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To the Graduate Council:

I am submitting herewith a thesis written by James Turner Guill entitled "The Repeatability of Cow Performance in Beef Cattle." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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THE REPEATABILITY OF COW PERFORMANCE IN BEEF CATTLE

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

James Turner Guill

August 1953

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INTRODUCTION

The repeatability of cow performance is of special interest to persons engaged in the breeding of beef cattle since the age at which low producing cows can be safely culled from herds depends largely upon this characteristic. If the repeatability of performance characteristics of the average cow is known a more definite herd replacement program may be followed since the success of selecting breeding females on the basis of production records depends on the correlation of observed and future production.

A greater percentage of the studies concerning the repeatability of cow performance in beef cattle has been with range Hereford cows; however, the reported observations in range herds are in fairly close agreement with the estimates reported for eastern herds. The differences observed between range and eastern cows may be attributed to climatic conditions, herd management, culling practices and grazing facilities.

It is hoped that the results of this study, involving the determination of the repeatability of birth and 180-day weights and the type and condition grades at weaning for successive calves from the same cows from herds at the University of Tennessee Agricultural Experiment Stations at Crossville and Greeneville, Tennessee, when added to calculations from other workers, will be helpful in indicating the average repeatability for these performance characteristics in beef cattle.

LITERATURE REVIEW

The reported estimates of repeatability from a limited number of investigators, as related to calf birth and weaning weights, are in fair agreement. The major differences may be due to the factors involved at various locations and different methods used to make the adjustments in the determination of the repeatability estimates.

Dawson et al. (1947) reported that birth weights of calves tended to increase at the rate of 0.23 pound for each month of increase in the age of dam until the dams were 6 years old; after which, there was no effect. Correlation between age of dam and birth weight of calf was 0.45 for the male and 0.35 for female calves. When birth weights were adjusted to the basis of 6 year-old dams, males averaged 4. 2 pounds heavier than females. Heritability estimates for birth weight was 11 per cent when birth weights were corrected for age of cow, sex and dam's index (average weight of all calves from a given dam).

Woodard et al. (1942) observed that when calves from large and small type Hereford cows of various age groups were compared, the calves from large type cows were heavier at birth and made larger daily gains from birth to weaning. Also, the type of their sire and dam affected the birth weights of calves more than the ration fed their dams.

Partial correlation studies by Knapp and Black (1941) indicated, that during the suckling period, milk consumption had the greatest influence on the rate of gain followed by consumption of hay and grain.

These three variables accounted for 41 per cent of the variation in the rate of gain during this period. Sex was found to have a significant influence on the rate of gain.

Knapp et al. (1940) using both beef and milking Shorthorn cows observed that in the former the males averaged 4.7 pounds heavier and in the latter 3.5 pounds heavier than the females at birth. The difference in the former was highly significant at the 0.01 level. Differences due to sex accounted for only 6.5 per cent of the total variance in birth weights in the beef Shorthorns and 2.1 per cent in the milking Shorthorns. The influence of calving sequence on birth weight indicated that the first calves were considerably lighter than the subsequent calves, but beyond this point the trend was not consistent. A correlation coefficient of 0.21 was derived between birth weights and calving sequence.

Using Hereford cows, Gregory et al. (1950) reported a significant difference in the birth weight between sexes but very little difference for the weaning weight. The male calves were 5 pounds heavier at one station and 4 pounds heavier at another. The weight of the dam had a significant influence on the birth weight and on the weaning weight in one herd but had a negative effect in the other. They stated that the cows tended to repeat their previous performance for gain of their calves from birth to weaning and for weaning weights of their calves to a higher degree than for birth weight.

Burris and Blunn (1952) found Hereford males to be 4.5 pounds heavier than females at birth. The mean birth weight for males was

69.9 ± 0.97 and for the females 65.4 ± 0.82 pounds. About 10 per cent of the sex difference was attributed to difference in gestation length. The mean birth weight was 63.5 pounds when the dam calved at 2-3 years of age and increased steadily to 76.2 pounds at 9-10 years of age. The regression of birth weight on age of dam was a highly significant figure of 1.04 pounds.

Over a period of weight years, Koger and Knox (1945) observed in high grade Hereford range calves a highly significant sex difference of 32 pounds (corrected to 205 days) at weaning in favor of steer calves. In another report, Knox and Koger (1945) stated that the mean weaning weight of calves increased with the age and weight of their dam until the cows were 6 to 8 years of age. They suggested the close correlation between weight of calf and weight of dam strongly indicated the relationship of production to plane of nutrition. The repeatability of yearly weaning weights and grades of calves from range cows was studied by Koger and Knox (1947). This data indicated that considerable progress can be made in selecting range cows on the basis of first calf record. The average correlation of all adjacent calves was 0.49; while a comparison of the first record with the average of various members of subsequent records gave a range of correlation coefficients from 0.51 to 0.53. The permanent difference in cows accounted for 51 per cent of the remaining variance after the influence of the age of the dam was removed. A computation of the correlation of all adjacent grades of calves was 0.24 and that of the first and various combination of subsequent records varied from 0.25 to 0.42. After variance due to age of dam and different

years was removed, differences in cows accounted for 33 per cent of the remaining variance.

With Hereford range cows, Koch (1951) observed that the males (average of bulls and steers) weaned 23 pounds heavier than the females. The difference between cows accounted for 52 per cent of the variance in the calves' corrected weaning weights. These weaning weights are adjusted for year, age of dam, sex of calf, age of calf at weaning, in-breeding of dam and in-breeding of the calf.

Using range Hereford cattle, Botkin and Whatley (1952) found repeatability estimates by intraclass correlation between weights of calves produced by the same cow to be 0.43 for weaning and 0.18 for birth weight. Regression of later records from the first toward the herd average was 0.49 for weaning and 0.14 for birth weights. For another group of cows that began calving at two years of age the correlation between the birth weights of the first and second calves was 0.25 and between their weaning weights 0.66.

Southwell and Warwick (1952) reported male Polled Hereford calves to be 5.3 pounds heavier at birth and 41 pounds heavier at 210 days than female calves. In general, calf weights at birth and 210 days increased with the age of cow to eight years. They found that from 35 to 43 per cent of the variance in 210 day calf weights could be accounted for by cow differences. The overall correlation between successive calves from the same cow was 0.44 and the regression coefficient was 0.36.

Using high grade Hereford cows Paysinger (1953) observed that 30 per cent of the variance between calf weights at 187 days was due to differences between cows. This figure was highly significant ($P = <0.01$). The average correlations of 0.25 for birth weights and 0.59 for weaning weights of successive calves from the same cow were observed. These values were significant ($P = <0.01$). The average regression coefficients for birth and weaning weights of calves were 0.26 and 0.49 respectively. The intraclass correlation for feeder type grades was 0.04 and for slaughter condition grade 0.07.

OBJECTIVE

The objective of this study was to determine the repeatability of performance of the beef cows at the Agricultural Experiment Stations of the University of Tennessee at Crossville and Greeneville through a statistical analysis of their calves' birth weights, 180-day weights, and grades for feeder type and slaughter condition at weaning.

History of the Herds

The Crossville herd had as its nucleus twenty-four grade heifers purchased in the fall of 1940 as short yearlings. Twelve of these heifers were from the Cumberland Plateau Area and twelve from the Central Basin of Tennessee. The original purpose in securing this herd was to compare the performance of cattle from these two areas and they were selected at random from various herds and were of mixed Shorthorn, Hereford and Angus breeding. The average feeder type and condition grades of these heifers when purchased was about medium. These heifers were grown out at the station and began calving in 1942 as 2-year-olds. In the third year of the study cows that dropped calves in July and August were eliminated from the herd and only cows calving in April and May were retained in the herd. In the fall of 1947 only nine of the original herd remained. There were also twenty-one cows produced from the original cows sired by two different Shorthorn bulls, all female calves being kept from two years production to obtain these cows. Two 2-year-old heifers were added in the fall of 1947 and six 2-year-olds in the spring of 1950. These 2-year-old females were by a Hereford bull.

The Greeneville herd was established from 48 grade Hereford heifers purchased as calves at the Ewing, Virginia, calf sale in the fall of 1945. These heifers were grown out on the station farm and began their productive life as three-year-old cows. No culling was practiced in this herd after the first year and no replacements were added. Cows which did not produce a calf the first year were sold. The following number of calves were weaned: 42 in 1948; 39 in 1949; 35 in 1950; 36 in 1951; and 29 in 1952.

Herd Management

These two herds were maintained on stations 150 miles apart and under quite different conditions. The Crossville station, located on the Cumberland Plateau in Tennessee, has an elevation of approximately 2000 feet. The winters are more severe, the summers cooler and the summer rainfall is more evenly distributed than at the Greeneville station which is located in Upper East Tennessee at an elevation of 1350 feet.

Until 1947 the Crossville herd was maintained on pasture consisting primarily of Kentucky Bluegrass, orchard grass and clovers. For the period of years from 1947 to 1952 the pastures were primarily native grasses and re-seeding clovers. The cows ran on the pasture the entire year but were put up at night and fed a limited amount of hay during the winter months until about the middle of April.

At Greeneville the pastures consisted primarily of Kentucky Bluegrass, orchard grass, white and hop clovers and was more luxuriant

than the pastures at the Crossville station. The Greeneville cows in the early calving group were fed considerably more and higher quality of feed than the herd at Crossville which calved in April and May.

Breeding Program

A controlled breeding program was practiced at Crossville with the cows calving in April and May. All cows were pasture bred and permitted to calve in the pasture. A total of three purebred Shorthorn and three purebred Hereford bulls were used in the years covered by this study, 1942 through 1952.

The bulls used at the Greeneville station were purebred Herefords and Angus. The cows were divided into early and late calving groups (fig. 1) and the bulls were alternated between groups in different years. In general, a cow that was bred to a Hereford bull one year was bred to an Angus bull the next. The cows were pasture bred and permitted to calve in the pasture.

Calf Management

The calves at both stations were weighed at birth and at regular 28-day intervals until weaning. All calves were weaned about November 1 each year. Grades for feeder type and slaughter condition were made at weaning or shortly after. In most instances the male calves were castrated about two months of age.

The calves were identified by ear tag at birth and later by ear tattoo.

The calves were not creep fed.

PROCEDURE

Animals

Only cows dropping three or more calves were used in the analysis of data from the Greeneville herd and cows dropping two or more calves in the Crossville herd. Twins were excluded from the study since the effect of twinning on repeatability estimates is not known. Data on 286 calves from 57 different cows in the Crossville herd and 184 calves from 42 different cows in the Greeneville herd were available for this study.

Only 283 birth weights from the Crossville herd were usable since one cow dropped only one calf and one set of twins was excluded from the study. In the analysis of variance of weaning weights only 281 calves were used; one calf died soon after birth and one died at approximately weaning age. One hundred and eighty-six calves were used in the analysis of variance for feeder type grade. In the analysis of variance for slaughter condition one hundred and eighty-four calves were used. The differences between the number of calves used in the analysis of variance for weaning weights and feeder type and slaughter condition grades was due to the fact that the calves were not graded in 1942, 1943, 1944 and 1945; also, some grades were missing in other years. One hundred and seventy-eight birth weights were usable in the analysis of variance of birth weights of calves from the Greeneville herd since only cows dropping three or more calves were considered. One hundred and seventy-six weaning weights were used. The reduction in calf numbers from birth to weaning was due to deaths and to

calves discarded because some cows dropped less than three calves. One hundred and seventy-four calves were used in the analysis of variance of both feeder type and slaughter condition grades.

Adjustment Factors

In the Crossville herd all calf weaning weights were adjusted to a 180-day basis by prorating the gain made during the 28-day period bracketing the standard age. Birth and 180-day weights were averaged by sex, age of dam and year dropped in order to determine the factors necessary for adjusting all records to a standard basis.

The mean birth weight of calves in the Crossville herd was 73.1 pounds for the males and 66.5 pounds for the females, a difference of 6.6 pounds in favor of the males. This figure is slightly higher than the average difference reported by other workers. Birth weights were adjusted to a male basis by adding 6.6 pounds to the weights of heifer calves. Further adjustments were made for age of dam since the birth weights of calves increased with the age of dam up to 4 years of age and then remained relatively constant for cows 4 - 11 years of age (fig. 2).

The birth weights of calves from 2 and 3-year-old dams were adjusted to the basis of 4 - 11 year-old dams by adding the following amounts:

	Males	Females
2-year-old dams	5.3 pounds	9.1 pounds
3-year-old dams	3.7 pounds	5.3 pounds

Corrections were also made for year dropped to the basis of 1950 calves by adding the following figures to corresponding years:

1942	0.50 pounds
1943	0.8 pounds
1944	4.4 pounds
1945	9.1 pounds
1946	3.4 pounds
1947	1.0 pounds
1948	8.4 pounds
1949	5.2 pounds
1950	0.0 pounds
1951	2.2 pounds
1952	1.0 pounds

For example, 0.50 pounds was added to the birth weight of all calves dropped in 1942.

The average 180-day weights for males was 460.0 pounds and 409.0 pounds for the females. The difference of 51.0 pounds was highly significant in favor of the males. A fairly consistent trend toward heavier 180-day weights was shown to six to seven years of age. The 180-day weights were adjusted to the basis of males from mature cows by adding 51.0 pounds to the weights of females and then adding the following amounts to the weights of all calves from cows of various ages:

2 year - 96 pounds	7 year - 0 pounds
3 year - 66 pounds	8 year - 14 pounds
4 year - 29 pounds	9 year - 10 pounds
5 year - 14 pounds	10 year - 26 pounds
6 year - 0 pounds	11 year - 36 pounds

Further adjustments were made for year dropped to the basis of 1947 calves by adding the following figures:

1942 - 71 pounds	1947 - 0 pounds
1943 - 85 pounds	1948 - 11 pounds
1944 - 110 pounds	1949 - 9 pounds
1945 - 63 pounds	1950 - 29 pounds
1946 - 16 pounds	1951 - 69 pounds
	1952 - 35 pounds

The weaning feeder type grades were adjusted for age of dam and year dropped. No adjustments were made for sex. The feeder type grades were adjusted to the basis of calves from three-year-old dams by adding the following figures:

2 year - 2.2 grade	7 year - 1.0 grade
3 year - 0 grade	8 year - 0.7 grade
4 year - 1.4 grade	9 year - 0.9 grade
5 year - 0.8 grade	10 year - 1.1 grade
6 year - 1.6 grade	11 year - 2.4 grade

These grades were further adjusted for year dropped to the basis of the 1952 calves by adding the following figures:

1946 - 1.3 grade	1950 - 0.8 grade
1947 - 1.1 grade	1951 - 0.2 grade
1948 - 1.2 grade	1952 - 0.0 grade
1949 - 0.6 grade	

The fewer years reported here for feeder type grade is due to the fact that the calves were not graded in 1942, 1943, 1944 and 1945. Some grades in other years were also missing.

The mean weaning slaughter condition grades were 10.9 (approximately high good) for the females and 10.2 (approximately good) for the males. Slaughter condition grades were adjusted to a female basis by adding 0.7 grade to the grades of the male calves. The calves were then standardized to the basis of calves from three-year-old cows by adding the following figures to calves from cows of various ages:

2 year - 2.2 grade	7 year - 1.3 grade
3 year - 0 grade	8 year - 0.2 grade
4 year - 1.2 grade	9 year - 0.1 grade
5 year - 1.4 grade	10 year - 0.9 grade
6 year - 1.2 grade	11 year - 1.6 grade

Further adjustments were made for year dropped to the basis of 1951 calves by adding the following amounts:

1946 - 1.4 grade	1950 - 1.4 grade
1947 - 2.1 grade	1951 - 0 grade
1948 - 1.6 grade	1952 - 0.6 grade
1949 - 1.2 grade	

In the Greeneville herd all calf weaning weights were adjusted to a 180-day basis by prorating the gain made during the 28-day period bracketing this age. For analysis of variance birth and 180-day weights and feeder type and slaughter condition grades were adjusted for sex of calf only. Since all of the cows used in the analysis at this station began calving as a group at 3 years of age and then successively as 4, 5, 6 and 7-year-olds, it was impossible to adjust for age of dam and year dropped. These factors were controlled statistically in the analyses of variance for the different characteristics.

In the correlation and regression analyses at the Greeneville station, all weights and grades were corrected for sex and for year dropped. The correction for year dropped included the effect of age of dam since all cows dropping calves in any one year were of the same age.

The mean birth weight by sex was 73 pounds for the males and 67 pounds for the females, a difference of 6.0 pounds in favor of the males. This difference was slightly larger than the average sex difference reported by other workers. Birth weights were adjusted to a male basis by adding 6.0 pounds to the weights of the heifer calves.

The average 180-day weight for the males was 403.2 and 377.4 for the females. The difference of 25.8 pounds was within the range observed by other investigators. The 180-day weights were adjusted to the basis of male calves by adding 25.8 pounds to the weights of all female calves.

The mean feeder type grade was 11.5 (approximately low choice) for males and 10.8 (approximately high good) for females. The difference of 0.7 grade was added to all female grades to adjust them to a male basis.

The average slaughter condition grades were 9.8 (approximately low good plus) for males and 10.0 (good) for the females. These grades were adjusted to a female basis by adding 0.2 grade to the grades of all male calves.

Statistical Methods

The characteristics studied, namely calf birth and 180-day weights and weaning grades for feeder type and slaughter condition, were subjected to analysis of variance and to correlation and regression analysis.

In the analysis of variance calculations for the Crossville herd, the sources of variation considered were those (1) between years in which the calves were dropped, (2) between cows within years, and (3) within cows. For the Greeneville herd the sources of variation considered were those (1) between groups (early vs. late calving), (2) between cows within years, (3) between years within groups, (4) between cows within groups, and (5) within cows. Methods of analysis were those outlined by Snedacor (1946).

The effective number of calves per cow was derived by the following formula:

$$k_o = \frac{1}{n-1}\left(Sk - \frac{Sk^2}{Sk}\right)$$ with Sk representing the total number of calves and Sk^2 the sum of the squares of the number of calves per cow. Using the data in Table XI as an example, the value of $k_o = 4.46$ was derived as follows:

$$k_o = \frac{1}{38}\left(176 - \frac{812}{176}\right)$$

$$k_o = 0.026\ (176 - 4.614)$$

$$k_o = 0.026\ (171.38)$$

$$k_o = 4.46$$

With k_o determined, the mean square between cows within years was divided into its theoretical components by the formula: $\sigma_w^2 + k_o \sigma_c^2$, where σ_w^2 = within cow variance and σ_c^2 = the additional variance due to cow differences. As an example, using the data in Table XIII the figure of 0.69 representing variance due to differences between cows was calculated as follows:

$$4.1 = 1.1 + 4.41\ \sigma_c^2$$

$$4.41\ \sigma_c^2 = 3.0$$

$$\sigma_c^2 = 0.69$$

The percentage of the total variance due to differences between cows was determined by the ratio of the two variances, $\frac{\sigma_c^2}{\sigma_w^2 + \sigma_c^2}$ = intraclass correlation.

Correlation and regression analysis were limited to calves of cows calving in successive years.

RESULTS AND DISCUSSION

Birth Weights

The analysis of variance of birth weights of calves from the Crossville cows and subsequent intraclass correlation (Table I) indicated that 3 per cent of the variance may be attributed to differences between cows. An intraclass correlation for calf birth weights of-0.01 (Table IX) was observed for calves from the Greeneville herd. These correlations were smaller than the observations of other investigators. Paysinger (1953) observed an intraclass correlation for differences between cows for calf birth weights of 0.30. Using range Hereford cattle Botkin and Whatley (1952) obtained a repeatability estimate by intraclass correlation for birth weights of calves produced by the same cow of 0.18.

An average correlation coefficient of - 0.01 (Table II) was obtained between birth weights of successive calves from the same cow at Crossville. The average correlation coefficient between birth weights of successive calves from the same cow of - 0.01 was also observed at Greeneville. These values are considerably lower than correlation coefficients reported by other workers. Paysinger (1953) observed a correlation coefficient of 0.25 for birth weight of adjacent calves and Knapp et al. (1940) obtained a correlation coefficient of 0.21 between birth weight and calving sequence. Regression coefficients of - 0.01 were obtained for both herds of cows (Tables II and X).

Botkin and Whatley (1952) reported a regression coefficient of 0.14 for birth weights of successive calves from the same cow. These values indicate that for each pound a cow's calf is below the herd average in one year, her next calf can be expected to be 0.01 pound below the average the next year.

180-day Weights

At Crossville the analysis of variance between calf weights at 180-days showed that approximately 21 per cent (Table III) of the variance between weights was due to differences between cows. This figure was highly significant ($P = <0.01$). Approximately 61 per cent ($P = <0.01$) of the variance between calf weights at 180-days was found to be due to permanent differences between cows at the Greeneville station (Table XI). The value for Crossville was considerably lower and the figure for Greeneville somewhat higher than estimates obtained by other workers. Koger and Knox (1947) and Koch (1951) found that cow differences accounted for 51 and 52 per cent of the variance, respectively, in weaning weights of range calves not creep fed. Southwell and Warwick (1952) observed that 35 to 43 per cent of the variance in 210 day weaning weights could be accounted for by differences between cows. Some of the differences in values obtained by different investigators may be due to differences between herds and to the varying herd environmental conditions between geographical sections.

At Crossville the average correlation coefficient between successive calves from the same cow at 180-days was 0.25 (Table IV)

and was highly significant ($P \leq 0.01$). At Greeneville an average within group correlation of 0.62 (Table XII) was observed between successive calves from the same cow. This figure was highly dignificant ($P \leq 0.01$). Koger and Knox (1947) obtained an average correlation of one year's calf with the next of 0.49; while a comparison of the first record with the average of various members of subsequent records gave a range of correlation coefficient from 0.51 to 0.53. The regression coefficient between successive calves from the same cows were found to be 0.24 (Table IV) and 0.64 (Table XII) for Crossville and Greeneville cows respectively. These figures indicate that for each pound a cow's calf weaned above the herd average in one year her next calf could be expected to wean 0.24 and 0.64 of a pound above the herd average for Crossville and Greeneville cows respectively.

Grades

Eleven per cent (Table V) of the variance between calf weaning grades for feeder type was found to be due to cow differences at Crossville. For Greeneville 39 per cent (Table XIII) of the variance between grades for feeder type was estimated to be due to cow differences and was highly significant ($P \leq 0.01$). Koger and Knox (1947) observed a correlation of 0.24 of all adjacent grades of calves and a range of 0.25 to 0.42 for combination of the first with various averages of subsequent records. Paysinger (1953) observed a correlation of 0.04 between the weaning type grade of adjacent calves from the same cow.

The average correlation coefficient for all adjacent grades for calf feeder type was 0.16 (Table VI) at Crossville and 0.28 (Table XIV) for Greeneville ($P = < 0.01$). A regression coefficient for calf feeder type grade of 0.17 (Table VI) was obtained at Crossville and 0.31 (Table XVI) at Greeneville. These figures indicate that for every point a cow's calf is above the herd average one year, her next calf be expected to be 0.17 and 0.31 of a grade above the herd average the next year for Crossville and Greeneville cows, respectively.

The intraclass correlation of calf weaning grades for slaughter condition at Crossville was 0.04 (Table VII). This was in agreement with results obtained by Paysinger (1953) but lower than those obtained by Koger and Knox (1947). At Greeneville the intraclass correlation of calf weaning slaughter condition grades of successive calves from the same cows was 0.51 (Table XV). This was considerably higher than the figure of 0.04 reported by Paysinger (1953).

For the Crossville herd an average correlation coefficient for weaning grades for slaughter condition of 0.19 (Table VIII) was obtained ($P = < 0.05 > 0.01$). This correlation was 0.45 (Table XVI) for the Greeneville herd and was highly significant. Regression coefficients for slaughter condition grades of 0.19 (Table VIII) and 0.50 (Table XVI) were obtained for the Crossville and Greeneville herds respectively. These figures indicate that for

each point a cow's calf is above the herd average one year, her next calf can be expected to be 0.19 points and 0.50 points above the average the next year.

The results obtained in the analysis of the repeatability of cow performance in the herds at the two locations involved in this study show considerable differences in the repeatability estimates obtained for 180-day weights and weaning grades for feeder type and slaughter conditions. Results were similar for estimates of the repeatability of birth weights at both Crossville and Greeneville. The differences obtained may be partially explained by differences in the cow herds influenced by origin and culling practices as well as different environmental conditions.

Variation within cows was similar at both stations but differences between cows were much greater for the Greeneville station as compared to the Crossville station. Since no culling was practiced in the Greeneville herd after the first calf crop, the rather high estimates obtained at this station might be partially explained by the fact that unusually good and poor producers were kept in the herd for the entire period covered by this study. At Crossville the first year production of most of the cows tended to be much nearer the average with less variation between cows and few extremely low or high producers.

SUMMARY

The repeatability of yearly calf birth weights, 180-day weights, feeder type and slaughter condition grades for cow herds at Crossville and Greeneville was studied. The performance of calf production of the cows was determined by the correlation between adjacent records from the same cow by analysis of variance.

Two hundred and eighty-three and one hundred and seventy-eight calves from cows at Crossville and Greeneville respectively were usable for this study. The actual numbers used in each analysis varied according to the requirements for statistical analysis, deaths and missing information.

The average birth weights for calves from the cow herd at Crossville was 73.1 pounds for males and 66.5 pounds for females. At Greeneville the average birth weights were 73.0 pounds for males and 67.0 pounds for females. All birth weights were adjusted to male basis by adding 6.6 and 6.0 pounds to the birth weights of female calves at Crossville and Greeneville respectively.

The mean 180-day calf weaning weights at Crossville was 460 pounds for males and 409 pounds for females. At Greeneville the average weaning weights were 403.2 pounds for males and 377.4 pounds for females. The 180-day calf weaning weights were adjusted to male basis by adding 51 pounds to the weights of female calves in the Crossville herd and 25.8 pounds to the weights of female calves at Greeneville. Adjustments for age of dam and for year difference were also made at the Crossville station. In the

correlation and regression analyses at Greeneville an adjustment for year differences only was made since differences due to age of dam was confounded with year differences at that station. The 180-day weights at both stations were determined by prorating the calf gains made during the twenty-eight day period bracketing this age.

The intraclass correlation for differences between cows at Crossville was 0.03 for birth weights, 0.21 for 180-day weights, 0.11 for weaning calf feeder type grades and 0.04 for slaughter condition grades. For the Greeneville herd the following intraclass correlations for differences between cows were 0.01, 0.61, 0.39 and 0.51 for birth weights, 180-day weaning weights, feeder type and slaughter condition grades respectively.

In the Crossville herd the average correlation coefficients for adjacent performance records of the same cows were 0.01 for calf birth weights, 0.25 for 180-day weaning weights, 0.16 for weaning feeder type grades and 0.19 for slaughter condition grades. The average correlation coefficient for cow performance at Greeneville were -0.01 for calf birth weights, 0.62 for 180-day weaning weights, 0.28 for feeder type grades and 0.45 for slaughter condition grades.

Regression coefficients for the Crossville herd were -0.01 for birth weights, 0.24 for 18-day weights, 0.17 for feeder type grades and 0.19 for slaughter condition grades. The regression coefficients for cow performance of -0.01, 0.64, 0.31 and 0.50 for calf birth and 180-day weights and weaning feeder type and slaughter condition grades respectively were observed in the Greeneville herd.

The results observed in this study indicate that the weaning weight of a cow's first calf is indicative of future performance in respect to weaning weight. Cows producing first calves below the herd average for weaning weight consistently produced calves below the herd average. The cows that produced calves above herd average as heifers continued as high producers up to six or seven years of age. In general, breeding cows may be selected with a certain amount of confidence for future productivity on the basis of the first calf record for weaning weight. Seldom would a potentially high producing cow be eliminated from the herd by culling on the basis of the first calf record for weaning weight.

In this study results indicate that the weaning feeder type and slaughter condition grades of a cow's first calf would be of some value in predicting her future performance for these characteristics. However, the accuracy of selection might be increased considerably if at least two or possibly more records from the same cow were available.

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APPENDIX

TABLE I

ANALYSIS OF VARIANCE OF CALF BIRTH WEIGHTS AT CROSSVILLE

Source	Degrees of Freedom	Sums of squares	Mean square	Theoretical composition of mean square	Components
Total	282	22,165.	78.6		
Between years dropped	6	822.1	137.0		
Between cows within years	49	4,304.3	87.8	$\sigma_w^2 + k_o \sigma_c^2$	2.5
Within cows	227	17,039.	75.1	σ_w^2	

k_o = Effective number of calves per cow = 5.0

$$\text{Intraclass correlation} = \frac{2.5}{75.1 + 2.5} = 0.03$$

TABLE II

CORRELATIONS AND REGRESSIONS AMONG BIRTH WEIGHTS OF CALVES FROM THE SAME COWS CALVING IN SUCCESSIVE YEARS AT CROSSVILLE

Cow age	Degrees of freedom	Sums of squares and products			Correlation coefficient	Regression coefficient
		Sx^2	Sxy	Sy^2		
2 - 3	35	2,256.5	440.1	2,305.2	+ 0.19	+ 0.02
3 - 4	29	4,671.5	679.5	1,280.9	+ 0.28	+ 0.15
4 - 5	28	2,552.6	-341.2	1,949.8	- 0.15	- 0.13
5 - 6	22	1,493.7	-209.2	1,568.9	- 0.14	- 0.14
6 - 7	22	1,429.8	438.2	2,612.9	+ 0.23	+ 0.31
7 - 8	21	2,401.1	-447.8	2,117.5	- 0.20	- 0.19
8 - 9	15	1,574.5	-174.1	1,546.5	- 0.11	- 0.11
9 - 10	7	1,007.2	-164.7	319.1	- 0.30	- 0.02
10 - 11	4	259.3	-112.1	422.3	- 0.34	- 0.43
Sums	183	17,646.2	-108.7	14,123.1	- 0.01	- 0.01

TABLE III

ANALYSIS OF VARIANCE OF 180-DAY CALF WEANING WEIGHTS AT CROSSVILLE[a]

Source	Degrees of freedom	Sums of squares	Mean square	Theoretical composition of mean square	Components
Total	280	831,960	2,971.3		
Between years dropped	6	127,448	21,241.3		
Between cows within years	49	239,413	4,886.9**	$\sigma^2_w + k_o\sigma^2_c$	556.0
Within cows	225	465,099	2,067.1	σ^2_w	2,067.1

k_o = Effective number of calves per cow = 5.1

$$\text{Intraclass correlation} = \frac{556.0}{2,067.1 + 556.0} = 0.21$$

[a] 281 weaning weights were used. The difference of 2 weights between birth weights and weaning weights analysis of variance is explained as follows: one cow gave birth to only one calf and was not used; one calf died near weaning age and was not used.

** $P = < .01$

TABLE IV

CORRELATIONS AND REGRESSIONS AMONG 180-DAY WEIGHTS OF CALVES FROM THE SAME COWS CALVING IN SUCCESSIVE YEARS AT CROSSVILLE

Cow age	Degrees of freedom	Sums of squares and products			Correlation coefficient	Regression coefficient
		Sx^2	Sxy	Sy^2		
2 - 3	35	102,943	57,427	120,906	+ 0.52 **	+ 0.56
3 - 4	27	52,484	24,262	60,438	+ 0.43 *	+ 0.46
4 - 5	26	56,393	- 6,665	42,615	- 0.01	- 0.12
5 - 6	22	48,223	- 3,463	64,384	- 0.06	- 0.07
6 - 7	22	58,736	- 7,031	33,265	- 0.14	- 0.12
7 - 8	21	46,233	24,599	22,935	+ 0.75 **	+ 0.53
8 - 9	16	18,551	5,086	11,846	+ 0.34	+ 0.27
9 - 10	7	8,315	698	13,994	+ 0.06	+ 0.08
10 - 11	3	4,069	1,629	2,713	+ 0.49	+ 0.40
Sums	179	395,947	96,542	373,096	+ 0.25 **	+ 0.24

*P = < .05 > .01

**P = < .01

TABLE V

ANALYSIS OF VARIANCE OF WEANING GRADES FOR FEEDER TYPE AT CROSSVILLE[a]

Source	Degrees of freedom	Sums of squares	Mean square	Theoretical composition of mean square	Components
Total	183	314.0	1.7		
Between years dropped	6	46.4	7.8		
Between cows within years	31	67.9	2.2*	$\sigma^2_w + k_o \sigma^2_c$	0.17
Within cows	146	199.6	1.4	σ^2_w	

k_o = Effective number of calves per cow = 4.8

$$\text{Intraclass correlation} = \frac{.17}{1.4 + .17} = 0.11$$

[a] 184 weaning grades for feeder type were used. This difference of 97 from the number of 180-day calf weaning weights is due to the fact that the calves were not graded in 1942, 1943, 1944 and 1945, and some grades were missing in other years.

*P = <.05 >.01

TABLE VI

CORRELATIONS AND REGRESSIONS AMONG WEANING GRADES FOR FEEDER TYPE OF CALVES FROM THE SAME COWS CALVING IN SUCCESSIVE YEARS AT CROSSVILLE

Cow age	Degrees of freedom	Sums of squares and products			Correlation coefficient	Regression coefficient
		Sx^2	Sxy	Sy^2		
2 - 3	5	1.5	0.5	1.3	+ 0.35	+ 0.33
3 - 4	8	4.8	- 0.3	9.2	- 0.04	- 0.05
4 - 5	14	13.4	3.3	16.0	+ 0.22	+ 0.25
5 - 6	15	17.0	1.4	19.1	+ 0.08	+ 0.08
6 - 7	20	27.5	1.9	28.2	+ 0.07	+ 0.07
7 - 8	18	24.5	9.0	18.7	+ 0.42	+ 0.37
8 - 9	15	24.2	15.8	17.9	+ 0.76 **	+ 0.66
9 - 10	5	5.2	- 7.2	12.2	- 0.90 **	- 1.38
10 - 11	3	7.9	- 3.2	5.3	- 0.50	- 0.40
Sums	103	126.1	21.2	127.9	+ 0.16	+ 0.17

**$P = < .01$

TABLE VII

ANALYSIS OF VARIANCE OF WEANING GRADES FOR SLAUGHTER CONDITION AT CROSSVILLE[a]

Source	Degrees of freedom	Sums of squares	Mean square	Theoretical composition of mean square	Components
Total	185	365.4	2.0		
Between years dropped	6	29.9	5.0		
Between cows within years	31	67.4	2.2	$\sigma_w^2 + k_o \sigma_c^2$	.07
Within cows	148	268.0	1.8	σ_w^2	1.8

k_o = Effective number of calves per cow = 4.87

$$\text{Intraclass correlation} = \frac{.07}{1.8 + .07} = .04$$

[a]186 weaning grades for slaughter condition were used. This difference of 95 from the number of 180-day weaning weights is due to the fact that the calves were not graded in 1942, 1943, 1944 and 1945, and some grades were missing in other years.

TABLE VIII

CORRELATIONS AND REGRESSIONS AMONG WEANING GRADES FOR SLAUGHTER CONDITION OF CALVES FROM THE SAME COWS CALVING IN SUCCESSIVE YEARS AT CROSSVILLE

Cow age	Degrees of freedom	Sums of squares and products			Correlation coefficient	Regression coefficient
		Sx^2	Sxy	Sy^2		
2 - 3	5	2.7	2.0	4.1	+ 0.61	+ 0.75
3 - 4	8	3.7	- 3.7	12.1	- 0.55	+ 0.10
4 - 5	14	13.6	0.9	15.8	+ 0.06	+ 0.07
5 - 6	15	26.3	13.3	25.9	+ 0.51 *	+ 0.51
6 - 7	21	27.9	2.3	19.7	+ 0.10	- 0.08
7 - 8	19	31.3	12.5	30.3	+ 0.40	+ 0.40
8 - 9	15	21.9	- 1.4	29.1	- 0.05	- 0.06
9 - 10	6	10.3	3.6	8.4	+ 0.39	+ 0.35
10 - 11	4	5.9	2.9	10.8	+ 0.38	+ 0.50
Sums	107	143.6	27.8	156.2	+ 0.19 *	+ 0.19

*P = <.05 >.01

TABLE IX

ANALYSIS OF VARIANCE OF CALF BIRTH WEIGHTS AT GREENEVILLE

Source	Degrees of freedom	Sums of squares	Mean square	Theoretical composition of mean square	Components
Total	177	13,200.0	74.6		
Between groups	1	25.3	25.3		
Between cows within years	176	13,174.7	74.9		
Between years within groups	8	2,874.1	359.3		
Remainder	168	10,300.6	61.3		
Between cows within groups	37	2,361.4	63.8	$\sigma_w^2 + k_o \sigma_c^2$	0.71
Within cows	131	7,399.2	60.6	σ_w^2	60.6

k_o = Effective number of calves per cow = 4.51

$$\text{Intraclass correlation} = \frac{.71}{60.60 + .71} = 0.01$$

TABLE X

CORRELATIONS AND REGRESSIONS AMONG BIRTH WEIGHTS OF CALVES FROM THE SAME COWS CALVING IN SUCCESSIVE YEARS AT GREENEVILLE

Cow age	Degrees of freedom	Sums of squares and products			Correlation coefficient	Regression coefficient
		Sx^2	Sxy	Sy^2		
3-4	36	2,115	-214	2,796	-0.09	-0.01
4-5	32	2,267	-243	1,958	-0.01	-0.01
5-6	29	2,337	- 76	1,864	-0.004	-0.003
6-7	23	1,732	418	938	+0.03	+0.02
Sums	120	8,451	-115	7,556	-0.01	-0.01

TABLE XI

ANALYSIS OF VARIANCE OF 180-DAY CALF WEANING WEIGHTS AT GREENEVILLE

Source	Degrees of freedom	Sums of squares	Mean square	Theoretical composition of mean square	Components
Total	175	435,776.	2,490.1		
Between groups	1	4,418.	4,418.0		
Within groups	174	431,358.	2,479.1		
Between years within groups	8	63,330.	7,916.3		
Remainder	166	368,028.	2,217.0		
Between cows within groups	37	255,382.3	6,902.2**	$6\sigma^2_w + k_o 6\sigma^2_c$	1,351.8
Within cows	129	112,646.7	873.2	$6\sigma^2_w$	873.2

k_o = Effective number of calves per cow = 4.46

$$\text{Intraclass correlation} = \frac{1,351.8}{873.2 + 1,351.8} = .61$$

**P = <.01

TABLE XII

CORRELATIONS AND REGRESSIONS AMONG 180-DAY WEIGHTS OF CALVES FROM THE SAME COWS CALVING IN SUCCESSIVE YEARS AT GREENEVILLE

Cow age	Degrees of freedom	Sums of squares and products			Correlation coefficient	Regression coefficient
		Sx^2	Sxy	Sy^2		
3 - 4	36	76,612.	45,044.	76,184.	+ 0.59 **	+ 0.59
4 - 5	32	66,746.	38,641.	66,208.	+ 0.58 **	+ 0.58
5 - 6	31	64,986.	44,368.	59,142.	+ 0.66 **	+ 0.68
6 - 7	26	41,176.	32,592.	62.051.	+ 0.64 **	+ 0.79
Sums	125	249,520.	160,645.	263.585	+ 0.62 **	+ 0.64

**P = <.01

TABLE XIII

ANALYSIS OF VARIANCE OF WEANING GRADES FOR FEEDER TYPE AT GREENEVILLE

Source	Degrees of freedom	Sums of squares	Mean square	Theoretical composition of mean square	Components
Total	173	355.7	2.1		
Between groups	1	1.1	1.1		
Within groups	172	354.5	2.1		
Between years within groups	8	66.9	8.4		
Remainder	164	287.7	1.8		
Between cows within groups	36	148.5	4.1	$** \sigma_w^2 + k_o \sigma_c^2$	0.69
Within cows	128	139.1	1.1	σ_w^2	1.1

k_o = Effective number of calves per cow = 4.41

Intraclass correlation = $\frac{.69}{1.1 + .69}$ = .39

$^{**}P$ = < .01

TABLE XIV

CORRELATIONS AND REGRESSIONS AMONG WEANING GRADES FOR FEEDER TYPE OF CALVES FROM THE SAME COWS CALVING IN SUCCESSIVE YEARS AT GREENEVILLE

Cow age	Degrees of freedom	Sums of squares and products			Correlation coefficient	Regression coefficient
		Sx^2	Sxy	Sy^2		
3 - 4	36	62.8	22.6	39.1	+ 0.46 **	+ 0.36
4 - 5	32	36.3	20.2	45.1	+ 0.50 **	+ 0.56
5 - 6	29	41.2	- .54	47.6	- 0.01	- 0.01
6 - 7	23	31.7	11.3	90.4	+ 0.21	+ 0.36
Sums	120	171.9	53.5	222.1	+ 0.28 **	+ 0.31

**P = <.01

TABLE XV

ANALYSIS OF VARIANCE OF WEANING GRADES FOR SLAUGHTER CONDITION AT GREENEVILLE

Source	Degrees of freedom	Sums of squares	Mean square	Theoretical composition of mean square	Components
Total	173	451.0	2.6		
Between groups	1	9.7	9.7		
Between cows within groups	172	441.4	2.6		
Between years within groups	8	213.2	26.7		
Remainder	164	228.1	1.4		
Between cows within groups	37	140.7	3.8 **	$6^2_w + k_o 6^2_c$	.71
Within cows	127	87.4	.69	6^2_w	.69

k_o = Effective number of calves per cow = 4.41

Intraclass correlation = $\frac{.71}{.69 + .71} = .51$

**P = <.01

TABLE XVI

CORRELATIONS AND REGRESSIONS AMONG WEANING GRADES FROM SLAUGHTER CONDITION OF CALVES FROM THE SAME COWS CALVING IN SUCCESSIVE YEARS AT GREENEVILLE

Cow age	Degrees of freedom	Sums of squares and products			Correlation coefficient	Regression coefficient
		Sx^2	Sxy	Sy^2		
3 - 4	36	43.4	18.9	40.9	+ 0.45 **	+ 0.44
4 - 5	32	41.1	18.9	31.4	+ 0.53 **	+ 0.46
5 - 6	29	20.1	16.3	42.1	+ 0.56 **	+ 0.81
6 - 7	23	23.3	10.2	46.0	+ 0.31	+ 0.44
Sums	120	127.9	64.3	160.4	+ 0.45 **	+ 0.50

** $P = < 0.1$

TABLE XVII

METHOD OF SCORING FOR FEEDER TYPE AND SLAUGHTER CONDITION GRADES

Type		Condition		Legend
Symbol	Number	Symbol	Number	
HF	17	HP	17	F = Fancy
F	16	P	16	P = Prime
LF	15	LP	15	C = Choice
HC	14	HC	14	G = Good
C	13	C	13	M = Medium
LC	12	LC	12	Co. = Common
HG	11	HG	11	Com.= Commercial
G	10	G	10	Ut. = Utility
LG	9	LG	9	Cut.= Cutter
HM	8	HCom.	8	Can.= Canner
M	7	Com.	7	
LM	6	LCom.	6	H = High
HCo.	5	HUt.	5	L = Low
Co.	4	Ut.	4	
LCo.	3	LUt.	3	
		Cut.	2	
		Can.	1	

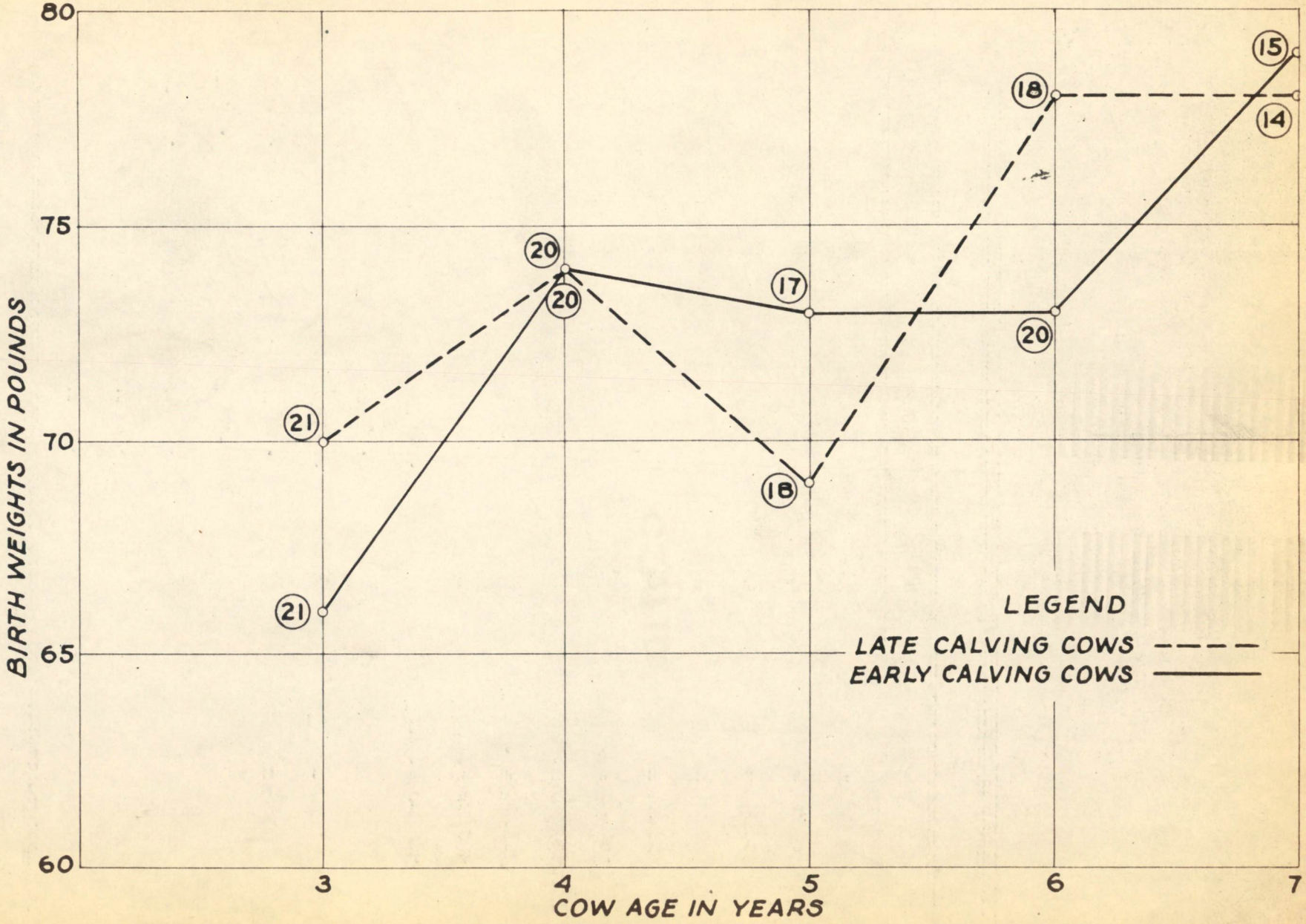


FIG. 1. MEAN CALF BIRTH WEIGHTS FOR ALL CALVES BY COW AGE AT GREENEVILLE. (ADJUSTED FOR SEX)

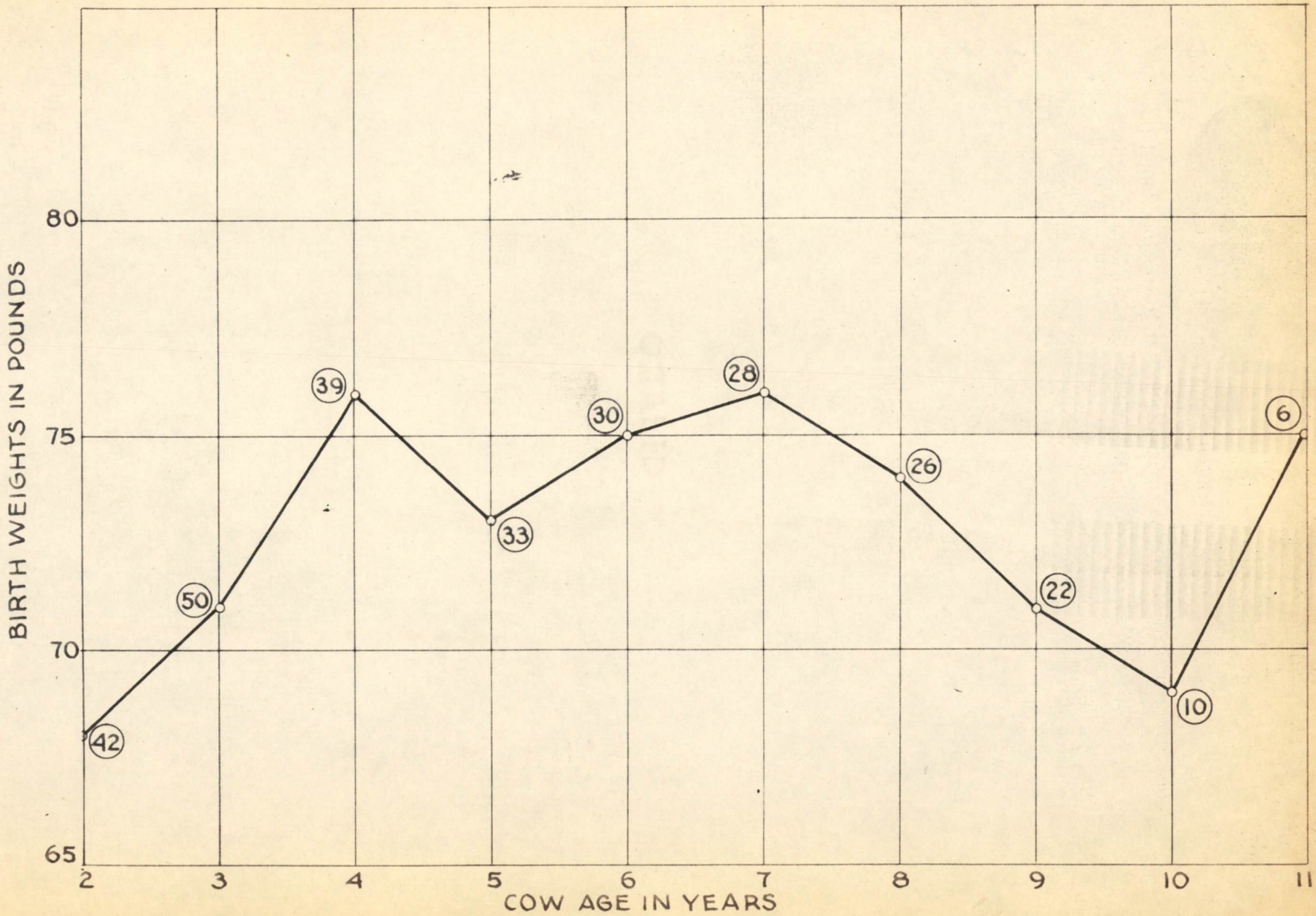


FIG. 2. MEAN CALF BIRTH WEIGHTS FOR ALL CALVES BY COW AGE AT CROSSVILLE. (ADJUSTED FOR SEX)

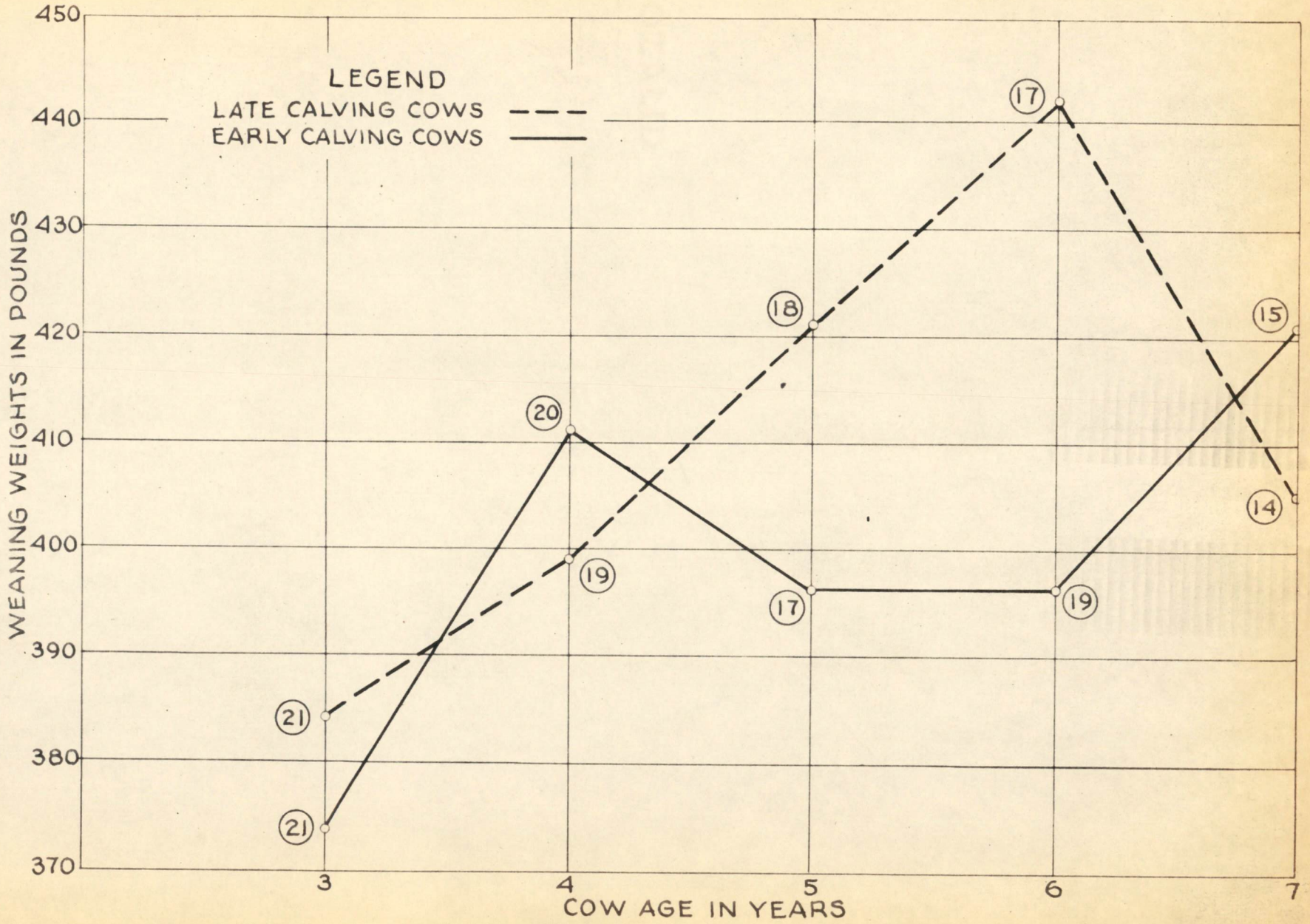


FIG. 3. MEAN WEANING WEIGHTS FOR ALL CALVES BY COW AGE AT GREENEVILLE. (ADJUSTED FOR SEX)

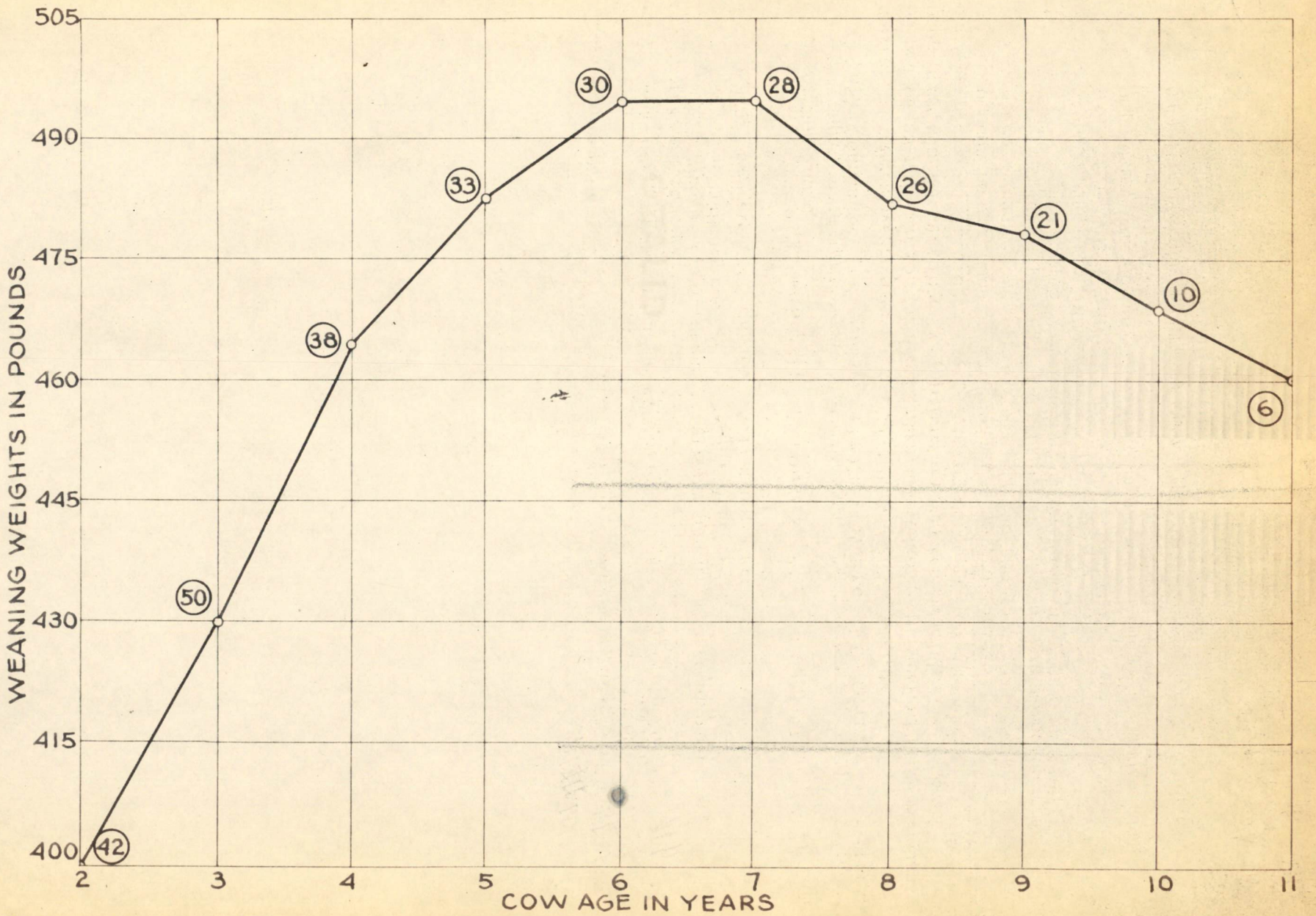


FIG. 4. MEAN WEANING WEIGHTS FOR ALL CALVES BY COW AGE AT CROSSVILLE. (ADJUSTED FOR SEX)