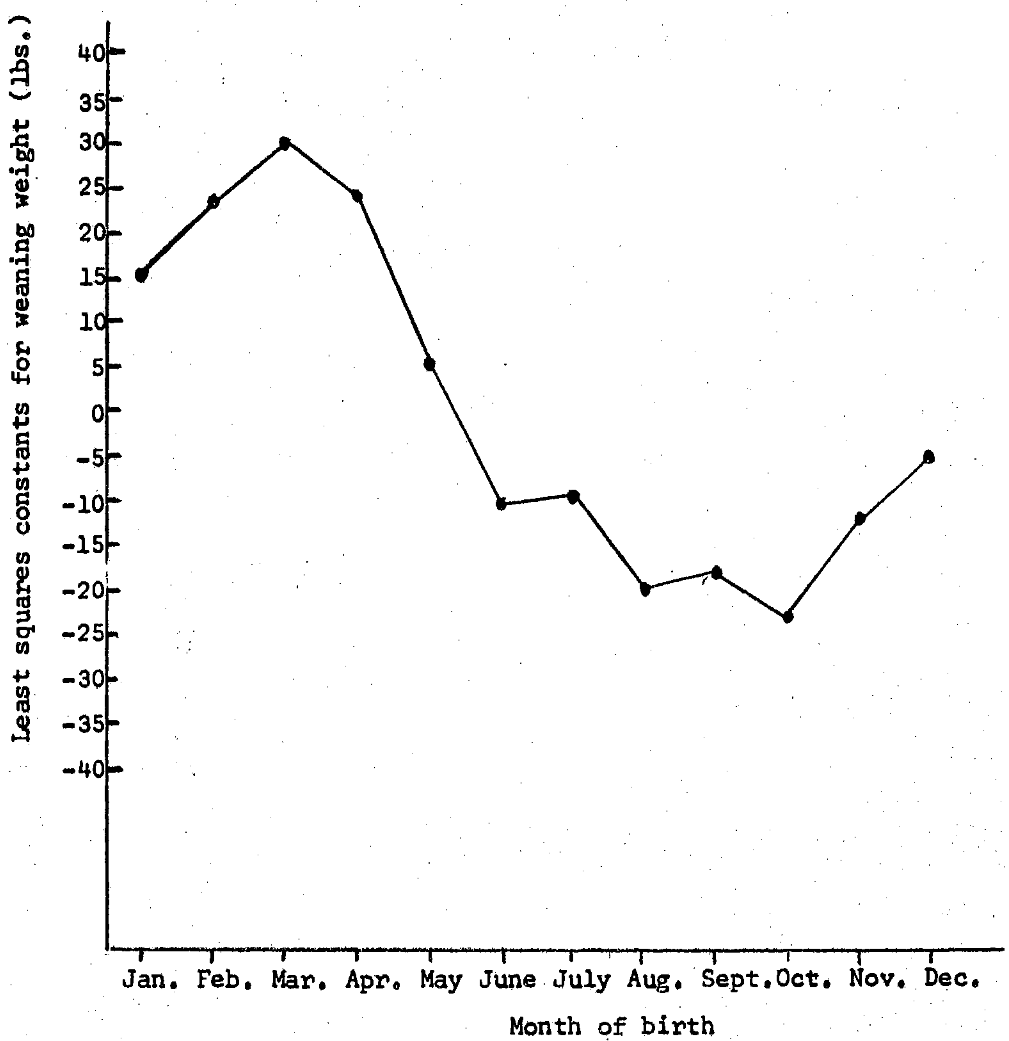


Figure 4. The effect of month of birth.

Summary on Overall Analysis

The analysis of variance revealed that age of dam, sex, area, month of birth, and type of management were the important sources of variation considered in this analysis. Each accounted for more than five percent of the total variation in weaning weight. Of these, the effects of age of dam, sex, month of birth, and type of management--where it is needed--should be considered in adjusting weaning weights of calves.

## Interactions

In the overall analysis it was assumed that there were no interactions among the effects of age of dam, sex, breed, type of pasture, areas, month of birth, and type of management. If this assumption is false and the interactions among these factors are important then correction factors derived from the overall analysis would not be appropriate for adjusting weaning weights of calves. Therefore, a knowledge of the importance of these interactions is needed before correction factors for the various factors are suggested.

### Interactions with age of dam

Age of dam by sex. The least squares constants computed in bulls, heifers, and steers for age of dam are given in Table 14a and Figure 5. The 95 percent confidence intervals on the age of dam constants in bulls and steers overlapped for each age group indicating that the effect of age of dam did not differ in bulls and steers. However, heifer calves deviated significantly less from their mean than bulls in 2-, 6-, and 8-year-old cows. It appears that the effect of age of dam was less curvilinear in heifers than in bulls (see Figure 5). Perhaps this is because bull calves tend to challenge their dams more and stimulate more milk flow than heifer calves. Similar results were obtained between steers and heifers. Least squares constants for age of dam

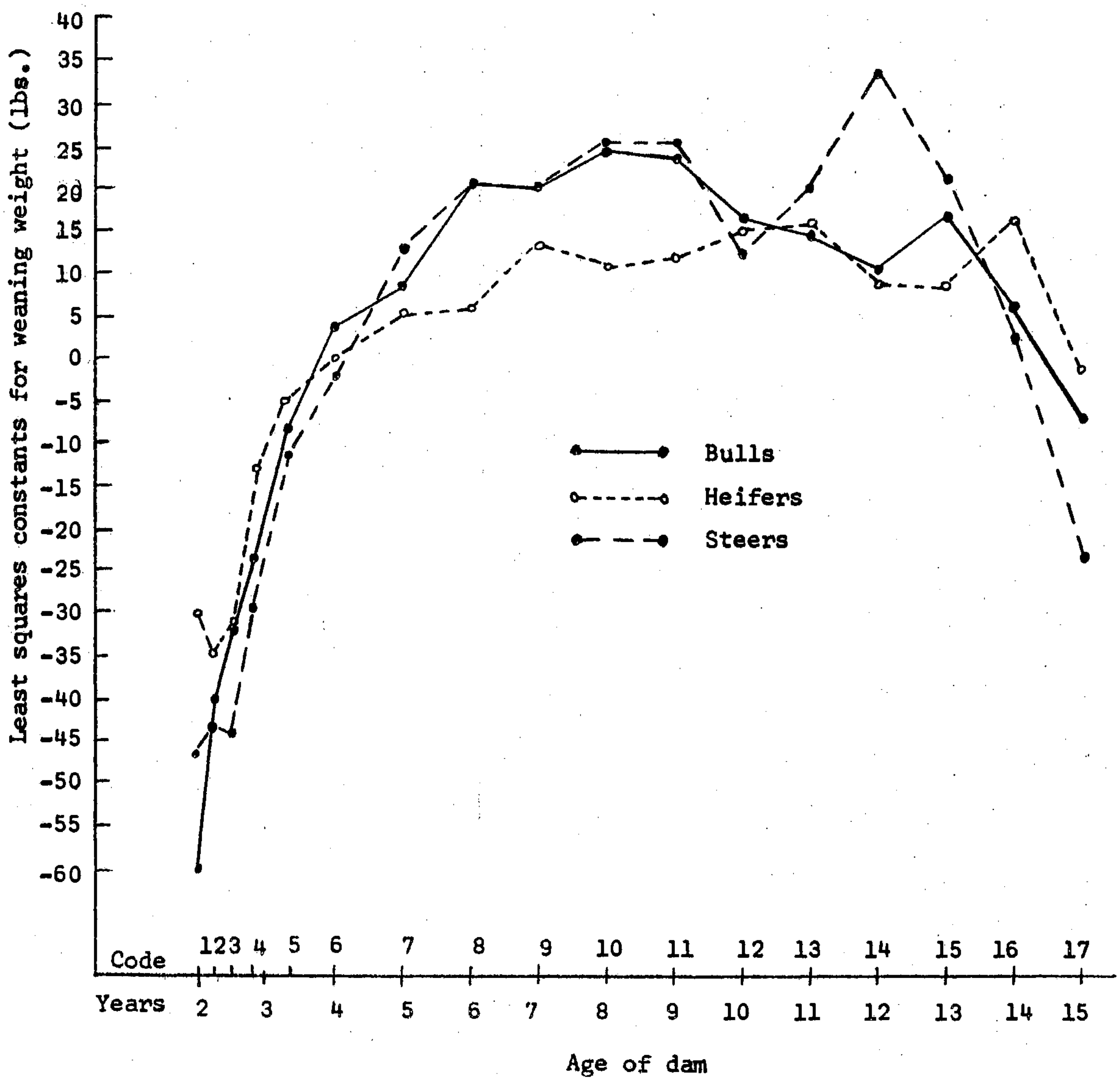


Figure 5. Age of dam by sex.

TABLE 14a

LEAST SQUARES ESTIMATES WITHIN SEX FOR AGE OF DAM

| Item | Bulls | | Heifers | | Steers | |
|---|---|---|---|---|---|---|
| | n[1] | constants[2] | n | constants | n | constants |
| General mean | 4,655 | 451.1 ± 3.0 | 6,904 | 394.8 ± 2.4 | 2,368 | 393.6 ± 5.0 |
| Age of dam | | | | | | |
| 27 mo. | 336 | -59.2 ± 7.2[a] | 381 | -30.0 ± 5.8[b] | 126 | -46.9 ± 10.6[a] |
| 28-30 mo. | 254 | -39.4 ± 8.0[a] | 374 | -34.7 ± 6.0[a] | 62 | -42.7 ± 14.8[a] |
| 31-33 mo. | 147 | -32.7 ± 10.2[a] | 238 | -31.2 ± 7.2[a] | 69 | -44.2 ± 14.0[a] |
| 34-39 mo. | 366 | -23.6 ± 6.8[ab] | 506 | -12.9 ± 5.2[a] | 187 | -29.2 ± 8.8[b] |
| 40-45 mo. | 339 | - 7.9 ± 7.0[a] | 544 | - 5.4 ± 5.0[a] | 122 | -11.5 ± 10.8[a] |
| 4 yrs. | 561 | 4.0 ± 5.8[a] | 925 | 0.3 ± 4.0[a] | 377 | - 2.7 ± 6.8[a] |
| 5 yrs. | 479 | 8.6 ± 6.2[a] | 751 | 5.5 ± 4.4[a] | 308 | 13.4 ± 7.4[a] |
| 6 yrs. | 444 | 21.5 ± 6.2[a] | 662 | 6.0 ± 4.6[a] | 233 | 21.2 ± 8.2[a] |
| 7 yrs. | 332 | 20.9 ± 7.0[a] | 574 | 13.5 ± 4.8[a] | 216 | 20.7 ± 8.4[a] |
| 8 yrs. | 356 | 24.7 ± 6.8[a] | 509 | 11.1 ± 5.2[b] | 178 | 25.5 ± 9.0[ab] |
| 9 yrs. | 334 | 24.1 ± 7.0[a] | 470 | 12.3 ± 5.2[a] | 180 | 25.4 ± 9.0[a] |
| 10 yrs. | 253 | 16.6 ± 8.0[a] | 390 | 15.6 ± 5.8[a] | 108 | 12.8 ± 11.2[a] |
| 11 yrs. | 206 | 15.5 ± 8.8[a] | 243 | 16.5 ± 7.0[a] | 89 | 21.4 ± 12.2[a] |
| 12 yrs. | 103 | 11.3 ± 12.0[ab] | 153 | 9.3 ± 18.8[a] | 52 | 33.9 ± 15.8[b] |
| 13 yrs. | 86 | 17.2 ± 13.2[a] | 102 | 8.6 ± 10.6[a] | 30 | 22.6 ± 20.4[a] |
| 14 yrs. | 42 | 6.1 ± 18.6[a] | 53 | 16.7 ± 14.6[a] | 11 | 3.6 ± 33.4[a] |
| 15 yrs. | 27 | - 7.7 ± 23.2[a] | 29 | - 1.2 ± 19.6[a] | 20 | -23.3 ± 25.0[a] |

[1]Number of observations in each subclass

[2]Least squares constants ± 95% confidence intervals. Estimates in the same age of dam group (row) with different superscripts differ significantly in that their 95% confidence intervals do not overlap.

TABLE 14b

LEAST SQUARES ESTIMATES WITHIN SEX FOR AGE OF DAM[1]

| Item | Bull means | Heifer means | Steer means |
|---|---|---|---|
| General mean | 451.1 ± 1.5 | 394.8 ± 1.2 | 393.6 ± 2.5 |
| Age of dam | | | |
| 27 mo. | 391.9 ± 3.5 | 364.8 ± 2.9 | 346.7 ± 5.5 |
| 28-30 mo. | 411.7 ± 4.1 | 360.1 ± 3.0 | 350.9 ± 7.7 |
| 31-33 mo. | 418.4 ± 5.3 | 363.6 ± 3.7 | 349.4 ± 7.4 |
| 34-39 mo. | 427.5 ± 3.4 | 381.9 ± 2.5 | 364.4 ± 4.6 |
| 40-45 mo. | 443.2 ± 3.5 | 389.4 ± 2.4 | 382.1 ± 5.5 |
| 4 yrs. | 455.1 ± 2.7 | 395.4 ± 1.9 | 390.9 ± 3.4 |
| 5 yrs. | 459.7 ± 3.0 | 400.3 ± 2.1 | 407.0 ± 3.7 |
| 6 yrs. | 472.6 ± 3.1 | 400.3 ± 2.2 | 414.8 ± 4.2 |
| 7 yrs. | 471.1 ± 3.6 | 408.3 ± 2.4 | 414.3 ± 4.3 |
| 8 yrs. | 475.8 ± 3.5 | 405.9 ± 2.5 | 419.1 ± 4.7 |
| 9 yrs. | 475.2 ± 3.5 | 407.1 ± 2.6 | 419.0 ± 4.6 |
| 10 yrs. | 467.3 ± 4.1 | 410.4 ± 2.9 | 406.4 ± 5.8 |
| 11 yrs. | 467.7 ± 4.5 | 411.3 ± 3.6 | 415.0 ± 6.5 |
| 12 yrs. | 462.4 ± 6.3 | 404.1 ± 4.5 | 427.5 ± 8.3 |
| 13 yrs. | 468.3 ± 6.9 | 403.4 ± 5.6 | 416.2 ± 10.8 |
| 14 yrs. | 457.2 ± 9.8 | 411.5 ± 7.7 | 397.2 ± 17.8 |
| 15 yrs. | 443.4 ± 12.3 | 393.6 ± 10.4 | 370.3 ± 13.3 |

[1]Least squares means ± Standard errors

TABLE 14c

ANALYSIS OF VARIANCE OF MEANS FOR AGE OF DAM BY SEX

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Age of dam | 16 | 1,550 |
| Sex | 2 | 18,435 |
| Age of dam by sex | 32 | 58 |

differed significantly when cows were 2 years, 34-39 months, 6 years, and 12 years old. In all four instances steers deviated further from their mean than heifers.

These results are in agreement with those of Clark et al. (1958) and agree in direction, but are of smaller magnitude than those reported by Pahnish et al. (1958). This is probably because the calves were weaned at different ages. The calves studied by Pahnish et al. (1958) were weaned at an average age of 270 days while those of the present study were weaned at an average of 205 days.

In general, however, it appears that the interaction between age of dam and sex was relatively small and unimportant. The means given in Table 14b and their analysis of variance given in Table 14c indicate that the main effect of age of dam and sex was considerably more important than their interaction.

Age of dam by breed. The constants given in Table 15a and Figure 6 indicate that as age of dam increased from 2 to 6 years, Hereford calves tended to be heavier at weaning relative to their breed average than Angus calves. After 8 years of age, however, the calves out of the Angus cows appeared to have a slight advantage in weaning weight. The results suggest a tendency for Herefords to develop in their maternal capacity at an earlier age, but for longevity of peak production to be greater in Angus cows.

These results are not in agreement with those reported by Marlowe (1962). In noncreep-fed calves, he observed the opposite trend. Calves out of 2-year-old Hereford cows had a slightly lower preweaning average daily gains than those out of 2-year-old Angus cows, and the Hereford cows maintained peak production longer than the Angus.

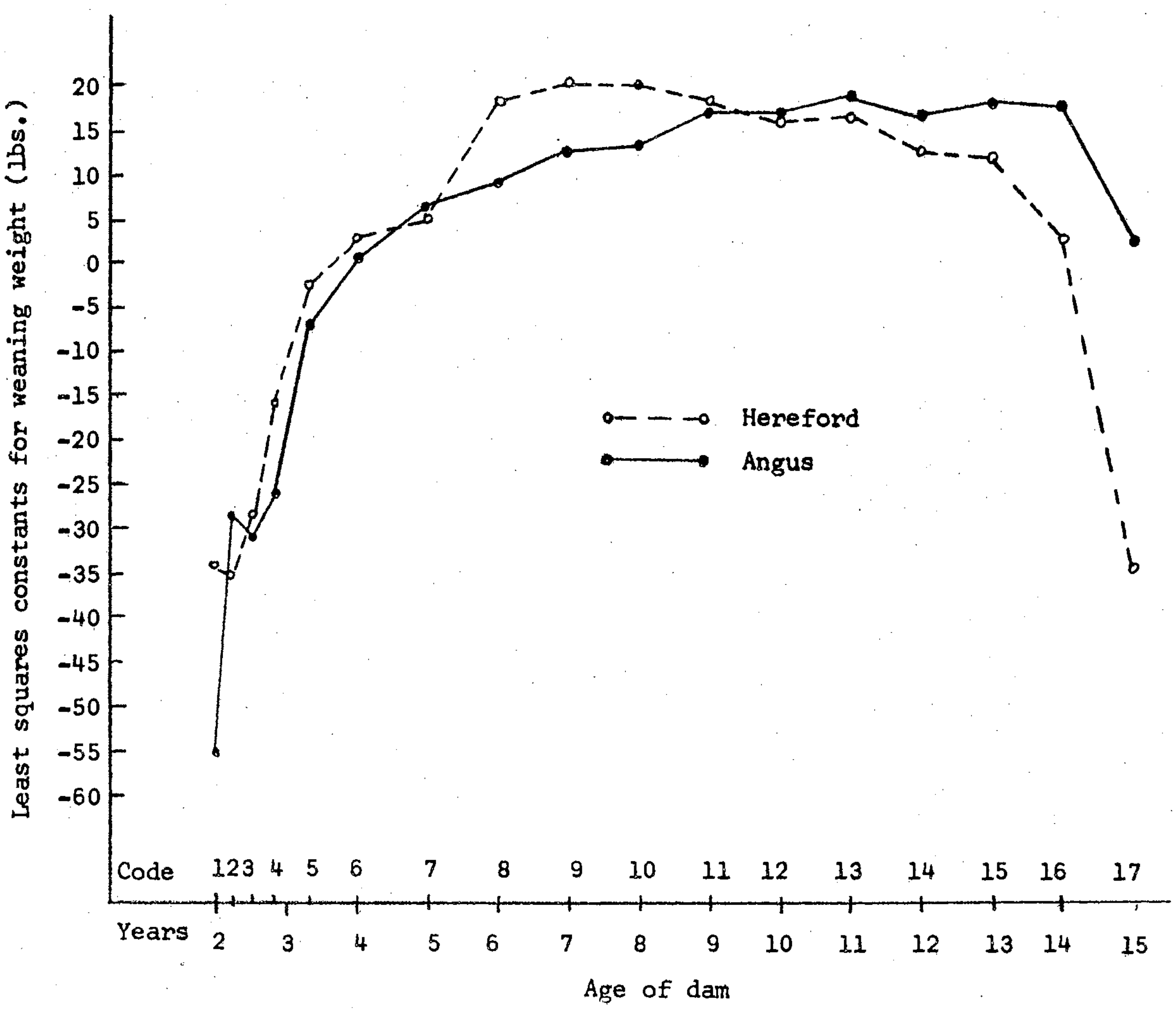


Figure 6. Age of dam by breed.

TABLE 15a

LEAST SQUARES ESTIMATES WITHIN BREED FOR AGE OF DAM

| Item | Hereford | | | Angus | | |
|---|---|---|---|---|---|---|
| | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 7,522 | 410.9 ± 3.4 | 410.9 ± 1.7 | 6,415 | 420.9 ± 2.8 | 420.9 ± 1.4 |
| Age of dam | | | | | | |
| 27 mo. | 320 | -33.7 ± 6.8[a] | 377.2 ± 3.6 | 523 | -55.2 ± 5.0[b] | 365.7 ± 2.6 |
| 28-30 mo. | 504 | -35.0 ± 5.6[a] | 375.9 ± 3.0 | 186 | -29.3 ± 8.0[a] | 391.6 ± 4.2 |
| 31-33 mo. | 245 | -28.9 ± 7.8[a] | 382.0 ± 4.1 | 209 | -31.3 ± 7.6[a] | 389.6 ± 4.1 |
| 34-39 mo. | 542 | -16.3 ± 5.4[a] | 394.6 ± 2.9 | 517 | -25.6 ± 5.0[a] | 395.3 ± 2.7 |
| 40-45 mo. | 611 | - 3.2 ± 5.2[a] | 407.7 ± 2.8 | 394 | - 7.4 ± 5.6[a] | 413.5 ± 3.0 |
| 4 yrs. | 1,018 | 2.9 ± 4.4[a] | 413.8 ± 2.3 | 845 | - 1.8 ± 4.0[a] | 419.1 ± 2.1 |
| 5 yrs. | 774 | 9.0 ± 4.8[a] | 419.9 ± 2.5 | 764 | 5.7 ± 4.2[a] | 426.6 ± 2.3 |
| 6 yrs. | 686 | 17.8 ± 5.0[a] | 428.7 ± 2.6 | 653 | 8.8 ± 4.6[a] | 429.7 ± 2.4 |
| 7 yrs. | 626 | 20.7 ± 5.2[a] | 431.6 ± 2.7 | 496 | 12.8 ± 5.0[a] | 433.7 ± 2.7 |
| 8 yrs. | 604 | 21.2 ± 5.2[a] | 432.1 ± 2.8 | 439 | 13.5 ± 5.4[a] | 434.4 ± 2.9 |
| 9 yrs. | 573 | 18.8 ± 5.4[a] | 429.7 ± 2.8 | 411 | 17.1 ± 5.4[a] | 438.0 ± 2.9 |
| 10 yrs. | 438 | 15.9 ± 6.0[a] | 426.8 ± 3.2 | 313 | 17.1 ± 6.2[a] | 438.0 ± 3.3 |
| 11 yrs. | 275 | 16.7 ± 7.4[a] | 427.6 ± 3.9 | 263 | 19.1 ± 6.8[a] | 440.0 ± 3.6 |
| 12 yrs. | 146 | 13.4 ± 9.8[a] | 424.3 ± 5.2 | 162 | 17.2 ± 8.4[a] | 438.1 ± 4.5 |
| 13 yrs. | 93 | 11.7 ± 12.0[a] | 422.6 ± 6.5 | 125 | 18.1 ± 9.6[a] | 439.0 ± 5.1 |
| 14 yrs. | 43 | 2.7 ± 17.6[a] | 413.6 ± 9.4 | 63 | 18.1 ± 13.2[a] | 439.0 ± 7.1 |
| 15 yrs. | 24 | -33.7 ± 23.6[a] | 377.2 ± 12.6 | 52 | 3.1 ± 14.6[b] | 424.0 ± 7.8 |

[1]Number of observations in each subclass

[2]Least squares constants ± 95% confidence intervals. Estimates in the same age of dam group (row) with different superscripts differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

TABLE 15b

ANALYSIS OF VARIANCE OF MEANS FOR AGE OF DAM BY BREED

| Source | Degrees of Freedom | Mean Square |
|---|---|---|
| Age of dam | 16 | 864 |
| Breed | 1 | 850 |
| Age of dam by breed | 16 | 78 |

In any event, the interaction between age of dam and breed appears to be small. The 95 percent confidence intervals failed to overlap only in 2-year-old and 15-year-old cows. Furthermore, the age by breed interaction mean square in the analysis of variance (Table 15b) of the means given in Table 15a was smaller than that for breeds which were not an important source of variation in the overall analysis.

Age of dam by pasture. There was essentially no interaction between age of dam and type of pasture. The age of dam constants in native pasture and improved pasture differed significantly only for the 31-33 month age group (see Table 16a and Figure 7). The analysis of variance given in Table 16 also indicates that this interaction is not important.

Age of dam by season. The constants for age of dam in each of the 4 seasons are given in Tables 17a and Figure 8 and the means in Table 17b. In ten out of 16 age groups, the constants did not differ significantly for the 4 seasons. The analysis of variance in Table 17c shows that the effect of interaction was small relative to the main effects.

Age of dam by management. There was very little interaction between age of dam and type of management (Table 18a and Figure 9). Creep-feeding did tend to reduce the effect of age of dam. Calves out of 2-year-old heifers that were creep-fed deviated significantly less from their mean than calves that were not creep-fed. The same trend was present in calves out of 15-year-old cows, but the difference between the constants was not significant. This suggests that calves out of young or old cows may compensate slightly for the low milk

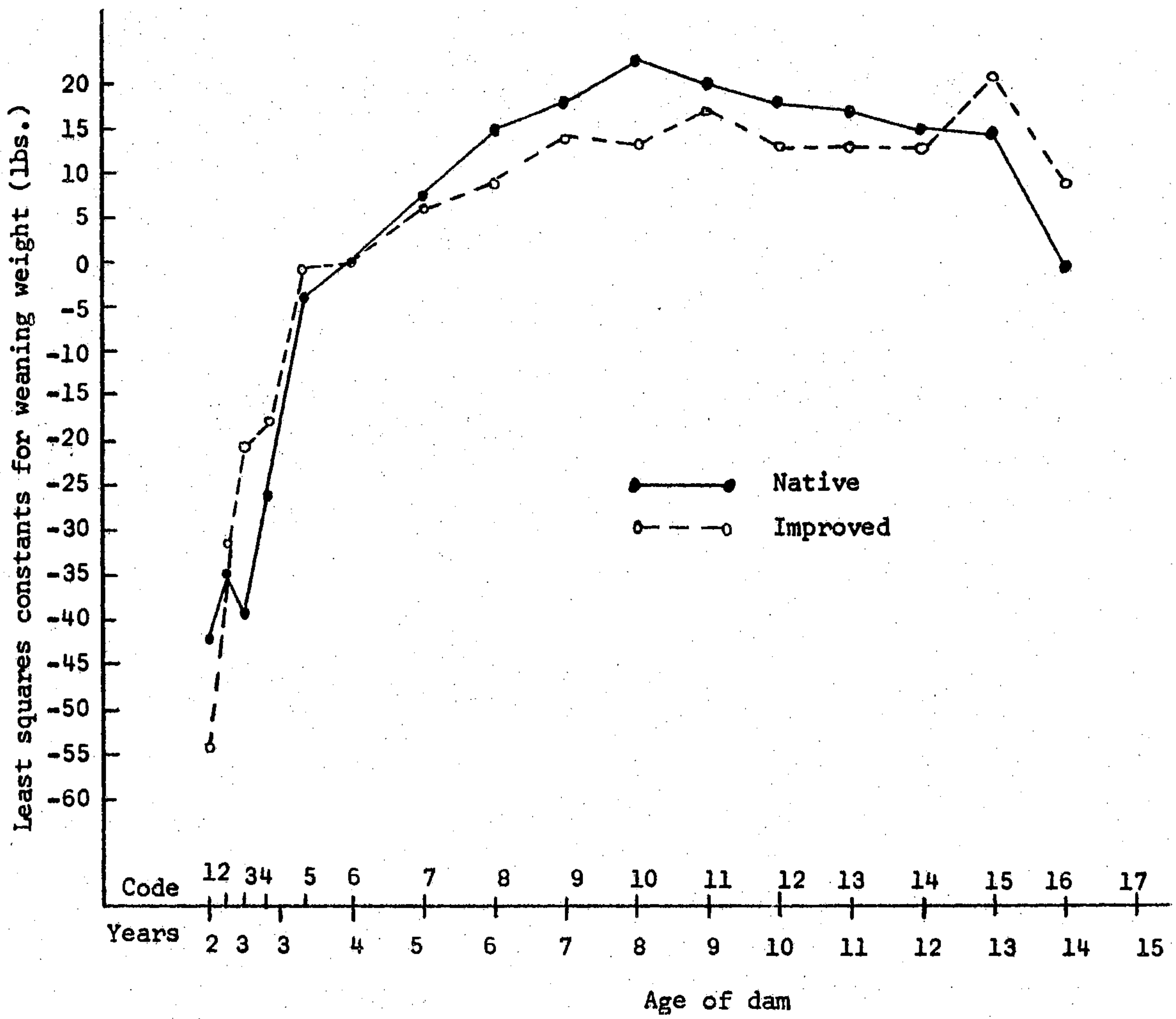


Figure 7. Age of dam by type of pasture.

TABLE 16a

LEAST SQUARES ESTIMATES WITHIN PASTURE FOR AGE OF DAM

| Item | Native pasture | | | Improved pasture | | |
|---|---|---|---|---|---|---|
| | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 6,002 | 424.5 ± 3.6 | 424.5 ± 1.8 | 5,102 | 414.5 ± 3.0 | 414.5 ± 1.5 |
| Age of dam | | | | | | |
| 27 mo. | 310 | -42.1 ± 6.4[a] | 382.4 ± 3.6 | 343 | -54.3 ± 6.0[a] | 360.2 ± 3.3 |
| 28-30 mo. | 324 | -34.9 ± 6.4[a] | 389.6 ± 3.6 | 217 | -31.1 ± 7.4[a] | 383.4 ± 4.1 |
| 31-33 mo. | 185 | -38.9 ± 8.2[a] | 385.6 ± 4.5 | 198 | -21.3 ± 7.8[b] | 393.2 ± 4.2 |
| 34-39 mo. | 392 | -26.4 ± 5.8[a] | 398.1 ± 3.3 | 426 | -17.8 ± 5.4[a] | 396.7 ± 2.9 |
| 40-45 mo. | 396 | - 4.1 ± 5.8[a] | 420.4 ± 3.3 | 370 | - 1.0 ± 5.8[a] | 413.5 ± 3.2 |
| 4 yrs. | 706 | 0.3 ± 4.4[a] | 424.8 ± 2.7 | 685 | - 1.4 ± 4.4[a] | 413.1 ± 2.4 |
| 5 yrs. | 627 | 7.5 ± 4.8[a] | 432.0 ± 2.8 | 575 | 6.4 ± 4.8[a] | 420.9 ± 2.6 |
| 6 yrs. | 580 | 14.9 ± 4.8[a] | 439.4 ± 2.8 | 463 | 8.8 ± 5.2[a] | 423.3 ± 2.8 |
| 7 yrs. | 535 | 17.8 ± 5.0[a] | 442.3 ± 2.9 | 399 | 13.5 ± 5.6[a] | 428.0 ± 3.0 |
| 8 yrs. | 495 | 22.6 ± 5.2[a] | 447.1 ± 3.0 | 357 | 13.0 ± 6.0[a] | 427.5 ± 3.2 |
| 9 yrs. | 488 | 20.3 ± 5.2[a] | 444.8 ± 3.0 | 315 | 16.8 ± 6.1[a] | 431.3 ± 3.4 |
| 10 yrs. | 368 | 18.0 ± 6.0[a] | 442.5 ± 3.4 | 260 | 13.4 ± 6.8[a] | 427.9 ± 3.7 |
| 11 yrs. | 281 | 17.2 ± 6.6[a] | 441.7 ± 3.8 | 182 | 12.6 ± 8.0[a] | 427.1 ± 4.3 |
| 12 yrs. | 162 | 14.6 ± 8.6[a] | 439.1 ± 4.7 | 107 | 13.2 ± 10.4[a] | 427.7 ± 5.6 |
| 13 yrs. | 91 | 14.3 ± 11.4[a] | 438.8 ± 6.2 | 102 | 20.5 ± 10.6[a] | 435.0 ± 5.7 |
| 14 yrs. or older | 62 | - 1.1 ± 13.8[a] | 423.4 ± 7.4 | 103 | 8.7 ± 10.6[a] | 423.2 ± 5.7 |

[1]Number of observations in each subclass

[2]Least squares constants ± 95% confidence intervals. Estimates in the same age of dam group (row) with different superscripts differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

TABLE 16b

ANALYSIS OF VARIANCE OF MEANS FOR AGE OF DAM BY PASTURE

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Age of dam | 15 | 918 |
| Pasture | 1 | 800 |
| Age of dam by pasture | 15 | 83 |

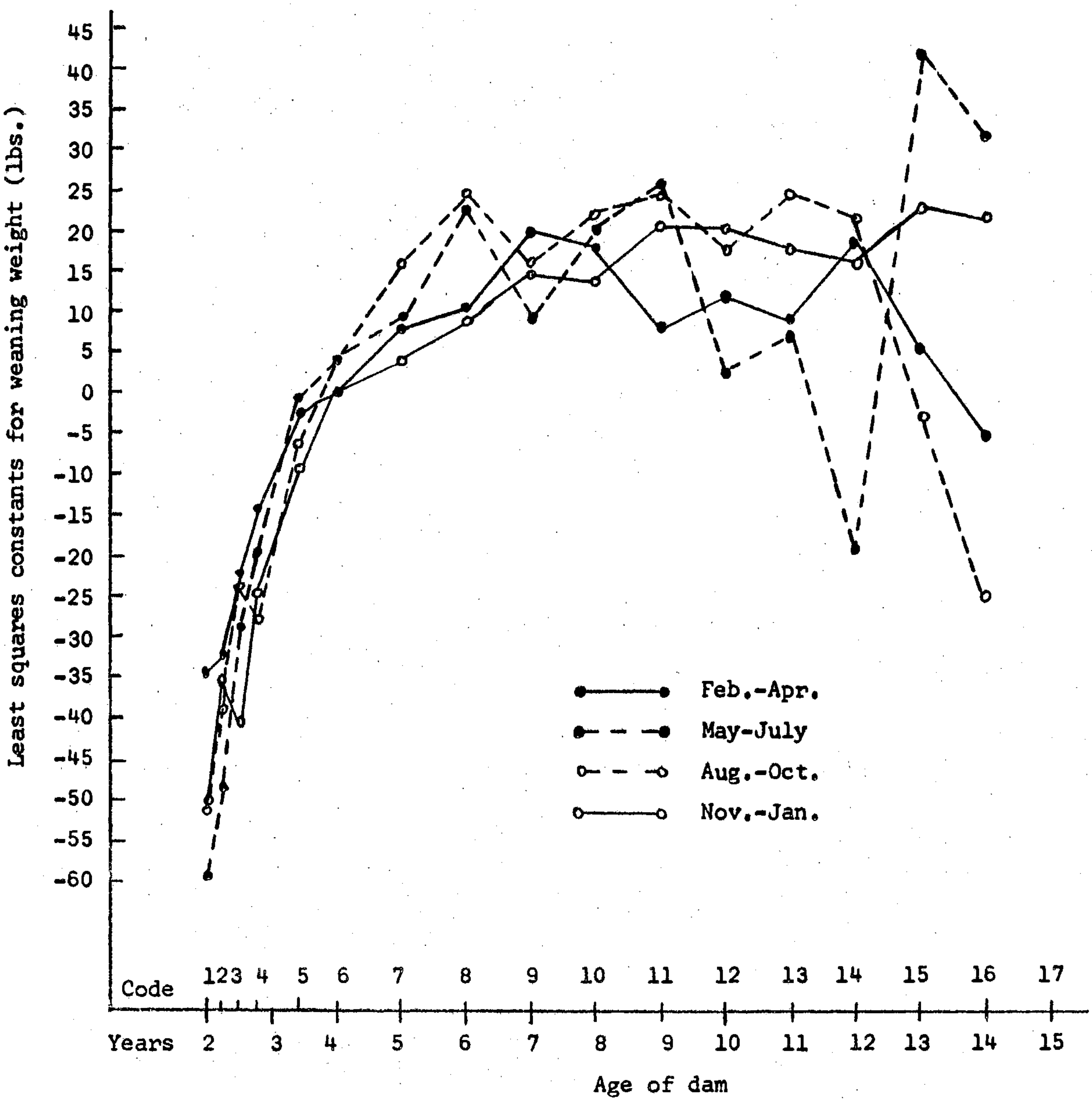


Figure 8. Age of dam by season of birth.

TABLE 17a

LEAST SQUARES ESTIMATES WITHIN SEASON FOR AGE OF DAM

| Item | Feb.-Apr. | | May-Jul. | | Aug.-Oct. | | Nov.-Jan. | |
|---|---|---|---|---|---|---|---|---|
| | n[1] | Constants[2] | n | Constants | n | Constants | n | Constants |
| General mean | 4,600 | 440.3 ± 2.4 | 1,213 | 414.4 ± 6.0 | 3,157 | 383.2 ± 3.4 | 4,967 | 415.1 ± 2.4 |
| Age of dam | | | | | | | | |
| 27 mo. | 414 | -34.0 ± 5.8$^{a}$ | 114 | -59.0 ± 12.0$^{ab}$ | 78 | -50.7 ± 13.2$^{ab}$ | 237 | -51.6 ± 7.4$^{b}$ |
| 28-30 mo. | 320 | -32.3 ± 3.3$^{a}$ | 80 | -49.3 ± 14.2$^{a}$ | 180 | -38.6 ± 9.0$^{a}$ | 110 | -35.2 ± 10.4$^{a}$ |
| 31-33 mo. | 69 | -22.5 ± 13.2$^{a}$ | 42 | -28.5 ± 19.0$^{a}$ | 113 | -23.7 ± 11.0$^{a}$ | 230 | -41.6 ± 7.4$^{a}$ |
| 34-39 mo. | 415 | -13.9 ± 5.8$^{a}$ | 88 | -21.0 ± 13.6$^{a}$ | 171 | -27.5 ± 9.2$^{a}$ | 385 | -24.7 ± 5.8$^{a}$ |
| 40-45 mo. | 262 | - 2.6 ± 7.2$^{a}$ | 108 | 0.1 ± 12.4$^{a}$ | 295 | - 5.9 ± 7.2$^{a}$ | 340 | - 9.1 ± 6.2$^{a}$ |
| 4 yrs. | 600 | 0.4 ± 5.0$^{a}$ | 151 | 4.3 ± 10.6$^{a}$ | 453 | 4.1 ± 6.0$^{a}$ | 659 | 0.2 ± 4.6$^{a}$ |
| 5 yrs. | 510 | 7.5 ± 5.4$^{ab}$ | 96 | 9.8 ± 13.0$^{ab}$ | 362 | 15.9 ± 6.6$^{b}$ | 570 | 4.1 ± 5.0$^{a}$ |
| 6 yrs. | 437 | 10.9 ± 5.6$^{a}$ | 98 | 23.0 ± 12.8$^{ab}$ | 301 | 25.1 ± 7.2$^{b}$ | 503 | 8.6 ± 5.2$^{a}$ |
| 7 yrs. | 376 | 20.1 ± 6.0$^{a}$ | 82 | 9.2 ± 14.0$^{a}$ | 220 | 16.1 ± 8.2$^{a}$ | 444 | 15.4 ± 5.6$^{a}$ |
| 8 yrs. | 308 | 18.0 ± 6.6$^{a}$ | 81 | 21.2 ± 14.0$^{a}$ | 250 | 22.7 ± 7.6$^{a}$ | 404 | 13.9 ± 5.8$^{a}$ |
| 9 yrs. | 295 | 7.5 ± 6.6$^{a}$ | 75 | 26.5 ± 14.4$^{ab}$ | 239 | 25.4 ± 7.8$^{b}$ | 375 | 21.2 ± 6.0$^{b}$ |
| 10 yrs. | 205 | 11.7 ± 7.8$^{a}$ | 75 | 2.5 ± 14.6$^{a}$ | 195 | 19.0 ± 8.6$^{a}$ | 276 | 21.0 ± 6.8$^{a}$ |
| 11 yrs. | 146 | 9.3 ± 9.2$^{a}$ | 46 | 6.7 ± 18.2$^{a}$ | 148 | 25.2 ± 9.8$^{a}$ | 198 | 17.9 ± 8.0$^{a}$ |
| 12 yrs. | 84 | 18.7 ± 12.0$^{a}$ | 33 | -19.3 ± 21.2$^{b}$ | 83 | 22.1 ± 12.8$^{a}$ | 108 | 15.7 ± 10.6$^{a}$ |
| 13 yrs. | 73 | 6.0 ± 13.0$^{a}$ | 25 | 42.0 ± 24.2$^{a}$ | 43 | - 3.3 ± 17.4$^{a}$ | 77 | 22.6 ± 12.4$^{a}$ |
| 14 yrs. or older | 86 | -4.8 ± 12.0$^{ab}$ | 19 | 31.8 ± 27.8$^{a}$ | 26 | -25.9 ± 22.4$^{b}$ | 51 | 21.6 ± 15.2$^{a}$ |

[1]Number of observations in each subclass

[2]Least squares constants ± 95% confidence intervals. Estimates in the same age of dam group with different superscripts differ significantly in that their 95% confidence intervals did not overlap.

TABLE 17b

LEAST SQUARES ESTIMATES WITHIN SEASON FOR AGE OF DAM

| Item | Feb.-Apr. means[1] | May-Jul. means | Aug.-Oct. means | Nov.-Jan. means |
|---|---|---|---|---|
| General mean | 440.3 ± 1.2 | 414.4 ± 3.0 | 383.2 ± 1.7 | 414.1 ± 1.2 |
| Age of dam | | | | |
| 27 mo. | 406.3 ± 2.9 | 355.4 ± 6.3 | 332.5 ± 6.9 | 363.5 ± 3.8 |
| 28-30 mo. | 408.0 ± 3.3 | 365.1 ± 7.3 | 344.6 ± 4.7 | 379.9 ± 5.5 |
| 31-33 mo. | 417.8 ± 7.1 | 385.9 ± 10.1 | 359.5 ± 5.7 | 373.5 ± 3.8 |
| 34-39 mo. | 426.4 ± 2.9 | 393.4 ± 7.1 | 355.7 ± 4.7 | 390.4 ± 3.0 |
| 40-45 mo. | 437.7 ± 3.7 | 414.5 ± 6.4 | 377.3 ± 3.6 | 406.0 ± 3.2 |
| 4 yrs. | 440.7 ± 2.4 | 418.7 ± 5.6 | 387.3 ± 2.9 | 415.3 ± 2.3 |
| 5 yrs. | 447.8 ± 2.6 | 424.2 ± 6.7 | 399.1 ± 3.3 | 419.2 ± 2.5 |
| 6 yrs. | 451.2 ± 2.9 | 437.4 ± 6.8 | 408.3 ± 3.6 | 423.7 ± 2.6 |
| 7 yrs. | 460.4 ± 3.1 | 423.6 ± 7.4 | 399.3 ± 4.2 | 430.5 ± 2.8 |
| 8 yrs. | 458.3 ± 3.4 | 435.6 ± 7.4 | 405.9 ± 3.9 | 429.0 ± 2.9 |
| 9 yrs. | 447.8 ± 3.4 | 440.9 ± 7.7 | 408.6 ± 4.0 | 436.3 ± 3.0 |
| 10 yrs. | 452.0 ± 4.1 | 416.9 ± 7.7 | 402.2 ± 4.4 | 436.1 ± 3.5 |
| 11 yrs. | 449.6 ± 4.8 | 421.1 ± 9.7 | 408.4 ± 5.1 | 433.0 ± 4.1 |
| 12 yrs. | 459.0 ± 6.4 | 395.1 ± 11.4 | 405.4 ± 6.7 | 430.8 ± 5.5 |
| 13 yrs. | 446.3 ± 6.8 | 456.4 ± 13.0 | 379.9 ± 9.3 | 437.7 ± 6.6 |
| 14 yrs. or older | 435.5 ± 6.3 | 446.2 ± 14.9 | 357.3 ± 11.9 | 436.7 ± 8.1 |

[1]Least squares means ± standard errors

TABLE 17c

ANALYSIS OF VARIANCE OF MEANS FOR AGE OF DAM BY SEASON

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Age of dam | 15 | 1,976 |
| Season | 3 | 8,744 |
| Age of dam by season | 45 | 140 |

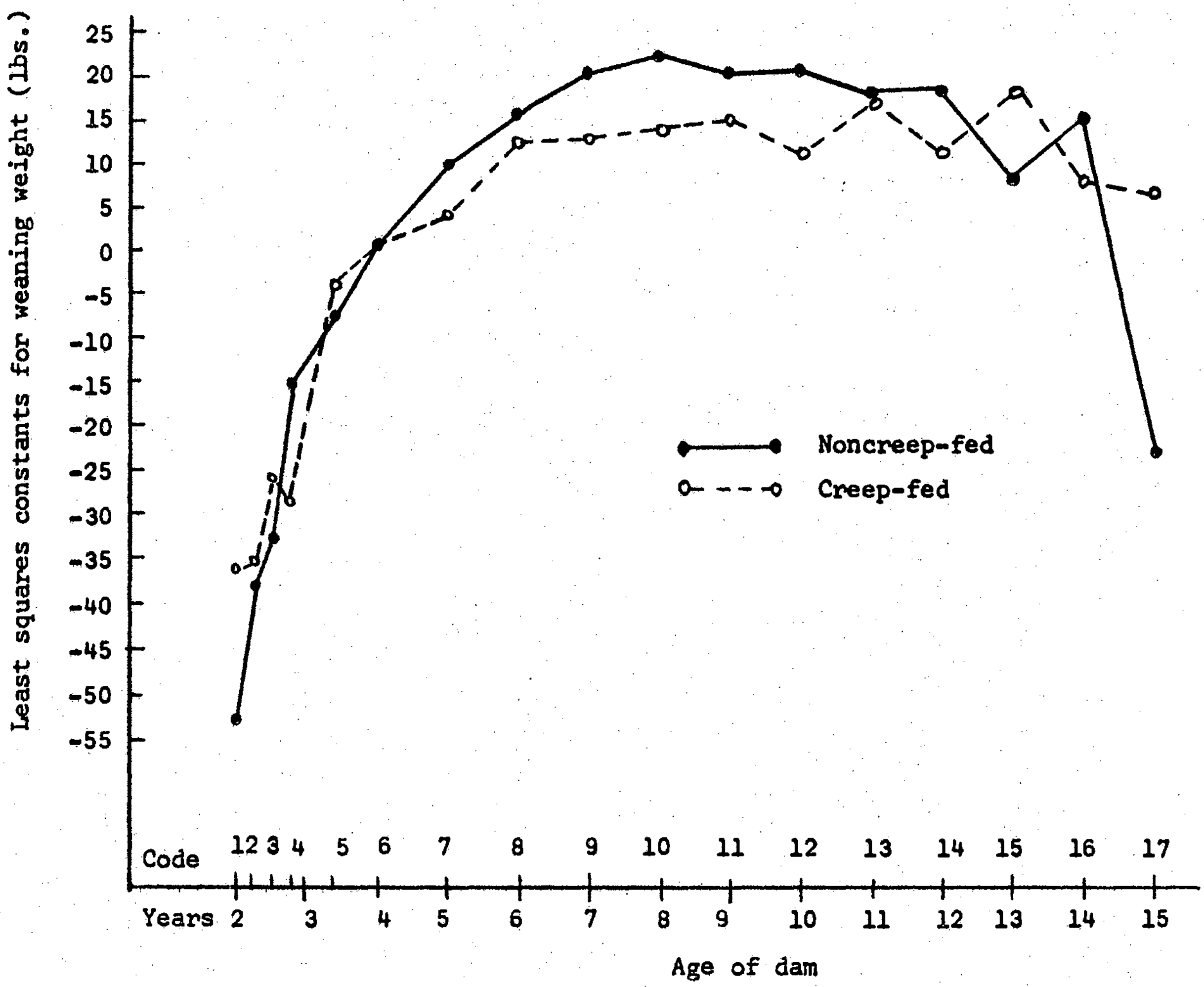


Figure 9. Age of dam by type of management.

## TABLE 18a

## LEAST SQUARES ESTIMATES WITHIN TYPE OF MANAGEMENT FOR AGE OF DAM

| Item | Not Creep-fed n[1] | Not Creep-fed Constants[2] | Not Creep-fed Means[3] | Creep-fed n | Creep-fed Constants | Creep-fed Means |
|---|---|---|---|---|---|---|
| General mean | 7,881 | 390.3 ± 6.2 | 390.3 ± 3.1 | 6,056 | 436.1 ± 3.2 | 436.1 ± 1.6 |
| Age of dam | | | | | | |
| 27 mo. | 471 | -53.2 ± 3.6[a] | 337.1 ± 3.1 | 372 | -35.6 ± 6.2[b] | 400.5 ± 3.2 |
| 28-30 mo. | 317 | -38.4 ± 6.8[a] | 351.9 ± 3.7 | 373 | -35.0 ± 6.2[a] | 401.1 ± 3.3 |
| 31-33 mo. | 266 | -33.2 ± 7.2[a] | 357.1 ± 3.9 | 188 | -25.8 ± 8.2[a] | 410.3 ± 4.4 |
| 34-39 mo. | 643 | -14.7 ± 4.8[a] | 375.6 ± 2.7 | 416 | -28.7 ± 5.8[b] | 407.4 ± 3.1 |
| 40-45 mo. | 488 | - 6.9 ± 5.4[a] | 383.4 ± 3.0 | 517 | - 4.2 ± 5.2[a] | 431.9 ± 2.8 |
| 4 yrs. | 1,084 | 1.2 ± 4.0[a] | 391.5 ± 2.3 | 779 | - 0.1 ± 4.4[a] | 436.0 ± 2.4 |
| 5 yrs. | 983 | 10.3 ± 4.2[a] | 400.6 ± 2.4 | 555 | 4.4 ± 5.2[a] | 440.5 ± 2.4 |
| 6 yrs. | 778 | 14.8 ± 4.6[a] | 405.1 ± 2.6 | 561 | 12.0 ± 5.2[a] | 448.1 ± 2.7 |
| 7 yrs. | 668 | 20.3 ± 4.8[a] | 410.6 ± 2.7 | 454 | 12.6 ± 5.6[a] | 448.7 ± 3.0 |
| 8 yrs. | 575 | 21.9 ± 5.2[a] | 412.2 ± 2.9 | 468 | 13.9 ± 5.4[a] | 450.0 ± 2.9 |
| 9 yrs. | 541 | 20.0 ± 5.2[a] | 410.3 ± 2.9 | 443 | 15.2 ± 5.6[a] | 451.3 ± 3.0 |
| 10 yrs. | 416 | 20.9 ± 5.8[a] | 411.2 ± 3.2 | 335 | 10.7 ± 6.4[a] | 446.8 ± 3.4 |
| 11 yrs. | 303 | 18.2 ± 6.8[a] | 408.5 ± 3.7 | 235 | 17.1 ± 7.4[a] | 453.2 ± 4.0 |
| 12 yrs. | 159 | 18.2 ± 9.2[a] | 408.5 ± 4.9 | 149 | 11.1 ± 9.2[a] | 447.2 ± 5.0 |
| 13 yrs. | 99 | 8.6 ± 11.4[a] | 398.9 ± 6.2 | 119 | 17.9 ± 10.2[a] | 454.0 ± 5.5 |
| 14 yrs. | 45 | 15.1 ± 11.8[a] | 405.4 ± 9.0 | 61 | 7.7 ± 14.2[a] | 443.8 ± 7.6 |
| 15 yrs. | 45 | -23.1 ± 16.8[a] | 367.2 ± 9.0 | 31 | 6.8 ± 19.8[a] | 442.9 ± 10.5 |

[1]Number of observations in each subclass

[2]Least squares constants ± 95% confidence intervals. Estimates in the same age of dam group with different superscripts differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

TABLE 18b

ANALYSIS OF VARIANCE OF MEANS FOR AGE OF DAM BY TYPE OF MANAGEMENT

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Age of dam | 16 | 873 |
| Management | 1 | 17,830 |
| Age of dam by management | 16 | 61 |

production of their dams by consuming more creep-feed. The same trend was present in the data of Marlowe and Gaines (1958), Marlowe (1962), and Furr et al. (1960, 1961).

In general, interactions between age of dam, and sex, breed, pasture, and type of management were small and of little practical significance. All of the age of dam curves (Figures 5, 6, 7, 8, 9) essentially describe the same age of dam effect as observed in the overall analysis (Figure 3). Therefore, correction factors for age of dam will be derived from the constants obtained in the overall analysis.

Interactions with sex

Sex by breed. The least squares constants and means obtained in the two breeds for sex are given in Table 19a. They indicate that the difference between steers and heifers was dependent on breed. In the Angus, steers were heavier than heifers at weaning; while in the Herefords, heifers had a slight advantage in weaning weight. These results tend to suggest that selection of bull calves was more intense in the Angus leaving a higher proportion of faster growing Angus steers. However, if this were the case, the Angus bulls should have deviated further from their mean than the Hereford. Since they did not, there must be some other environmental effect not accounted for in the model of the two breeds that was confounded with the effects of breed by sex. One possibility is the effect of areas which was not included in the model for the two breeds because of linear dependency. To examine this possibility, the observations in each sex by breed subclass were subdivided further according to areas ($n_{ijk}$) as shown in Table 19b. The

TABLE 19a

LEAST SQUARES ESTIMATES WITHIN BREED FOR SEX OF CALF

| Item | Hereford | | | Angus | | |
|---|---|---|---|---|---|---|
| | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 7,522 | 410.9 ± 3.4 | 410.9 ± 1.7 | 6,415 | 420.9 ± 2.8 | 420.9 ± 1.4 |
| Sex | | | | | | |
| Bulls | 2,584 | 42.9 ± 2.2[a] | 453.9 ± 1.8 | 2,081 | 29.9 ± 2.2 | 450.8 ± 1.7 |
| Heifers | 3,853 | -19.3 ± 2.0[a] | 391.6 ± 1.8 | 3.051 | -23.2 ± 1.8[b] | 397.7 ± 1.6 |
| Steers | 1,085 | -23.6 ± 2.8[a] | 387.3 ± 2.9 | 1,283 | - 6.7 ± 2.4[b] | 414.2 ± 2.0 |

[1]Number of observations per subclass

[2]Least squares constants ± 95% confidence intervals. Estimates with different superscripts in the same sex differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

TABLE 19b

EFFECT OF AREAS ON SEX BY BREED

| | Hereford | | | Angus | | | Area |
|---|---|---|---|---|---|---|---|
| | Bulls | Heifers | Steers | Bulls | Heifers | Steers | effects |
| Area 1 | 1,254[1] | 2,051 | 610 | 796 | 1,407 | 628 | -.13 |
| Area 2 | 6 | 120 | 140 | 849 | 1,017 | 440 | -32.6 |
| Area 3 | 821 | 1,012 | 171 | 343 | 458 | 115 | 18.8 |
| Area 4 | 134 | 231 | 71 | 33 | 103 | 78 | -35.4 |
| Area 5 | 336 | 404 | 87 | 45 | 47 | 15 | 19.7 |
| Area 6 | 33 | 35 | 6 | 15 | 19 | 7 | 30.8 |
| Total effect[2] | 17,968.2 | 15,706.4 | -2,043.2 | -21,152.2 | -26,861.8 | -14,513.7 | |
| No. observations[3] | 2,584 | 3,853 | 1,085 | 2,081 | 3,051 | 1,283 | |
| Average effect[4] | 7.0 | 4.1 | -1.8 | -10.2 | -8.8 | -11.3 | |

[1]The number of observations ($n_{ijk}$) in the $i^{th}$ breed, of the $j^{th}$ sex, and the $k^{th}$ area.
[2]The effect = $_{k}\, n_{ijk} R_k$ where each $n_{ijk}$ is defined as above and $R_k$ is a particular area effect.
[3]Total number of observations inthe $i^{th}$ breed and $j^{th}$ sex = $_{k}\, n_{ijk}$
[4] $_{k}\, n_{ijk} R_k \,/\, _{k}\, n_{ijk}$

TABLE 19c

SEX BY BREED ESTIMATES ADJUSTED FOR AREAS

| Sex | Hereford | Angus |
|---|---|---|
| Bulls | 35.9 | 40.1 |
| Heifers | -23.4 | -14.4 |
| Steers | -21.8 | 4.6 |

estimates of areas from the overall analysis were then used to assess the influence of areas on the sex by breed estimates as outlined in Table 19b.

The estimates of the average effect of area on each of the sex by breed estimates are given in Table 19b. These estimates were used to adjust the breed by sex constants for the effect of areas. The resulting estimates of breed by sex, given in Table 19c, indicate that disproportionality of numbers among the 6 areas accounted for most of the interaction observed between breed and sex.

Sex by pasture. The least squares constants and means shown in Table 20a and the analysis of variance of the means presented in Table 20b indicate that the effect of sex was essentially the same in native pasture as in improved pasture.

Sex by season. Least squares constants for bull, heifer, and steer calves dropped in the seasons of (1) February-April, (2) May- July, (3) August-October, and (4) November-January are given in Table 21a. The effect of sex was not significantly different in seasons 1, 2, and 4. In season 3 the estimate for bulls was significantly greater than in the other seasons while that for steers was correspondingly lower. Perhaps this was because the calves dropped in this season were predominantly purebred calves and selection for growth rate in bulls was more intense than in the other seasons. The means are given in Table 21b. Their analysis of variance shown in Table 21c evidences that the interaction between sex and season was small, however, and of little practical significance.

Sex by management. The 95 percent confidence intervals on the least squares constants given in Table 22a overlapped for the estimates

TABLE 20a

LEAST SQUARES ESTIMATES WITHIN PASTURE FOR SEX OF CALF

| Item | Native pasture | | | Improved pasture | | |
|---|---|---|---|---|---|---|
| | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 6,002 | 424.5 ± 3.6 | 424.5 ± 1.8 | 5,102 | 414.5 ± 3.0 | 414.5 ± 1.5 |
| Sex | | | | | | |
| Bulls | 1,807 | 36.7 ± 2.4[a] | 461.2 ± 2.1 | 1,952 | 35.4 ± 2.4[a] | 449.9 ± 1.7 |
| Heifers | 3,080 | -22.0 ± 2.0[a] | 402.5 ± 1.9 | 2,378 | -22.7 ± 2.2[a] | 391.8 ± 1.6 |
| Steers | 1,115 | -14.7 ± 2.6[a] | 409.8 ± 2.4 | 772 | -12.7 ± 3.0[a] | 401.8 ± 2.4 |

[1]Number of observations per subclass

[2]Least squares constants ± 95% confidence intervals. Estimates with different superscripts in the same sex (row) differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

TABLE 20b

ANALYSIS OF VARIANCE OF MEANS FOR SEX BY PASTURE

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Sex | 2 | 1,987 |
| Pasture | 1 | 150 |
| Sex by pasture | 2 | 2 |

TABLE 21a

LEAST SQUARES ESTIMATES WITHIN SEASON FOR SEX OF CALF

| | Feb.-Apr. | | May-Jul. | | Aug.-Oct. | | Nov.-Jan. | |
|---|---|---|---|---|---|---|---|---|
| Item | n[1] | Constants[2] | n | Constants | n | Constants | n | Constants |
| General mean | 4,600 | 440.3 ± 2.4 | 1,213 | 414.4 ± 6.0 | 3,157 | 383.2 ± 3.4 | 4,967 | 415.1 ± 2.4 |
| Sex | | | | | | | | |
| Bulls | 1,505 | 33.1 ± 2.6[a] | 535 | 33.0 ± 6.4[a] | 1,170 | 46.0 ± 3.4[b] | 1,455 | 33.8 ± 2.6[a] |
| Heifers | 2,278 | -23.0 ± 2.4[a] | 587 | -19.7 ± 6.0[a] | 1,573 | -20.4 ± 3.0[a] | 2,466 | -20.3 ± 2.2[a] |
| Steers | 817 | -10.1 ± 3.0[a] | 91 | -13.3 ± 9.6[ab] | 414 | -25.6 ± 4.4[a] | 1,046 | -13.5 ± 2.8[a] |

[1]Number of observations per subclass

[2]Least squares constants ± 95% confidence intervals. Estimates with different superscripts in the same sex differ significantly in that their 95% confidence intervals do not overlap.

TABLE 21b

LEAST SQUARES ESTIMATES WITHIN SEASON FOR SEX OF CALF

| Item | Feb.-Apr. mean[1] | May-Jul. mean | Aug.-Oct. mean | Nov.-Jan. mean |
|---|---|---|---|---|
| General mean | 440.3 ± 1.2 | 414.4 ± 3.0 | 383.2 ± 1.7 | 415.1 ± 1.2 |
| Sex | | | | |
| Bulls | 473.4 ± 1.7 | 447.4 ± 3.4 | 429.2 ± 2.1 | 448.9 ± 1.7 |
| Heifers | 417.3 ± 1.5 | 394.7 ± 3.1 | 362.8 ± 1.9 | 394.8 ± 1.4 |
| Steers | 430.2 ± 2.3 | 401.1 ± 6.9 | 357.6 ± 3.3 | 401.6 ± 2.0 |

[1]Least squares means ± standard errors.

TABLE 21c

ANALYSIS OF VARIANCE OF MEANS FOR SEX BY SEASON

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Sex | 2 | 4,019 |
| Season | 3 | 1,639 |
| Sex by season | 6 | 45 |

TABLE 22a

LEAST SQUARES ESTIMATES WITHIN TYPE OF MANAGEMENT FOR SEX OF CALF

| | Not Creep-fed | | | Creep-fed | | |
|---|---|---|---|---|---|---|
| Item | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 7,881 | 390.3 ± 6.2 | 390.3 ± 3.1 | 6,056 | 436.1 ± 3.2 | 436.1 ± 1.6 |
| Sex | | | | | | |
| Bulls | 2,196 | 32.5 ± 2.0[a] | 422.8 ± 2.0 | 2,469 | 38.5 ± 4.0[b] | 474.6 ± 1.7 |
| Heifers | 4,007 | -19.6 ± 1.8[a] | 370.7 ± 1.9 | 2,897 | -23.6 ± 3.8[a] | 412.5 ± 1.6 |
| Steers | 1,678 | -12.9 ± 2.2[a] | 377.4 ± 2.2 | 690 | -14.9 ± 4.4[a] | 421.2 ± 2.7 |

[1]Number of observations per subclass

[2]Least squares constants ± 95% confidence intervals. Estimates in the same sex with different superscripts differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

TABLE 22b

ANALYSIS OF VARIANCE OF MEANS FOR SEX BY TYPE OF MANAGEMENT

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Sex | 2 | 1,920 |
| Management | 1 | 3,146 |
| Sex by management | 2 | 14 |

of heifers and steers, but not for bulls. Bull calves that were creep-fed deviated significantly more from their mean than those that were not creep-fed. These estimates are in agreement with those of Marlowe (1962). They suggest that bull calves possess greater growth potential than steers or heifers and that this potential is revealed even more completely when calves are creep-fed than when they are not creep-fed. These results indicate further that, in herds where some calves are kept as bulls, different correction factors should be used depending on whether calves are creep-fed or not creep-fed. The analysis of variance shown in Table 22b indicate, however, that the effect of interaction was small relative to the main effects of sex and type of management.

Interactions with month of birth

Month by breed. The least squares constants and means for month of birth in Herefords and Angus are presented in Table 23a and Figure 10. Hereford calves dropped in October, December, and January were significantly heavier at weaning relative to their breed average than Angus calves. Angus calves, however, had a significant advantage during May, June, and September. Marlowe (1962) also observed differential effects for month of birth in Herefords and Angus (see Figure 1). The differential effect observed in this work in Virginia is, however, not fully in agreement with that observed in the present study. The month by breed mean square in the analysis of variance of the means given in Table 23b was small relative to the main effects indicating that the interaction was unimportant. Therefore, breeds will not be considered separately in deriving correction factors for the effect of seasonality.

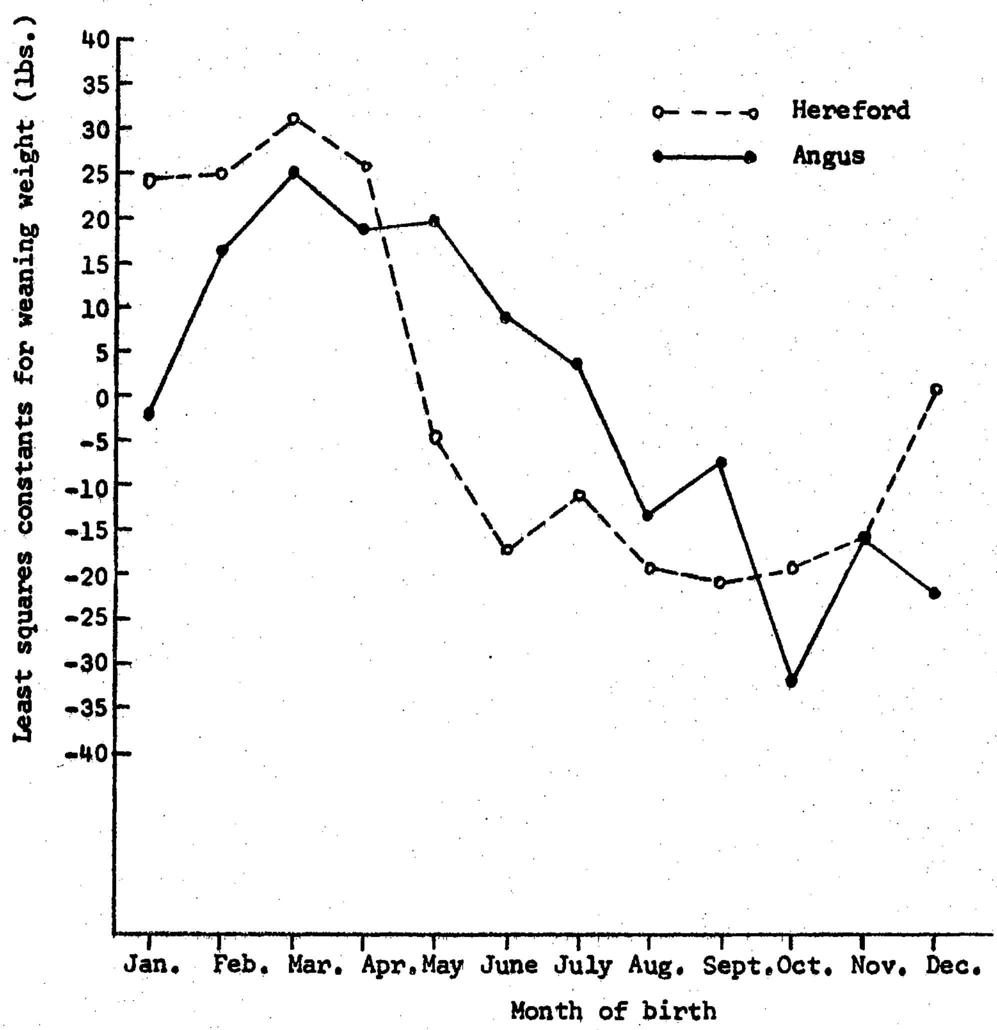


Figure 10. Month of birth by breed.

TABLE 23a

LEAST SQUARES ESTIMATES WITHIN BREED FOR MONTH OF BIRTH

| Item | Hereford | | | Angus | | |
|---|---|---|---|---|---|---|
| | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 7,552 | 410.9 ± 3.4 | 410.9 ± 1.7 | 6,415 | 420.9 ± 2.8 | 420.9 ± 1.4 |
| Month of birth | | | | | | |
| Jan. | 670 | 24.1 ± 5.0[a] | 435.0 ± 2.6 | 729 | - 2.0 ± 4.4[b] | 418.9 ± 2.3 |
| Feb. | 822 | 24.8 ± 4.8[a] | 435.7 ± 2.4 | 497 | 16.4 ± 5.2[a] | 437.3 ± 2.7 |
| Mar. | 1,114 | 31.6 ± 4.4[a] | 442.5 ± 2.2 | 821 | 25.4 ± 4.2[a] | 446.3 ± 2.2 |
| Apr. | 763 | 26.4 ± 4.8[a] | 437.3 ± 2.5 | 583 | 18.9 ± 9.8[a] | 439.8 ± 2.5 |
| May | 371 | - 4.7 ± 6.4[a] | 406.2 ± 3.4 | 420 | 19.8 ± 5.4[b] | 440.7 ± 3.0 |
| June | 160 | -17.0 ± 9.2[a] | 393.9 ± 5.0 | 132 | 8.8 ± 9.2[b] | 429.7 ± 4.9 |
| July | 44 | -11.1 ± 17.0[a] | 399.8 ± 9.3 | 86 | 3.9 ± 11.2[a] | 424.8 ± 6.1 |
| Aug. | 44 | -19.4 ± 17.0[a] | 391.5 ± 9.3 | 44 | -11.0 ± 15.6[a] | 409.9 ± 8.4 |
| Sept. | 920 | -21.4 ± 4.6[a] | 389.5 ± 2.4 | 334 | - 8.9 ± 6.0[b] | 412.0 ± 3.2 |
| Oct. | 1,164 | -19.4 ± 4.2[a] | 391.5 ± 2.1 | 651 | -32.5 ± 4.6[b] | 388.4 ± 2.3 |
| Nov. | 896 | -15.4 ± 4.6[a] | 395.5 ± 2.3 | 1,093 | -16.6 ± 4.0[a] | 404.3 ± 1.9 |
| Dec. | 554 | 1.5 ± 5.4[a] | 412.4 ± 2.8 | 1,025 | -22.2 ± 4.0[b] | 398.7 ± 2.0 |

[1]Number of observations per subclass

[2]Least squares constants ± 95% confidence intervals. Estimates in the same month with different superscripts differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

TABLE 23b

ANALYSIS OF VARIANCE OF MEANS FOR MONTH OF BIRTH BY BREED

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Month of birth | 11 | 628 |
| Breed | 1 | 600 |
| Month of birth by breed | 11 | 150 |

Month by pasture. Least squares constants for month of birth in native and improved pasture are given in Table 24a and Figure 11. These estimates indicate that the effect of month of birth was dependent on the type of pasture utilized. Calves raised on native grass had a significant advantage in weaning weights relative to their average when they were dropped in January, March, October, November, and December. On the other hand, calves raised on improved pastures had an advantage when dropped in the summer months, although, the constant for July was the only one that differed significantly.

The analysis of variance of the means is given in Table 24b. The mean square for month of birth by pasture was more than one-third the size of the mean squares for the two main effects also indicating that this interaction may be important. Therefore, it appears that separate correction factors for each type of pasture should be developed for month of birth.

Month by type of management. The least squares constants and means given in Table 25a and Figure 12 indicate that creep-feeding definitely reduced the influence of month of birth on weaning weight. The creep-fed calves deviated significantly less from their mean than those that were not creep-fed when dropped in January, February, March, April, June, and August. The data in Figure 13 shows that the advantage of creep-feeding was greater for calves dropped in the fall months than for those dropped in the spring, and calves dropped in the summer months benefited even more from creep-feeding. These results suggest that calves born during the more adverse summer and fall seasons tend to compensate for the low milk production of their dams and the

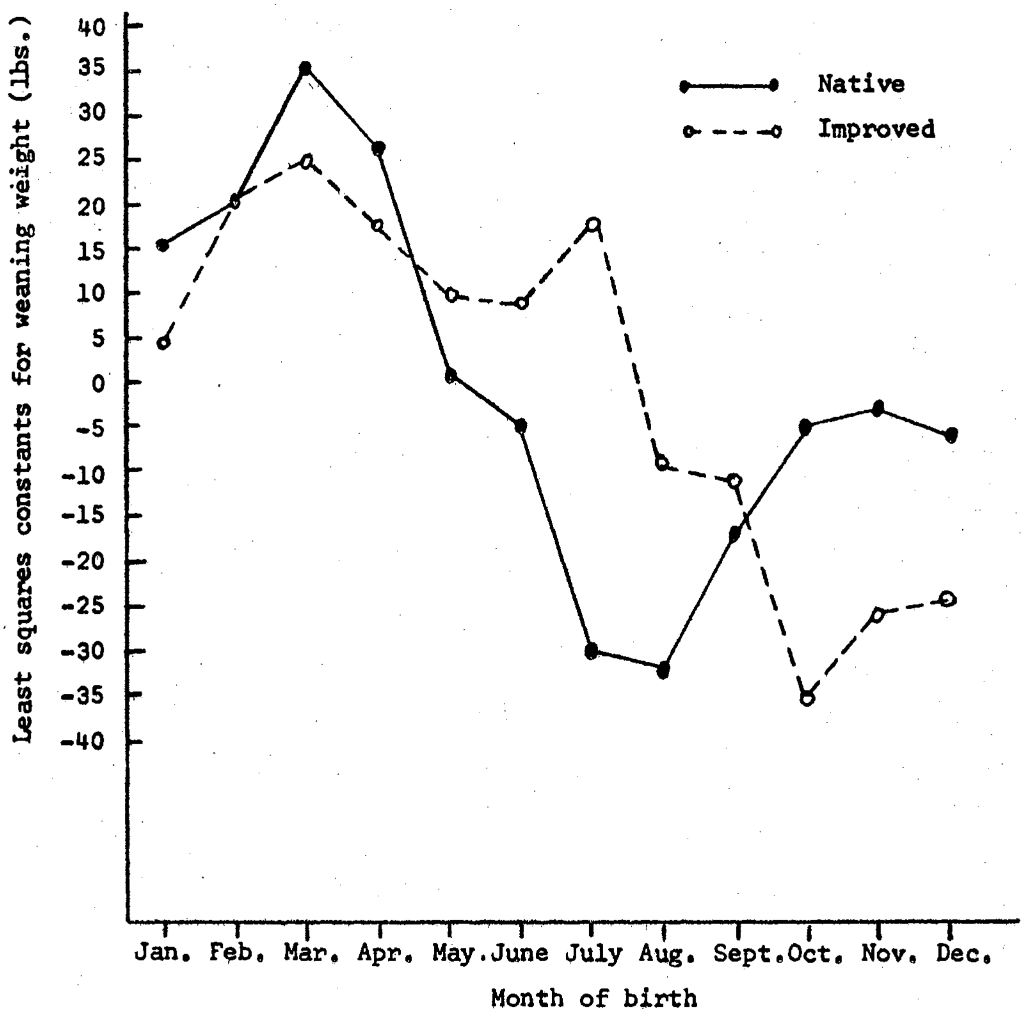


Figure 11. Month of birth by type of pasture.

TABLE 24a

LEAST SQUARES ESTIMATES WITHIN TYPE OF PASTURE FOR MONTH OF BIRTH

| Item | Native pasture | | | Improved pasture | | |
|---|---|---|---|---|---|---|
| | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 6,002 | 424.5 ± 3.6 | 424.5 ± 1.8 | 5,102 | 414.5 ± 3.0 | 414.5 ± 1.5 |
| Month of birth | | | | | | |
| Jan. | 763 | 15.9 ± 5.0[a] | 440.4 ± 2.2 | 373 | 4.5 ± 5.8[b] | 419.0 ± 3.1 |
| Feb. | 594 | 20.5 ± 5.4[a] | 445.0 ± 2.5 | 444 | 20.3 ± 5.6[a] | 434.8 ± 2.8 |
| Mar. | 564 | 35.7 ± 5.4[a] | 460.2 ± 2.6 | 834 | 24.9 ± 4.4[b] | 439.4 ± 2.1 |
| Apr. | 418 | 26.6 ± 6.0[a] | 451.1 ± 3.0 | 559 | 18.3 ± 5.0[a] | 432.8 ± 2.5 |
| May | 229 | - 0.7 ± 7.6[a] | 423.8 ± 3.9 | 422 | 10.3 ± 5.6[a] | 424.8 ± 3.0 |
| June | 132 | - 4.3 ± 9.6[a] | 420.2 ± 5.1 | 125 | 9.2 ± 9.6[a] | 423.7 ± 5.2 |
| July | 31 | -30.2 ± 19.0[a] | 394.3 ± 10.3 | 76 | 17.5 ± 12.2[b] | 432.0 ± 6.6 |
| Aug. | 18 | -32.4 ± 25.0[a] | 392.1 ± 13.6 | 47 | - 9.1 ± 15.4[a] | 405.4 ± 8.4 |
| Sept. | 611 | -17.3 ± 5.4[ab] | 407.2 ± 2.5 | 352 | -11.0 ± 6.0[a] | 403.5 ± 3.2 |
| Oct. | 901 | - 4.7 ± 4.8[a] | 419.8 ± 2.2 | 509 | -34.9 ± 5.2[b] | 379.6 ± 2.6 |
| Nov. | 872 | - 2.9 ± 5.0[a] | 421.6 ± 2.1 | 848 | -26.3 ± 4.4[b] | 388.2 ± 2.1 |
| Dec. | 869 | - 6.2 ± 5.0[a] | 418.3 ± 2.1 | 513 | -23.7 ± 5.2[b] | 390.8 ± 2.6 |

[1]Number of observations per subclass

[2]Least squares constants ± 95% confidence intervals. Estimates in the same month with different superscripts differ signifcantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

TABLE 24b

ANALYSIS OF VARIANCE OF MEANS FOR MONTH OF BIRTH BY PASTURE

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Month of birth | 11 | 624 |
| Type of pasture | 1 | 600 |
| Month by pasture | 11 | 238 |

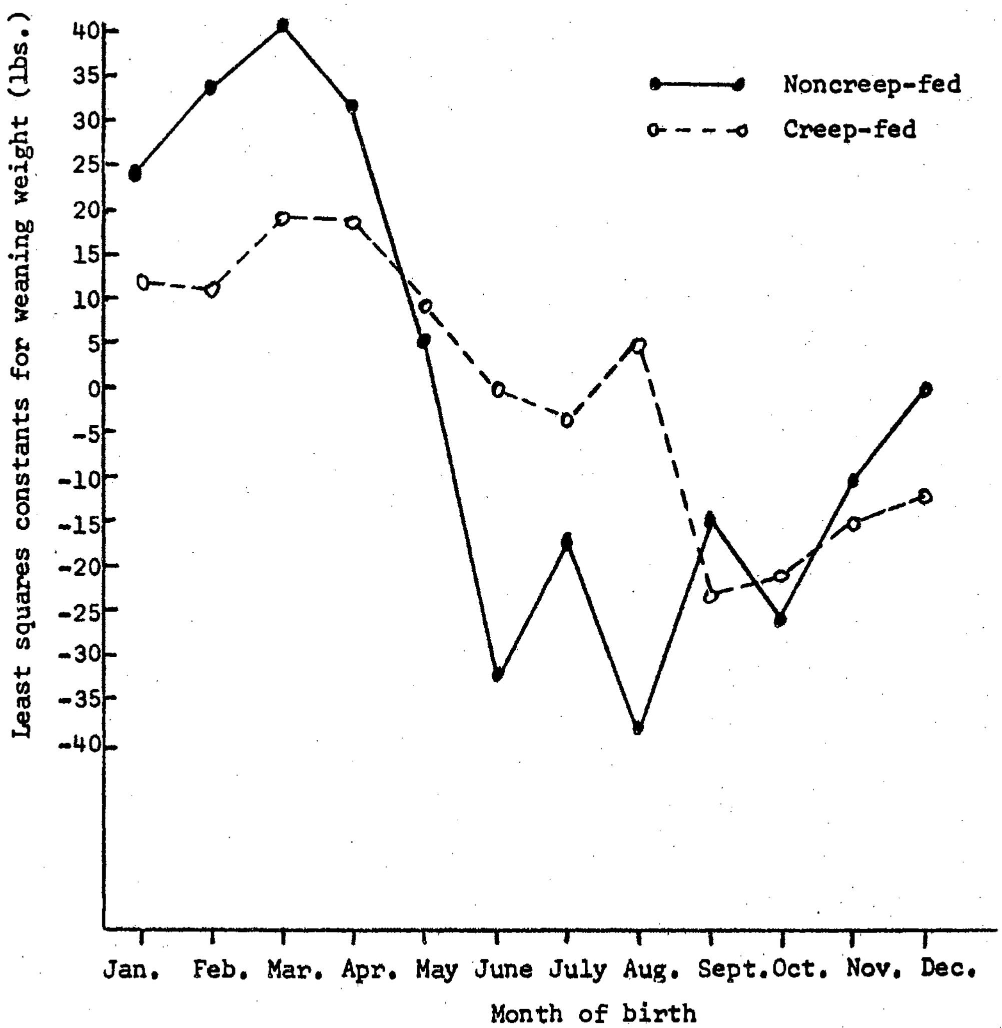


Figure 12. Month of birth by type of management.

TABLE 25a

LEAST SQUARES ESTIMATES WITHIN TYPE OF MANAGEMENT FOR MONTH OF BIRTH

| | Noncreep-fed | | | Creep-fed | | |
|---|---|---|---|---|---|---|
| Item | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 7,881 | 390.3 ± 6.2 | 390.3 ± 3.1 | 6,056 | 436.1 ± 3.2 | 436.1 ± 1.6 |
| Month of birth | | | | | | |
| Jan. | 731 | 24.3 ± 5.0[a] | 414.6 ± 2.4 | 668 | 11.7 ± 4.8[b] | 447.8 ± 2.5 |
| Feb. | 942 | 34.3 ± 4.8[a] | 424.6 ± 2.1 | 377 | 11.3 ± 6.0[b] | 447.4 ± 3.2 |
| Mar. | 1,315 | 41.3 ± 4.4[a] | 431.6 ± 1.8 | 620 | 19.4 ± 4.8[b] | 455.5 ± 2.6 |
| Apr. | 809 | 32.1 ± 5.0[a] | 422.4 ± 2.3 | 537 | 18.6 ± 5.2[b] | 454.7 ± 2.8 |
| May | 275 | 5.6 ± 7.2[a] | 395.9 ± 3.7 | 516 | 9.6 ± 5.2[a] | 445.7 ± 2.9 |
| June | 57 | -32.9 ± 14.8[a] | 357.4 ± 7.9 | 235 | - 0.5 ± 7.4[b] | 435.6 ± 4.0 |
| July | 25 | -16.7 ± 22.0[a] | 373.6 ± 11.9 | 105 | - 3.8 ± 10.6[a] | 432.3 ± 5.8 |
| Aug. | 43 | -38.4 ± 16.8[a] | 351.9 ± 9.1 | 45 | 5.1 ± 16.8[b] | 441.2 ± 8.8 |
| Sept. | 400 | -13.7 ± 6.4[a] | 376.8 ± 3.2 | 854 | -23.5 ± 4.4[a] | 412.6 ± 2.3 |
| Oct. | 1,113 | -26.6 ± 4.6[a] | 363.7 ± 2.0 | 702 | -21.3 ± 4.6[a] | 414.8 ± 2.5 |
| Nov. | 1,284 | -10.0 ± 4.4[a] | 380.3 ± 1.9 | 705 | -14.8 ± 4.6[a] | 421.3 ± 2.5 |
| Dec. | 887 | 0.7 ± 4.8[a] | 391.0 ± 2.2 | 692 | -11.8 ± 5.0[b] | 424.3 ± 2.5 |

[1]Number of observations per subclass

[2]Least squares constants ± 95% confidence intervals. Estimates in the same month with different superscripts differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

TABLE 25b

ANALYSIS OF VARIANCE OF MEANS FOR MONTH OF BIRTH BY MANAGEMENT

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Month of birth | 11 | 769 |
| Management | 1 | 12,586 |
| Month by management | 11 | 217 |

reduced level of forage available to them by consuming more creep-feed. In this manner it appears that creep-feeding tends to standardize the preweaning environment and reduce the effect of season of birth relative to calves that are not creep-fed. These results are in close agreement with those reported by Marlowe and Gaines (1958), Brown (1960), and Marlowe (1962).

The mean square for month of birth by management in the analysis of variance of the means (Table 25b) was about 28 percent as large as that for month of birth. Thus, it appears that separate correction factors should be developed for month of birth depending on whether the calves are creep-fed or not creep-fed.

Other interactions

Type of management by breed. The least squares constants and means given in Table 26a and the analysis of variance in Table 26b indicate that there was very little interaction between type of management and breed.

Type of management by pasture. There was essentially no interaction between type of management and pasture detected in the least squares constants and means presented in Table 27a and the analysis of variance in Table 26b.

Breed by pasture. A significant interaction between breed and type of pasture was indicated by the least squares constants and means given in Table 28. This was primarily because the effects of area and breed by pasture were badly confounded. When corrections for areas were applied to the breed by pasture constants, as described for sex by breed, this interaction became small and unimportant.

TABLE 26a

LEAST SQUARES ESTIMATES WITHIN BREED FOR TYPE OF MANAGEMENT

| Item | Hereford | | | Angus | | |
|---|---|---|---|---|---|---|
| | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 7,522 | 410.9 ± 3.4 | 410.9 ± 1.7 | 6,415 | 420.9 ± 2.8 | 420.9 ± 1.4 |
| Type of management | | | | | | |
| Noncreep-fed | 4,670 | -17.1 ± 0.8[a] | 393.8 ± 1.8 | 3,211 | -15.2 ± 0.8[a] | 405.7 ± 1.6 |
| Creep-fed | 2,852 | 17.1 ± 0.8[a] | 428.0 ± 1.9 | 3,204 | 15.2 ± 0.8[a] | 436.1 ± 1.6 |

[1]Number of calves per subclass

[2]Least squares constants ± 95% confidence intervals. Estimates for the same type of production with different superscripts differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

TABLE 26b

ANALYSIS OF VARIANCE OF MEANS FOR TYPE OF MANAGEMENT BY BREED

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Type of management | 1 | 1,043 |
| Breed | 1 | 100 |
| Management by breed | 1 | 4 |

## TABLE 27a

## LEAST SQUARES ESTIMATES WITHIN PASTURE FOR TYPE OF MANAGEMENT

| | Native pasture | | | Improved pasture | | |
|---|---|---|---|---|---|---|
| Item | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 6,002 | 424.5 ± 3.6 | 424.5 ± 1.8 | 5,102 | 414.5 ± 3.0 | 414.5 ± 1.5 |
| Type of management | | | | | | |
| Noncreep-fed | 3,843 | -14.8 ± 1.6[a] | 409.7 ± 1.9 | 2,041 | -16.6 ± 1.8[a] | 397.9 ± 1.8 |
| Creep-fed | 2,159 | 14.8 ± 1.6[a] | 439.3 ± 2.0 | 3,061 | 16.6 ± 1.8[a] | 431.1 ± 1.6 |

[1]Number of observations per subclass

[2]Least squares constants ± 95% confidence intervals. Estimate in the same type of production with different superscripts differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares mean ± standard errors

TABLE 27b

ANALYSIS OF VARIANCE OF MEAN FOR TYPE OF MANAGEMENT BY PASTURE

| Source | Degrees of freedom | Mean square |
|---|---|---|
| Type of management | 1 | 986 |
| Pasture | 1 | 100 |
| Management by pasture | 1 | 3 |

TABLE 28

LEAST SQUARES ESTIMATES WITHIN PASTURE FOR BREED

| Item | Native pasture | | | Improved pasture | | |
|---|---|---|---|---|---|---|
| | n[1] | Constants[2] | Means[3] | n | Constants | Means |
| General mean | 6,002 | 424.5 ± 3.6 | 424.5 ± 1.8 | 5,102 | 414.5 ± 3.0 | 414.5 ± 1.5 |
| Breed | | | | | | |
| Hereford | 4,054 | - 6.2 ± 1.8[a] | 418.3 ± 1.7 | 1,463 | 3.5 ± 1.8[b] | 418.0 ± 1.9 |
| Angus | 1,948 | 6.2 ± 1.8[a] | 430.7 ± 2.2 | 3,639 | - 3.5 ± 1.8[b] | 411.0 ± 1.5 |

[1]Number of observations per subclass

[2]Least squares constants ± 95% confidence intervals. Estimates in the same breed with different superscripts differ significantly in that their 95% confidence intervals do not overlap.

[3]Least squares means ± standard errors

Summary on interactions

These results have shown that the effect of age of dam is essentially the same regardless of sex, breed, type of pasture, season, or type of management. Further, sex by breed, sex by pasture, sex by season, month of birth by breed, type of management by breed, and type of management by pasture interactions were small and unimportant. Three interactions appeared important enough to be taken into account in adjusting weaning weights. These were sex by type of management, month of birth by type of pasture, and month of birth by type of management.

## Method of Adjustment

Both additive and multiplicative adjustments are currently being used for classifiable environmental factors such as age of dam and sex. With additive adjustments, the mean difference between the subclass chosen as standard and the subclass represented by a particular calf is added to the calf's weaning weight. With multiplicative adjustments, the calf's weaning weight is multiplied by the ratio of the respective subclass means. Both methods make the same adjustment for mean values, but are different for animals at extreme weights. Multiplicative factors increase or decrease the weight of a calf relative to the existing weight while additive factors do not. Thus, they differ in their effect on variances within subclasses. Adding or subtracting a constant value does not alter variances within adjusted groups while multiplicative adjustments raise or lower the variance in proportion to the square of the ratio used depending on whether it is larger or smaller than one.

In order for correction factors to be most satisfactory they should equalize means between subclasses and variances within subclasses. Therefore, additive adjustments are most appropriate when standard deviations are equal and multiplicative adjustments are appropriate when scaler effect causes the coefficients of variation to be equal. Additive versus multiplicative adjustments are considered in this section for age of dam, sex, season of birth, and type of management.

Age of dam

The means ( least squares), variances, standard deviations, and coefficients of variation obtained for each age of dam are given in Table 29a. Bartletts' test for homogeneity of variances indicated that the variances differed significantly among the age of dam subclasses ($P < .05$). The standard deviations indicate that calves out of 2-year-old cows were more variable in weaning weight than those in the subsequent age of dam groups. The standard deviations fluctuated from 53 to 59 pounds for cows aging from 2-1/2 to 12 years showing only a slight tendency toward reduction in the older age groups. The standard deviations dropped off in 13- and 14-year-olds where degrees of freedom were limited, but increased in 15-year-olds. The coefficients of variation showed a trend toward reduction as age of dam increased. This is primarily due to the small means in the younger age groups and the small variances in the older age groups.

It is difficult to judge from the data given in Table 29a, which is most appropriate in adjusting for age of dam, an additive or a multiplicative correction factor. Therefore, estimates of the effect of additive and multiplicative corrections on the means and variances in these data were obtained.

The additive and multiplicative corrections derived from these data are shown in Table 29b along with the means that would result from their use. No corrections were made for cows ranging in age from 6 through 13 years since their average weaning weights had a range of only six pounds. The means were equalized fairly well by both methods.

TABLE 29a

MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION FOR AGE OF DAM

| Age of dam | d.f. | $\bar{X}$ | S.D. | C.V. |
|---|---|---|---|---|
| 27 mo. | 779 | 368.6 | 62.2 | 16.9 |
| 28 - 30 mo. | 635 | 381.4 | 55.5 | 14.6 |
| 31 - 33 mo. | 399 | 389.3 | 56.8 | 14.6 |
| 34 - 39 mo. | 995 | 397.8 | 59.4 | 14.9 |
| 40 - 45 mo. | 940 | 413.2 | 55.4 | 13.4 |
| 4 yrs. | 1,796 | 418.3 | 56.4 | 13.5 |
| 5 yrs. | 1,471 | 424.6 | 54.0 | 12.7 |
| 6 yrs. | 1,277 | 430.9 | 54.6 | 12.7 |
| 7 yrs. | 1,055 | 433.5 | 58.8 | 13.6 |
| 8 yrs. | 981 | 436.0 | 58.8 | 13.5 |
| 9 yrs. | 923 | 435.8 | 58.5 | 13.4 |
| 10 yrs. | 687 | 433.3 | 53.9 | 12.4 |
| 11 yrs. | 478 | 433.8 | 53.4 | 12.3 |
| 12 yrs. | 257 | 430.2 | 54.5 | 12.7 |
| 13 yrs. | 168 | 432.4 | 50.4 | 11.7 |
| 14 yrs. | 69 | 427.4 | 49.4 | 11.6 |
| 15 yrs. | 49 | 412.7 | 57.6 | 14.0 |

TABLE 29b

CORRECTION FACTORS FOR AGE OF DAM

| Age of dam | Additive | | Multiplicative | |
|---|---|---|---|---|
| | Factor | X̄ | Factor | adj. X̄ |
| 27 mo. | +64 | 433 | 1.17 | 431 |
| 28 - 30 mo. | +52 | 433 | 1.13 | 431 |
| 31 - 33 mo. | +44 | 433 | 1.11 | 432 |
| 34 - 39 mo. | +35 | 433 | 1.09 | 434 |
| 40 - 45 mo. | +20 | 433 | 1.05 | 434 |
| 4 yrs. | +15 | 433 | 1.04 | 435 |
| 5 yrs. | + 8 | 433 | 1.02 | 433 |
| 6 yrs. | 0 | 431 | 1.00 | 431 |
| 7 yrs. | 0 | 433 | 1.00 | 433 |
| 8 yrs. | 0 | 436 | 1.00 | 436 |
| 9 yrs. | 0 | 436 | 1.00 | 436 |
| 10 yrs. | 0 | 433 | 1.00 | 433 |
| 11 yrs. | 0 | 434 | 1.00 | 434 |
| 12 yrs. | 0 | 430 | 1.00 | 430 |
| 13 yrs. | 0 | 432 | 1.00 | 432 |
| 14 yrs. | + 6 | 433 | 1.01 | 432 |
| 15 yrs. | +20 | 433 | 1.05 | 433 |

Since variance does not change when additive corrections are used, the standard deviations would remain unchanged. However, when multiplicative corrections are used, the variance increases in proportion to the square of the correction factor, since the variance of a constant times a variable (cx) is expected to be the constant squared times the variance of the variable ($c^2 \sigma_x^2$). Thus, the standard deviation that would be expected to result in these data if multiplicative factors were used was estimated by multiplying the correction factor times the observed standard deviation (multiplicatively adjusted S.D. = $\sqrt{c^2 \sigma_x^2} = c \sigma_x$).

Table 29c gives the standard deviations that would be expected after adjustment with additive and multiplicative corrections. The additively adjusted standard deviations have a range of 12.8 pounds and themselves a standard deviation of 3.2 pounds. The multiplicatively adjusted standard deviations have a greater range of 22.9 pounds and a larger standard deviation of 5.7 pounds. These results indicate that additive adjustments are more appropriate than multiplicative factors in adjusting weaning weight for the effect of age of dam. Although additive adjustments could not equalize the variance, they would at least not cause further divergence as would multiplicative adjustments.

Sex of calf

Because of the important interaction between sex and type of management the method of adjusting for sex was studied separately according to whether or not calves were creep-fed. The results for

TABLE 29c

EXPECTED STANDARD DEVIATIONS AFTER ADJUSTING FOR AGE OF DAM

| Age of dam | Additive adj. S.D. | Multiplicative adj. S.D. |
|---|---|---|
| 27 mo. | 62.2 | 72.8 |
| 28 - 30 mo. | 55.5 | 62.7 |
| 31 - 33 mo. | 56.8 | 63.0 |
| 34 - 39 mo. | 59.4 | 64.7 |
| 40 - 45 mo. | 55.4 | 58.2 |
| 4 yrs. | 56.4 | 58.7 |
| 5 yrs. | 54.0 | 55.1 |
| 6 yrs. | 54.6 | 54.6 |
| 7 yrs. | 58.8 | 58.8 |
| 8 yrs. | 58.8 | 58.8 |
| 9 yrs. | 58.5 | 58.5 |
| 10 yrs. | 53.9 | 53.9 |
| 11 yrs. | 53.4 | 53.4 |
| 12 yrs. | 54.5 | 54.5 |
| 13 yrs. | 50.4 | 50.4 |
| 14 yrs. | 49.4 | 49.9 |
| 15 yrs. | 57.6 | 60.5 |
| Avg. adj. S.D. | 55.7 | 58.1 |
| Range | 12.8 | 22.9 |
| Standard deviation | 3.2 | 5.7 |

sex are given in Table 30. Bartletts' test indicated that the variances in the three sexes were not homogeneous in either type of management. F tests revealed that variance among bulls was significantly greater than that among steers or heifers in both creep-fed and noncreep-fed calves.

In calves that were not creep-fed the coefficients of variation differed slightly ranging from 14.1 percent for bulls to 15.1 percent for steers. The standard deviations indicate that multiplicative correction would reduce the variance in bulls to a level below that observed in steers by about as much as an additive adjustment would leave it greater than that in steers. The results for steers and heifers suggest that multiplicative correction would tend to equalize their variances. The coefficients of variation were essentially equal for the three sexes in calves that were creep-fed. These results suggest that multiplicative corrections are more appropriate than additive corrections when calves are creep-fed and at least equally appropriate when they are not creep-fed.

This study suggests further that multiplicative adjustments have an advantage over additive corrections by accounting for the interaction between sex and type of management. In deriving the multiplicative corrections, the procedure of taking the ratios of the means of steers to bulls and steers to heifers completely accounted for the interaction of sex and type of management. Even though the differences between the sexes were larger for creep-fed calves than for those not creep-fed, the ratios came out the same for both types of management since the mean for creep-fed calves was larger than that for noncreep-fed

TABLE 30

ADDITIVE VERSUS MULTIPLICATIVE ADJUSTMENTS FOR SEX ACCORDING TO TYPE OF MANAGEMENT

| Type of management and sex | d.f. | $\bar{X}$ | S.D. | C.V. | Multiplicative Factor | Multiplicative adj. S.D. |
|---|---|---|---|---|---|---|
| Noncreep-fed: | | | | | | |
| Bulls | 2,023 | 422.8 | 59.8 | 14.1 | 0.89 | 53.2 |
| Heifers | 3,820 | 370.7 | 54.9 | 14.8 | 1.02 | 56.0 |
| Steers | 1,520 | 377.4 | 56.8 | 15.1 | 1.00 | 56.8 |
| Creep-fed: | | | | | | |
| Bulls | 2,289 | 474.6 | 61.7 | 13.0 | 0.89 | 54.9 |
| Heifers | 2,712 | 412.5 | 52.3 | 12.7 | 1.02 | 53.3 |
| Steers | 594 | 421.2 | 54.2 | 12.9 | 1.00 | 54.2 |

calves in proportion to the sex discrepancies. Hence, the multiplicative corrections are the same for both types of management.

The results of this analysis are probably biased some since the effect of castration is confounded with the effect of selection for size in the bulls in these data. However, these findings are in close agreement with those of Koch et al. (1959) and Brinks et al. (1961), who also reported that multiplicative factors were more appropriate than additive factors in adjusting preweaning average daily gain and weaning weight for the effect of sex. In their studies, the effect of sex was not confounded with that of selection.

Season of birth

The results for season of birth are given in Table 31. The interactions of type of pasture and type of management with season of birth were not considered in this analysis because of the limited number of observations during the summer seasons. The standard deviations indicate that variation in weaning weight was only slightly greater for calves born in the spring months (S.D. = 56.5) than for those born during the late fall months (S.D. = 55.2). The coefficients of variation show that relative to their average weight, spring calves were less variable than fall calves. If fall calves were adjusted to a spring calf basis with a multiplicative adjustment, their standard deviation would be 59.1 pounds which differs from that for the spring calves of 56.5 pounds by a greater amount than the observed standard deviations.

The variation among calves born in the summer seasons was greater than that observed for calves born in the spring even though the average weaning weights were lower. This is probably a result of increased environmental variation. Perhaps some ranchers provided special care to some or all of their calves while others did not. This could, in part, account for the large standard deviations and coefficients of variation observed in calves born in the summer seasons.

The observed variances, even though they were not homogeneous ($P < .005$) were more nearly equal for the four seasons than the variances would have been had multiplicative adjustments been used. Consequently, it appears that additive adjustments would be more satisfactory than multiplicative corrections in adjusting for season of birth.

Type of management

Table 31 also gives the results for type of management. The standard deviations were essentially the same in creep- and noncreep-fed calves. Bartletts' test indicated that the variances were not significantly different ($P > .10$). The coefficient of variation was smaller for creep-fed calves, however, since they weighed on the average of 28 pounds more than calves that were not creep-fed. These results indicate that where adjustment is needed for type of management an additive correction is more appropriate than a multiplicative adjustment.

Summary on method of adjustment

The results of this study indicate that additive adjustments are more appropriate than multiplicative factors in adjusting for the effects of age of dam, season of birth, and type of management. Multiplicative adjustments are more appropriate than additive corrections in adjusting for the effect of sex.

TABLE 31

ADDITIVE VERSUS MULTIPLICATIVE ADJUSTMENTS FOR SEASON OF BIRTH AND TYPE OF MANAGEMENT

| | | | | | Multiplicative | |
|---|---|---|---|---|---|---|
| Factor | d.f. | $\overline{X}$ | S.D. | C.V. | Factor | adj. S.D. |
| **Season** | | | | | | |
| Feb.-Apr. | 4,329 | 443.9 | 56.5 | 12.7 | 1.00 | 56.5 |
| May-July | 1,015 | 417.5 | 62.1 | 14.9 | 1.06 | 65.8 |
| Aug.-Oct. | 2,919 | 396.4 | 57.0 | 14.4 | 1.12 | 63.8 |
| Nov.-Jan. | 4,696 | 415.4 | 55.2 | 13.3 | 1.07 | 59.1 |
| **Management** | | | | | | |
| Noncreep-fed | 7,363 | 403.5 | 56.7 | 14.0 | 1.00 | 56.7 |
| Creep-fed | 5,596 | 431.7 | 56.5 | 13.1 | 0.93 | 52.5 |

## Correction Factors

In order for a breeder to be most successful in his breeding program, it is requisite that he handle all calves as alike as possible and keep correction factors to a minimum. The proportion of observable differences in animals due to genetic effects increases as the environment becomes more and more standardized. Some environmental effects can be controlled rather well simply by good management. On the other hand, there are some effects over which breeders have little or no managerial control. Correction factors are useful in reducing environmental variation due to such effects.

In this study, age of dam, sex, month of birth, area of the state, and type of management had a significant and important influence on weaning weight. Each accounted for more than five percent of the total variation observed in weaning weights. Of these five factors individual ranchers will be most concerned about the statistical control of differences due to age of dam, sex, and month of birth, and possibly that due to type of management. There is no need to adjust for the effect of areas since a rancher is usually located in a given area.

### Age of dam

Correction factors are needed to adjust for the effect of age of dam on weaning weight as it is impossible to control this source of variation through management. The correction factors found most appropriate for adjusting the effect of age of dam on calves raised in Oklahoma are given in Table 32a. These correction factors are based on the overall analysis since interactions between age of dam and

TABLE 32a

CORRECTION FACTORS FOR AGE OF DAM SUGGESTED FOR USE IN OKLAHOMA BASED ON THE PRESENT STUDY

| Age of dam | Additive correction factors |
|---|---|
| 24 - 27 mo. | +64 |
| 28 - 30 mo. | +52 |
| 31 - 33 mo. | +44 |
| 34 - 39 mo. | +35 |
| 40 - 45 mo. | +20 |
| 4 yrs. | +15 |
| 5 yrs. | + 8 |
| 6 yrs. | 0 |
| 7 yrs. | 0 |
| 8 yrs. | 0 |
| 9 yrs. | 0 |
| 10 yrs. | 0 |
| 11 yrs. | 0 |
| 12 yrs. | 0 |
| 13 yrs. | 0 |
| 14 yrs. | + 6 |
| 15 yrs. | +20 |

other factors were of no practical importance and they are additive since additive corrections more nearly equalized variances within age of dam groups than multiplicative adjustments.

Table 32b gives the age of dam correction factors currently being used by the Oklahoma Beef Cattle Improvement Association (OBCIA) along with those that have been recommended by the United States Beef Cattle Records Committee (1965). Multiplicative corrections based on the present study are also included in Table 31b for purposes of comparison. The correction factors for age of dam currently used by Performance Registry International (PRI) are given in Table 32c. The factors currently used by the OBCIA and PRI as well as those recommended by the United States Beef Cattle Records Committee, are in close agreement with those obtained in this study up to 6 years of age. The present study indicated that no adjustment is needed for cows ranging in age from 6 to 13 years of age. It appears that the use of correction factors currently used by the OBCIA and PRI in Oklahoma result in overadjustment of weaning weights of calves out of cows ranging in age from 8 to 13 years and older. Apparently environmental conditions in Oklahoma are more sustentative to longevity of production in cows than the current corrections indicate. The correction factors recommended by the United States Beef Cattle Records Committee (1965) agree more closely with those of the present study than the currently used OBCIA and PRI corrections. This investigation has revealed that increases in age of 3- to 5-month increments have an important influence on cow productivity in cows ranging from 2 to 4 years of age and that accuracy in adjusting weaning weights could be improved by classifying cows into

TABLE 32b

SOME AGE OF DAM CORRECTION FACTORS CURRENTLY AVAILABLE TO CATTLEMEN IN OKLAHOMA

| Present study | | Current corrections | | |
|---|---|---|---|---|
| Age of dam | Mult. factors | Age of dam | OBCIA | U. S. Beef cattle com. |
| 24 - 27 mo. | 1.17 | 2 yrs. | 1.16 | 1.15 |
| 28 - 30 mo. | 1.13 | | | |
| 31 - 33 mo. | 1.11 | 3 yrs. | 1.10 | 1.10 |
| 34 - 39 mo. | 1.09 | | | |
| 40 - 45 mo. | 1.05 | | | |
| 4 yrs. | 1.04 | 4 yrs. | 1.04 | 1.05 |
| 5 yrs. | 1.02 | 5 yrs. | 1.01 | 1.00 |
| 6 yrs. | 1.00 | 6 yrs. | 1.00 | 1.00 |
| 7 yrs. | 1.00 | 7 yrs. | 1.00 | 1.00 |
| 8 yrs. | 1.00 | 8 yrs. | 1.01 | 1.00 |
| 9 yrs. | 1.00 | 9 yrs. | 1.02 | 1.00 |
| 10 yrs. | 1.00 | 10 yrs. | 1.04 | 1.00 |
| 11 yrs. | 1.00 | 11 yrs. | 1.07 | 1.05 |
| 12 yrs. | 1.00 | 12 yrs. | 1.11 | 1.05 |
| 13 yrs. | 1.00 | 13 yrs. | 1.16 | 1.05 |
| 14 yrs. | 1.01 | 14 yrs. | 1.16 | 1.05 |
| 15 yrs. | 1.05 | 15 yrs. | 1.16 | 1.05 |

TABLE 32c

AGE OF DAM CORRECTIONS USED CURRENTLY BY PERFORMANCE REGISTRY INTERNATIONAL

| Age of dam | | | Age of dam | | |
|---|---|---|---|---|---|
| Year | Month | Factor | Year | Month | Factor |
| 2 | 0-1 | 1.16 | 7 | 0-11 | 1.00 |
| | 2-3 | 1.10 | 8 | 0-11 | 1.01 |
| | 4-5 | 1.14 | 9 | 0-5 | 1.02 |
| | 6-7 | 1.13 | | 6-11 | 1.03 |
| | 8-9 | 1.12 | 10 | 0-3 | 1.04 |
| | 10-11 | 1.11 | | 4-7 | 1.05 |
| 3 | 0-1 | 1.10 | | 8-11 | 1.06 |
| | 2-3 | 1.09 | 11 | 0-2 | 1.07 |
| | 4-5 | 1.08 | | 3-5 | 1.08 |
| | 6-7 | 1.07 | | 6-8 | 1.09 |
| | 8-9 | 1.06 | | 9-11 | 1.10 |
| | 10-11 | 1.05 | 12 | 0-1 | 1.11 |
| 4 | 0-1 | 1.04 | | 2-3 | 1.12 |
| | 2-5 | 1.03 | | 4-5 | 1.13 |
| | 6-11 | 1.02 | | 6-7 | 1.14 |
| 5 | 0-11 | 1.01 | | 8-9 | 1.15 |
| 6 | 0-11 | 1.00 | | 10-11 | 1.16 |
| | | | 13 and older | | 1.16 |

3- and 6-month increments between 2 and 4 years of age. Also, the present study indicates that additive corrections are more appropriate than multiplicative corrections in adjusting for the effect of age of dam.

Sex of calf

The effect of sex is another factor over which the breeder has no control. When a breeder is concerned with only one sex, such as in selecting replacement heifers, or bull prospects, sex corrections are not needed. However, they are needed in progeny testing, sib-testing, and for comparing productivity of dams, since a disproportionate distribution of sexes in sire, dam, or group averages can easily bias the tests.

The correction factors obtained for sex in this study are given in Table 33a. These factors are multiplicative since they were found to be more appropriate than additive corrections in adjusting for the effects of sex. They also account for the interaction observed between sex and type of management. These correction factors are not in close agreement with those currently used by the OBCIA or with those recommended by the United States Beef Cattle Records Committee (Table 33b). The sex corrections obtained in this study are not appropriate for use in the field since they are based on records where the effect of sex was confounded with that of selection for size. As a result, the corrections for bulls and heifers are biased downward relative to the steers. This study has indicated, however, that multiplicative adjustments are more appropriate than additive corrections in adjusting for the effect of sex since they more nearly equalize

TABLE 33a

SEX CORRECTION FACTORS BASED ON THE PRESENT STUDY

| Sex | Correction factor |
|---|---|
| Bull | 0.89 |
| Steer | 1.00 |
| Heifer | 1.02 |

TABLE 33b

SOME SEX CORRECTION FACTORS CURRENTLY AVAILABLE TO CATTLEMEN IN OKLAHOMA

| Sex | Current OBCIA correction | U. S. Beef cattle records comm. |
|---|---|---|
| Bulls | 0 | 0.95 or 1.00 |
| Steers | +25 | 1.00 or 1.05 |
| Heifers | +50 | 1.05 or 1.10 |

variances within sexes and account for the interaction between sex and type of management.

### Season of birth

At the present time, beef cattle improvement programs available to cattlemen in Oklahoma do not include adjustments for the effect of season of birth. This study has indicated that month of birth has an important influence on weaning weights of calves raised in Oklahoma. A breeder can reduce this source of variation most effectively by restricting the calving season to a two- or three-month period. However, in herds where calves are born in more than one season of the year, adjustments for season of birth would result in more accurate comparisons of calves than if the effect of seasons were ignored.

The interaction analyses indicated that the effect of month of birth is dependent upon the type of pasture utilized (native or improved) and on whether or not the calves are creep-fed. Since there was no interaction between type of pasture and type of management, it was not necessary to obtain least squares estimates for month of birth within each type of pasture by management class. Instead, it was possible to obtain these estimates by deduction from the data already available.

The means estimated for month of birth in the least squares analyses for each type of pasture, native or improved, consisted of

$$(\mu + P_i) + (M_j + PM_{ij})$$

where $\mu + P_i$ = the mean for each pasture analysis with $i = 1,2$.

and $M_j + PM_{ij}$ = the least squares constants for month of birth in each pasture analysis with $j = 1,2,\ldots,12$.

Thus, it was possible to estimate pasture by month interaction effects by

$$PM_{ij} = \frac{(M_j + PM_{1j}) - (M_j + PM_{2j})}{2}$$

$$= \frac{PM_{1j} - PM_{2j}}{2}$$

$$= + PM_{1j} \text{ or } - PM_{2j}$$

These estimates measured the failure of the effect of month of birth to be the same in native pasture ($P_1$) and improved pasture ($P_2$).

In the type of management analyses the means for each month of birth were

$$(\mu + C_k) + (M_j + C_{kj})$$

where $\mu + C_k$ = the mean in each type of management analysis with $k = 1,2$.

and $M_j + CM_{kj}$ = the least squares constants for month of birth in each type of management analysis.

Addition of the type of production means to the pasture interaction effects give

$$[(\mu + C_k) + (M_j + CM_{kj})] + PM_{ij} = \mu + M_j + C_k + MC_{jk} + PM_{ij}$$

This approximates the expected mean for each month of birth within each type of pasture and type of management

$$E[\overline{M}_j \text{ within } PC_{ik}] = \mu + P_i + M_j + C_k + PM_{ij} + PC_{ik} + MC_{jk} + PMC_{ijk}$$

assuming that $PMC_{ijk} = 0$, and knowing from previous analyses that $P_i \cong 0$ and $PC_{ik} \cong 0$.

The least squares estimates for each month of birth in the two types of pasture ($M_j + PM_{ij}$) and the estimates of month of birth by pasture interaction ($PM_{ij}$) are given in Table 34a. The estimates of interaction were then added to the means for month of birth in each type of management (Table 34a) to obtain estimates in each type of pasture by management subclass. These estimates are given in Table 34b. The mean estimates fluctuated up and down particularly during the summer months, in calves raised on improved pasture with no creep, native pasture with creep, and improved pasture with creep. In view of the inconsistent month estimates and because they were only approximate due to the method by which they were obtained, these data were considered inadequate for deriving within season corrections for the effects of month of birth. However, they were considered adequate for estimating seasonal corrections. Months which showed approximately the same seasonal effect were grouped together to establish seasons appropriate for each management by type of pasture subclass. The seasonal means given in Table 34c were computed by taking the unweighted average of weaning weights for each respective season. Additive correction factors to adjust to a spring calving basis were then derived from these seasonal means.

The correction factors for season of birth are given in Table 34d. These corrections allow for the differential seasonal effects observed in each system of management. Creep-feeding tended to standardize the preweaning environment reducing the effect of season of birth. Also calves dropped during the fall months raised on improved pasture were at a greater disadvantage than those raised on native pasture, while those dropped during the summer months raised on improved pasture were not handicapped as much as those on native pasture.

TABLE 34a

DATA FOR ESTIMATING MONTH OF BIRTH BY MANAGEMENT EFFECTS

| Month | L.S. Estimates[1] Native | Improved | ½ Nat.-Imp.[2] | Means[3] Noncreep-fed | Creep-fed |
|---|---|---|---|---|---|
| Jan. | 16 | 4 | +6 | 415 | 448 |
| Feb. | 20 | 20 | 0 | 425 | 447 |
| Mar. | 36 | 25 | +5 | 432 | 456 |
| Apr. | 27 | 18 | +4 | 422 | 455 |
| May | -1 | 10 | -6 | 396 | 446 |
| June | -4 | 9 | -7 | 357 | 431 |
| July | -30 | 18 | -24 | 374 | 432 |
| Aug. | -32 | -9 | -12 | 352 | 441 |
| Sept. | -17 | -11 | -3 | 377 | 413 |
| Oct. | -5 | -35 | +15 | 364 | 415 |
| Nov. | -3 | -26 | +12 | 380 | 421 |
| Dec. | -6 | -24 | +9 | 391 | 429 |

[1]Taken from Table 24a.

[2]These value estimate month $PM_{1j}$. By changing their sign $PM_{2j}$ is estimated.

[3]Taken from Table 25a.

TABLE 34b

MEANS FOR MONTH OF BIRTH BY MANAGEMENT

| Month | Noncreep-fed Native | Improved | Creep-fed Native | Improved |
|---|---|---|---|---|
| Jan. | 421 | 409 | 454 | 442 |
| Feb. | 425 | 425 | 447 | 447 |
| Mar. | 437 | 427 | 461 | 451 |
| Apr. | 426 | 418 | 459 | 451 |
| May | 390 | 402 | 440 | 452 |
| June | 357 | 364 | 424 | 438 |
| July | 350 | 398 | 408 | 456 |
| Aug. | 340 | 364 | 429 | 453 |
| Sept. | 374 | 380 | 410 | 416 |
| Oct. | 379 | 349 | 430 | 400 |
| Nov. | 392 | 368 | 433 | 409 |
| Dec. | 400 | 382 | 438 | 420 |

TABLE 34c

SEASONAL MEANS

| Noncreep-fed | | | Creep-fed | | |
|---|---|---|---|---|---|
| Native | Mo. | Improved | Native | No. | Improved |
| | Jan. | 409 | | Jan. | |
| 427 | Feb. | | 455 | Feb. | |
| | Mar. | 420 | | Mar. | |
| | Apr. | | | Apr. | |
| 394 | May | 402 | 433 | May | 449 |
| | June | | | June | |
| 349 | July | | | July | |
| | Aug. | | 416 | Aug. | |
| 376 | Sept. | 372 | | Sept. | |
| | Oct. | | | Oct. | 411 |
| 396 | Nov. | | 433 | Nov. | |
| | Dec. | | | Dec. | |

TABLE 34d

SUGGESTED CORRECTION FACTORS FOR SEASON OF BIRTH
BASED ON THE PRESENT STUDY

| Noncreep-fed | | | Creep-fed | | |
|---|---|---|---|---|---|
| Native | Mo. | Improved | Native | Mo. | Improved |
| | Jan. | +11 | | Jan. | |
| 0 | Feb. | | 0 | Feb. | |
| | Mar. | 0 | | Mar. | |
| | Apr. | | | Apr. | |
| +33 | May | +18 | +22 | May | 0 |
| | June | | | June | |
| +78 | July | | | July | |
| | Aug. | | +39 | Aug. | |
| +51 | Sept. | +48 | | Sept. | |
| | Oct. | | | Oct. | +38 |
| +33 | Nov. | | +22 | Nov. | |
| | Dec. | | | Dec. | |

These corrections are based on the average effect of season of birth in Oklahoma within the four general type of management by type of pasture subclasses. Ranchers that wean a large number of calves should use corrections for their own particular situation based on their own records possibly within each year. The corrections obtained in this study should, however, be useful in small herds or in large herds where only a small number of calves are dropped during certain seasons.

Type of management

Regarding the effect of type of management it is unsound from the standpoint of an ideal breeding program to creep-feed some calves and not others. Inasmuchas all calves are handled alike no correction would be necessary. However, the practice of creep-feeding bull calves and not heifer calves may be sound from an economic point of view since bull calves apparently benefit more from creep-feeding than heifer calves.

The results of this study have indicated that correction for the effects of sex and type of management would not be too difficult in instances where such a management scheme were practiced. By using a multiplicative correction to adjust to a common sex one could account for the effects of sex and sex by management interaction simultaneously. All that would remain is the adding of an appropriate correction for the effect of creep-feeding.

The present study has indicated that an additive correction of 28 pounds can be used to adjust for the effect of creep-feeding in instances where some calves are creep-fed and others are not. This represents an estimate of the average effect of creep-feeding in

Oklahoma. Obviously, for any given breeder, this value could change depending on composition of ration and many other factors. Thus, it would be advisable for breeders with large enough numbers to develop their own correction factor for the effect of creep-feeding specific to their conditions.

# SUMMARY

The data used in this study were the adjusted 205-day weaning weights of 13,937 Hereford and Angus calves recorded in the Oklahoma Beef Cattle Improvement Program over a four-year period, from 1959 through 1962. Each calf was classified according to age of dam, sex, breed, type of pasture, area of the state, month of birth, and type of management. The data were analyzed by the method of least squares according to a model including the seven factors.

The results of the overall analysis of variance indicated that age of dam, sex, area, month of birth, and type of management had important influences on weaning weight, each accounting for more than five percent of the total variance in weaning weight. The least squares estimates for age of dam indicated that weaning weight increased 46 pounds as cows increased in age from 2 to 4 years. Productivity continued to increase until cows were 8 years old and showed only a slight reduction before the 14th and 15th year of age. It appears that classifying cows into 3- and 5-month increments between 2 and 4 years of age would result in more accurate corrections than yearly increments.

To investigate all possible two-way interactions least squares analyses were computed within each sex, breed, type of pasture, season, and type of management. The effect of interactions was

examined by comparing least squares constants computed for a given level of one factor (e.g. a particular age of dam subclass) within different levels of another factor (e.g. creep and no creep). The criterion for assessing the significance of interactions was whether or not 95 percent confidence intervals on the least squares constants overlapped.

The results of the interaction analyses indicated that the effect of age of dam was essentially the same regardless of sex, breed, type of pasture, season of birth, or type of management. Three interactions appeared important enough to be taken into account in adjusting weaning weights. An important interaction was observed between sex and type of management. The differences between bulls and steers and bulls and heifers were larger in calves that were creep-fed than in those that were not indicating that bulls benefit more from creep-feeding than steers or heifers. Also, the effect of month of birth was dependent on type of management. Apparently, creep-feeding tends to standardize the preweaning environment and reduce the effect of month of birth. The third important interaction observed was that between month of birth and type of pasture. Calves raised on native pasture had a significant advantage over those raised on improved pasture when born in the spring or fall. Those raised on improved pasture had an advantage over those raised on native pasture when born during the summer months.

A study of additive versus multiplicative adjustments was conducted for age of dam, sex, season of birth, and type of management by determining which method of adjustment would more nearly equalize means among subclasses and variances within subclasses in the data of the present study. Additive corrections were found to be more appropriate than multiplicative corrections in adjusting for the effects of age of dam, season of birth, and type of management. Multiplicative corrections were found to be more appropriate in adjusting for the effect of sex. In addition to more nearly equalizing variances within sexes, multiplicative corrections completely accounted for the interaction observed between sex and type of management.

Correction factors considered most appropriate for use in Oklahoma based on the results of this study were derived for age of dam, sex, season of birth, and type of management. Additive corrections based on the overall analysis were derived for age of dam. Multiplicative correction factors derived from the separate analyses of creep- and noncreep-fed calves were given for sex. These corrections were not considered appropriate for use in the field, however, because the effect of castration in the males was confounded with the effect of selection for size. In view of the significant month of birth by type of pasture and month of birth by type of management interactions, separate corrections were recommended for season of birth according to whether calves are raised on native or improved pasture and whether or not they receive creep-feed. An additive correction of 28 pounds was presented for use when adjustment is needed for type of management.

## LITERATURE CITED


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

Brethour, J. R. and W. W. Duitsman. 1958. Value of creep feeding sorghum grain or whole oats in the production of finished yearling steers and heifers from fall-dropped calves. Kan. Agr. Exp. Sta. Cir. 359:15.

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

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

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

Brown, C. J., M. L. Ray, Warren Gifford and R. S. Honea. 1956. Growth and development of Hereford cattle. Ark. Agr. Exp. Sta. Bul. 570.

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

Clark, R. T., C. E. Shelby, J. R. Quesenberry, R. R. Woodward, and F. S. Willson. 1958. Production factors in range cattle under Northern Great Plains conditions. U. S. Dept. Agr. Tech. Bul. 1181.

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

Duitsman, W. W. and F. B. Kessler. 1956. Creep-feeding versus noncreep-feeding in the production of finished yearling steers and heifers from spring- and fall-dropped calves. Kan. Agr. Exp. Sta. Cir. 334:13.

Duitsman, W. W. and F. B. Kessler. 1957. Creep-feeding versus noncreep-feeding in the production of finished yearling steers and heifers from 1955 fall-dropped calves. Kan. Agr. Exp. Sta. Cir. 348:12.

Evans, Lee E., J. V. Craig, G. F. Cmarik and R. J. Webb. 1955. Influence of age of calf, sex and age of dam on weaning weight of Herefords. J. Animal Sci. 14:1181 (Abstr.).

Flock, D. K., R. C. Carter and B. M. Priode. 1962. Linear body measurements and other birth observations on beef calves as predictors of preweaning growth rate and weaning type score. J. Animal Sci. 21:651.

Foster, J. E., H. H. Biswell and E. M. Hostetler. 1946. Grazing and creep-feeding calves on native range. N. C. Agr. Exp. Sta. Bul. 355.

Furr, R. D., A. B. Nelson, W. D. Campbell and G. R. Waller. 1959. Levels of supplemental winter feeding of beef cows and creep-feeding fall calves. Okla. Agr. Exp. Sta. MP-55:72.

Furr, R. D., A. B. Nelson, G. R. Waller and W. D. Campbell. 1960. Effect of level of wintering fall calving beef cows and replacement heifers. Okla. Agr. Exp. Sta. MP-51:117.

Furr, R. D., A. B. Nelson, G. R. Waller and W. D. Campbell. 1961. Effect of level of wintering fall-calving beef cows and replacement heifers. Okla. Agr. Exp. Sta. MP-64:34.

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

Hamann, H. K., S. Wearden and W. H. Smith. 1963. Estimation of genetic and environmental factors affecting weaning weights of creep-fed cattle. J. Animal Sci. 22:319.

Harvey, Walter R. 1960. Least-squares analysis of data with unequal numbers. Agr. Res. Service. U.S.D.A., ARS-20-8.

Hazen, M. W. and J. E. Comfort. 1943. Comparison of corn and corn-molasses mixture for fattening calves before and after weaning. U.S.D.A. Tech. Bul. 862.

Hoover, C. D., D. Chambers, J. A. Whatley, Jr., and D. F. Stephens. 1956. Production of beef cows as appraised by calf weight at 112 and 210 days of age. J. Animal Sci. 15:1224 (Abstr.).

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

Kieffer, N. M. 1959. Inheritance of certain maternal traits in beef cattle, Ph.D. thesis, Oklahoma State University.

Knapp, B. J., A. L. Baker, J. R. Quesenberry and R. T. Clark. 1942. Growth and production factors in range cattle. Mont. Agr. Exp. Sta. Bul. 400.

Knapp, Bradford, Jr., and R. W. Phillips. 1942. Differences in performance between sexes in offspring of beef bulls. J. Animal Sci. 1:346 (Abstr.).

Knox, J. H. and M. Koger. 1945. Effect of age on the weight and production of range cows. N. Mex. Agr. Exp. Sta. Press Bul. 1004.

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

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

Koger, Marvin and J. H. Knox. 1945. The effect of sex on the weaning weight of range calves. J. Animal Sci. 4:15.

Koger, M., W. L. Reynolds, J. H. Meade, W. G. Kirk, F. M. Peacock, and R. W. Ridder. 1962. Environment, sex and age of dam effects. J. Animal Sci. 21:973. (Abstr.).

Kuhlman, Lester R. 1962. Creep-feeding fall calves. M.S. Thesis, Oklahoma State University.

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

Lush, Jay L., J. M. Jones, W. H. Dameron, and O. L. Carpenter. 1930. Normal growth of range cattle. Texas Agr. Exp. Sta. Bul. 409.

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

Mahmud, A. and E. H. Cobb. 1963. Factors affecting weaning weights, preweaning gains, and conformation scores of beef calves in Hawaii. J. Animal Sci. 22:820. (Abstr.).

Marlowe, Thomas J. 1962. Weights and grades of beef cattle and their relation to performance. Virginia Agr. Exp. Sta. Bul. 537.

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

Marlowe, T. J., C. C. Mast and D. M. Sheehan. 1964. Two methods of estimating age of cow effect on calf performance. J. Animal Sci. 23:851 (Abstr.).

McCroskey, J. E., W. D. Campbell, and A. B. Nelson. 1964. Creep-feeding fall calves. Okla. Agr. Exp. Sta. MP-74:57.

Minyard, J. A. and C. A. Dinkel. 1960. Factors influencing weaning weight of beef calves. J. Animal Sci. 19:1223 (Abstr.).

Nelson, A. B., G. Bratcher, R. D. Humphrey and R. W. MacVicar. 1955. Creepfeeding spring calves. Okla. Agr. Exp. Sta. Bul. 462.

Pahnish, O. F., C. B. Roubicek, E. B. Stanley, Ralph Bogard and C. E. Shelby. 1958. The influence of age of dam on the 270-day weaning weights of bull and heifer calves. Proc. Western Section Am. Soc. An. Prod. 9:XLVIII-1.

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

Pope, L. S., D. Acker, R. D. Humphrey and V. G. Heller. 1955. Methods of management for a commercial herd producing fat slaughter calves. Okla. Agr. Exp. Sta. MP-43:84.

Pope, L. S., R. D. Humphrey, V. G. Heller and Duane Acker. 1956. Methods of management for the small commercial herd producing "two-way" calves. Okla. Agr. Exp. Sta. MP-45:66.

Pope. L. S., R. D. Humphrey and D. Stephens. 1957. Methods of management for the small commercial herd producing "two-way" calves. Okla. Agr. Exp. Sta. MP-48:57.

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

Snedecor, George W. 1956. Statistical Methods (5th ed.). Iowa State University Press, Ames, Iowa.

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

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

Thrift, Fred A. 1964. Weaning weight of calves as affected by age, sex, season of birth, and age of dam. M. S. Thesis, University of Georgia.

United States Beef Cattle Records Committee Report. 1965. Recommended procedures for measurement of traits of economic value in beef cattle. U.S.D.A., Federal Extension Service, Agriculture Science, Technology and Management Division. AST & M-37 (2-65).

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