REPEATABILITY OF WEIGHTS AND GAINS IN RANGE BEEF CATTLE

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Bachelor of Science-1948

Master of Science - 1949

University of Wyoming

Laramie, Wyoming

Submitted to the Faculty of the Graduate School of

the Oklahoma Agricultural and Mechanical College

in Partial Fulfillment of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

May, 1952

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1952

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ACKNOWLEDGEMENT

The writer wishes to express his appreciation to Dr. James A. Whatley, Jr., Professor of Animal Husbandry, for many helpful suggestions during the present study and the preparation of this thesis. The helpful suggestions of Dr. Doyle Chambers, Associate Professor of Animal Husbandry, and Dr. A. E. Darlow, Head of the Animal Husbandry Department are also deeply appreciated.

He also wishes to acknowledge the assistance of Dr. Arnold B. Nelson and Mr. W. D. Campbell of the Animal Husbandry Department in making available records which were used in this study.

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PART I

REPEATABILITY OF PRODUCTION IN RANGE BEEF COWS

INTRODUCTION

The most powerful force a breeder has available for the improvement of his livestock is selection, either by itself or in conjunction with some form of controlled mating system. Selection is a differential reproductive rate, and any selection practiced by breeders is the elimination of undesirable animals, allowing the more desirable ones to reproduce at a proportionately greater rate. Some differential in reproductive rate occurs automatically as a result of natural selection, and it is only after this has occurred that the breeder can exert any influence. The extent to which genetic improvement can be influenced by selection is limited by the heritability of the trait and the size of the selection differential. The selection differential depends on the size of the population, the amount of variability, and the percentage of offspring which must be saved as replacements. Heritability, in the narrowest sense, is the portion of variance which is due to the additive effects of genes. Any increase in the variance may permit a larger selection differential, but only an increase in the additively genetic portion of the variance would increase the effectiveness of selection. An increase of the additively genetic portion of the variance without a corresponding increase of the other portions of the total variance would also increase the heritability; thus the two main factors influencing the effectiveness of selection both depend on the amount of variance due to the additive effects of genes. Genetic variability is required in order for selection to be effective. Anything which reduces the environmental portion of the variance, such as a uniform environment, would increase the heritability and thus the effectiveness of selection.

If heritability is low, selection of individuals on their phenotype is subject to several sources of error: confusing genotypes because of dominance or epistasis; confusing environmental effects, either temporary or permanent, with the effects of genes; and inaccuracy in measuring performance. As far as the latter is concerned, no selection procedure will be of any help; only some means of increasing accuracy or of obtaining better measures can be useful. If genotypes are confused because of dominance or complex gene interactions, then phenotypes of ancestors, collateral relatives, or progeny can be used to increase the accuracy of predicting an individual's genotype. Much of the variation in expression of economic traits from one time to another is due to variation in environmental effects. As a result, it is very likely that some confusion will result in an attempt to properly evaluate an animal's breeding ability from its own phenotype. The most effective method of eliminating inaccuracies of prediction which are due to temporary environmental influences is the use of repeated records, or of lifetime averages. Obviously, the use of repeated records is most helpful for those traits which are least constant from time to time in an individual's life.

In range beef cattle, production is measured by weights or gains, or both: thus selection for production is based on one or both of these traits. Birth weights, weaning weights, and gain from birth to weaning occur only once in the life of an individual, and it is only when these traits are considered as characteristics of the dam or sire that repeated records become available. The most useful measure of a beef cow's annual production is the weaning weight of her calf. Gain from birth to weaning makes up a large portion of the weaning weight, so is quite comparable to weaning weight as a measure of production. The earliest measure available is the birth weight of the calf, but the accuracy of birth weight as a measure of a cow's production would depend on the correlation between birth weight and weaning weight.

If selection is to be very effective, the producing ability of the cows must be known at a reasonably early age, while there is still opportunity for selection to be practiced. In order to use lifetime production averages most effectively in selection, the repeatability of the trait must be known. Also the repeatability must be known in order to accurately compare the producing abilities of cows with varying numbers of records.

Repeatability is the correlation between recurrent expressions of a trait by the same animal. It is that fraction of the variance in individual calves which is due to permanent differences between cows. In this sense, then, the repeatability should set the upper limit of heritability. The repeatability fraction includes the additively genetic portion of the variance, the variance due to dominance and epistasis, as well as any effects of environment which permanently affect the performance of an individual but are not transmissible to the offspring. Repeatability can be obtained by correlations between records by the same cow, by regression of subsequent records on earlier records by the same cow, or by means of an intraclass correlation (the ratio of variance among cows to the total variance) which can be obtained directly from an analysis of variance.

In addition to being useful as an aid in selection, an estimate of the repeatability can be used as an indication of whether or not experimental animals should be allotted on the basis of past production records. When repeatability of the trait is high, future performance of an animal can be fairly accurately predicted from past performance, and animals can be assigned to outcome levels, or the lots equalized on the basis of past performance, so as to increase the precision of mean differences. On the other hand, if repeatability is low the future performance cannot be accurately estimated from past performance, and little increase in experimental precision is gained by allotment according to past performance.

Several workers have reported studies on repeatability of weaning weight, and one report also dealt with repeatabilities of birth weight and gain from birth to weaning. Even though the studies were conducted in different localities and data were obtained under quite different climatic conditions, the estimates obtained for repeatability of weaning weight are in fairly close agreement. The present study was undertaken to determine the repeatability of certain traits in beef cattle under variable conditions as found in Oklahoma and to determine their usefulness as an aid in selection of breeding stock. Also, an attempt was made to evaluate the influence of several factors which influence birth and weaning weights and to establish usable corrections for these factors.

REVIEW OF LITERATURE

Knapp et al (1942) studied the effect of various factors on birth weights and weaning weights of range beef cattle. Their study included records on 770 calves produced by 112 cows. Analysis of birth weights showed that differences in cows accounted for about 19 percent of the variance, while an analysis of weaning weights showed that about 20 percent of the variance was due to cow influences. Their study also indicated that sex of calf, sire, and age of dam had significant effects on both birth and weaning weights. The authors expressed the belief that more than 20 percent of the variation in a random selected population could be attributed to cow influences, since their study included a select population of cows, all capable of producing large calves.

Koger and Knox (1947) reported the results of a study on repeatability of yearly production of beef cattle. The study included 77 cows which had 5 year records, 96 with 4 year records, 121 with 3 year records and 142 with 2 year records. Correlations for weaning weight and grade of calf were determined between adjacent records by the same cow. The average correlation between the weaning weights of all adjacent calves was .49. The correlation between weaning weights of first and second calves was .66. When the weight of the first calf was compared with the average of various combinations of subsequent calf weights, correlations varied from .51 to .53. When the average of the first two calf weights was compared with various combinations of subsequent calf weights, the correlations varied from .54 to .59. For those cows which had five consecutive records, the portion of variance in weaning weight of calves due to differences between cows was .51 after variance due to age of dam was removed. Comparisons made were within birth year groups, and in general the environmental conditions were relatively constant. For these reasons the authors felt that their estimate of repeatability for weaning weight of calves was higher than that likely to be obtained under different conditions.

The grade of calves was determined by averaging the scores of three judges, and correlations were determined similarly to those for weaning weight. The correlation between grades of first and second calves was .24, and when the first calf grade was compared with an average of two or more subsequent calves' grades, correlations varied from .39 to .42. Averaging grades of the first two calves in the first observation resulted in a marked increase in correlation with subsequent calves' grades, correlations ranging from .46 to .69. Analysis of variance showed that after influences of age of dam were removed, differences in cows accounted for about 33 percent of the variance in calf grades.

Gregory et al (1950) made a similar study, in which estimates of repeatability were obtained by means of correlation and regression coefficients. The data were from two sources, and were therefore analyzed in two groups. Estimates were obtained for repeatability of weaning weight, as well as for birth weight and gain from birth to weaning. Correlations between first and second records were higher than those between second and third or first and third in all three traits studied. Estimates ranged from .35 to .50 for weaning weight, from .38 to .57 for gain from birth to weaning, and from -.12 to .24 for birth weight. Correcting the birth weights for sex differences increased the correlations, but for one source of data, the correlation was still negative. However, the number of calves was rather small and a wide variation in estimates could be expected. At any rate, repeatability of birth weight was considerably lower than that for weaning weight or for gain from birth to weaning. Sex differences were significant for birth weight but not for weaning weight, and sire differences were not significant for either.

Correlation and regression coefficients were determined for different cow-calf weight relationships. Correlation between birth weight and cow weight immediately after calving was .21 in the North Platte data, and correlation between birth weight and last weight of cow before calving was .32 in the Valentine data. Gains from birth to weaning and cow gains from calving to weaning were negatively correlated, -.12 at North Platte and -.34 at Valentine. Correlations between weaning weight and weight of cow at weaning were .20 and -.11 at North Platte and Valentine respectively. The correlations between birth weight and gain from birth to weaning were .07 at North Platte and .44 at Valentine, and between birth weight and weaning weight were .27 at North Platte and .60 at Valentine. Heritability estimates as obtained from paternal half-sib correlations were .45 and 1.00 for birth weight, 0 and .45 for gain from birth to weaning, and .26 and .52 for weaning weight at North Platte and Valentine respectively.

Koch (1950), analyzing data obtained from 745 calves produced by 180 cows at Miles City, Montana, determined the repeatability of weaning weight by means of a ratio of variances. His method of correction for variables was the method of least squares and the fitting of constants. The factors considered were: age of calf, sex, year, age of dam, inbreeding of calves, inbreeding of cows and cow influences. His estimate of the portion of the variance due to permanent differences between cows was .52, with upper and lower limits at the 5 percent confidence interval of .60 and .44 respectively.

Woodward and Clark (1950) reported data on the repeatability of performance by several different Hereford sires. Although the degree of repeatability was not measured, the sires did tend to repeat their performance. The variance due to different sires was significantly greater than variance within sire groups for birth weight, gain from birth to weaning, rate of gain and efficiency of gain in the feedlot.

Lush and Arnold (1937) studied milk production records from 676 daughters and dams in Iowa Cow Testing Associations to find what share of the differences between single records were due to permanent differences between individual cows and what share of those permanent differences were transmitted to the daughters. Cows mated to the same sire were divided into high and low groups on the basis of the amount of fat produced in the first lactation tested. Regression of later records toward the herd average showed the extent to which differences in the first records were due to temporary environmental conditions. The differences between the average records of the daughters of the two groups of cows, when doubled and divided by the average difference between the first records of their dams, measured the degree to which variations in single records were inherited and the amount of gain which could be obtained in the first generation of selection. The estimate obtained for repeatability was .43, and that for the inherited portion of variation was .28. Thus 15 percent of the variance was due to permanent but non-transmissible differences between cows.

Dickerson (1940) determined the repeatability of butterfat yield on 1574 unadjusted lactation records from 274 Holstein cows in 41 herds. Records at 240 days, 305 days, 365 days, and total lactation were analyzed, and repeatability estimates ranged from .23 for 240 day records to .26 for total lactation records. Also 1456 testing year butterfat records were studied and the repeatability obtained was .24. Correction for age significantly increased the repeatability of all five kinds of records by from 1/6 to 1/2, the increase being greater for 240 day and 305 day records than for longer lactation records. A sharp reduction in variation among records of the same cow as well as an increase in variation between cow means resulted from the age correction. Likewise, correction for calving interval to a 365 day basis significantly increased the repeatability.

Berry (1945), using data obtained from HIR yearbooks on 454 Holstein cows which had completed six or more lactations, found a gross repeatability for butterfat production of .41 and an intra-herd repeatability of .29 for six record cows. The repeatabilities were .38 and .23, gross and intra-herd respectively, for seven record cows. The actual correlations between single records and various combinations of preceding records made by the same cow were in very close agreement with expected values for those combinations. In his formula for predicting the real producing ability of cows, he used W^2 in place of repeatability. W^2 was that part of the repeatability left after effects of proximity were removed, and was approximately .03 to .09 less than repeatability.

In sows the repeatability of litter size and litter weight has been studied by various workers, and reports indicate that the repeatability of production records in swine is low. The most extensive study reported is that of Lush and Molln (1942), in which 7415 litters from 2560 sows were analyzed for number of pigs farrowed, 4920 litters from 1634 sows analyzed for number of pigs weaned, and 2144 litters from 830 sows analyzed for weaning weight of the litter. Data were collected in experiment stations and college herds of eight states and in herds maintained by the United States Bureau of Animal Industry. Three estimates were obtained for each trait, the estimates being .15, .13 and .17 for number farrowed; .16, .13 and .17 for number weaned; and .13, .12 and .18 for weaning weight of litter.

Blunn and Baker (1949) estimated the heritability of various traits in swine, using the repeatability estimate and intra-sire regression of daughter on dam. The estimate of repeatability of litter weaning weight was .53 as compared to an estimate of .21 from intra-sire regression of offspring on dam. Averaged, the two estimates gave .37 for heritability of litter weaning weight.

Bywaters (1937) estimated the relative importance of heredity and environment in causing variation of weaning weight in swine. The heredity of the pig accounted for 18 percent of the total variance, and of this, less than one fourth was due to additive effects of genes. His estimate of the portion of variance due to permanent differences between dams was 10 percent.

Whatley (1942) estimated the heritability of 180 day weight in swine by means of several different methods. His estimates ranged from .20 to .62. The general conclusion drawn from the study was that at least 30 percent and perhaps more than 40 percent of the individual differences in 180 day weights was due to the additive effects of genes.

Baker et al (1943) investigated the relative importance of heredity and environment in growth of pigs at various ages, and found that the heredity of the pig played an increasingly important role in development from birth to 112 days. The genetic variance in rate of gain during relatively short intervals increased from 7 percent to 31 percent. After 112 days, the relative importance of heredity decreased considerably. The genetic variance in weight increased from zero at birth to 28 percent at 112 days and decreased thereafter.

Cummings et al (1947) found the heritability of litter weaning weight to be 7 percent. However, when effects of size of litter at birth and survival were held constant, the heritability of litter weaning weight was found to be 59 percent. It was suggested that the latter estimate might be a close approximation for heritability of milk production.

The only known estimate of repeatability of weaning weights in sheep is that reported by Sidwell and Grandstaff (1949). Their study included weaning weights of 1506 lambs from 414 ewes, and weights were corrected for the effects of age of dam, breed of sire, type of birth and rearing, sex and year. After the weights were corrected, an analysis of variance was made on the corrected weights. Repeatability was measured by the ratio of variance between ewes to the total variance. The estimate obtained for repeatability of weaning weight was .22.

Heritability estimates of weaning weights of lambs have been reported by Hazel and Terrill (1945, 1946). Estimates were determined by half-sib correlations and offspring-dam regressions for range Columbia, Corriedale and Targhee lambs as follows:

Columbia		Corriedale		Targhee	
Half-sib	Offspring-Dam	Half-sib	Offspring-Dam	Half-sib	Offspring-Dam
.16	.21	.32	.45	.08	-.01

The average for heritability of weaning weight of all three breeds was .17.

In range Rambouillet lambs, the average of four estimates by means of half-sib correlations was .27, and the average by means of intra-sire regression of offspring on dam was .34.

MATERIALS AND METHODS

The data used in this study were birth weights and weaning weights of calves produced in the experimental herd of grade Hereford cows at the Lake Blackwell area near Stillwater and from the experimental herd at the Fort Reno Experiment Station. There were birth weights on 620 calves and weaning weights on 611 calves produced by 151 cows during the eight year period from 1944 through 1951 at the Lake Blackwell area, and birth and weaning weights of 98 calves from 49 cows during 1950 and 1951 at the Fort Reno station. The cows in the experimental herd at Stillwater all calved first as three year olds, while the group at Fort Reno calved first as two year olds. Data from the two sources were analyzed separately even though range conditions and methods of handling were quite similar at both places.

Most of the calves were dropped over the three month period of February, March and April, although a few were dropped in January and May. All calves were weighed within twenty four hours of birth. All calves were dehorned and the males were castrated in late April with the exception of a few late calves which were not dehorned or castrated until Fall. Each year, all calves were weaned at the same time, usually sometime in October. The average age of all calves at weaning was 217 days. With the exception of one group of 26 calves which were creep fed during the summer of 1951, all calves were allowed to run with their dams from birth to weaning without access to feed other than their mothers' milk and what grass they would eat. The cows in the experimental herd were subjected to different treatments. Some were in an experiment to test methods of wintering, and some were in an experiment to test various levels of phosphorous, and later, different levels of manganese in the ration. The cows in one group were weighed at monthly intervals, while the other group were weighed at about six weeks intervals. Corrections for the effects of the various treatments on calf weights are discussed in the following section.

The methods used to determine repeatability were the determination of the intraclass correlation coefficient from the analysis of variance and the regression of subsequent records on earlier records by the same cow. All analyses were made on corrected weights.

CORRECTIONS FOR KNOWN VARIABLES

When making comparisons of different calves' weights, some allowance should be made for the effects of certain known variables. Weaning weight or birth weight can be standardized by correcting for the effects of measurable variables. The procedure is to correct the calf weight to what it would have been under standard conditions in which those known variables were controlled. Although this method will be correct on the average, it is not necessarily correct for any individual weight. Since there is not complete control of any particular variable, this method is likely to be helpful for only a few of the important variables. If too many corrections are attempted, it is possible to reach a point where corrections are useless. At any rate, too little increase in accuracy will be gained to make the effort worth while. The variables considered in the present study were: age of calf, sex, age of dam, year and treatment.

Age of Calf

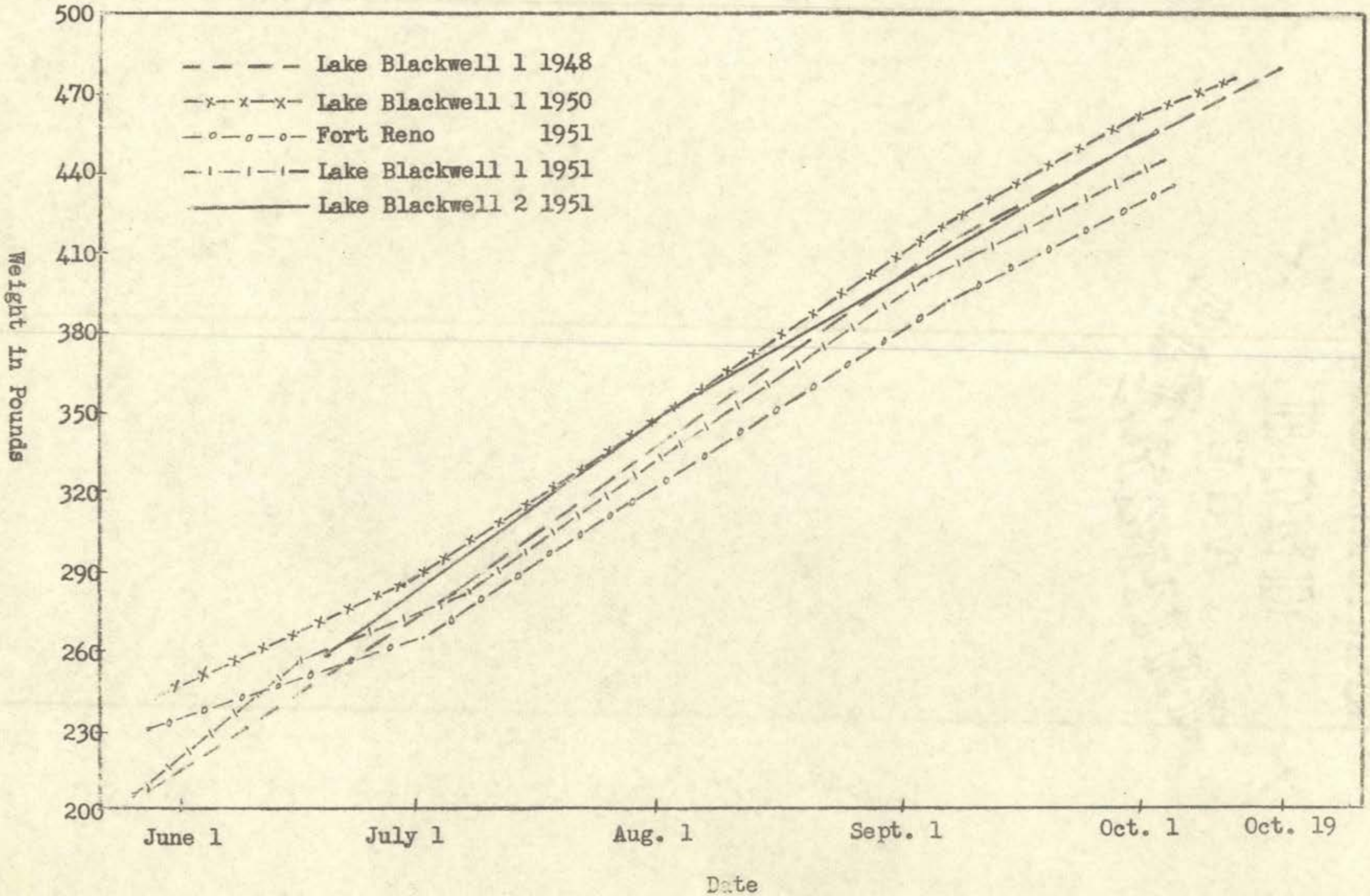
The most accurate method of eliminating variation in weaning weight due to differences in age of calves would be to weigh them at a constant age. However, the extra time and labor required for weighing each calf when it reaches a certain age make this method impractical for use under range conditions. Usually all calves are weaned on the same day to avoid extra handling of the cattle, and for the most part the calves included in this study were handled in this manner. Therefore, the weights obtained are from calves varying considerably in age. The weaning age of calves included in this study varied from 120 days to 262 days.

The method used to correct for differences in age is a method used by Bywaters and Willham (1935) and Whatley and Quaife (1937) for standardizing the weights of pigs of varying ages. The method was used by Phillips and Brier (1940) for standardizing weights of lambs to an age of twenty weeks. More recently, the method has been extended for use in beef cattle by Johnson and Dinkel (1951) and weaning weights were corrected to an average of 190 days. Since the method is based on the regression of weaning weight on weaning age, it assumes that the growth rate of calves is essentially linear during that portion of the growth curve in which corrections are applied. Johnson and Dinkel used monthly weights to plot a growth curve and divided the curve into two portions - 0 to 154 days, and 155 to 225 days. Each portion of the curve was very nearly linear, but the regression coefficients differed. In the present study, monthly weights were available for only three of the eight years, and in two of these three years monthly weights were available for only about one half of the calves. The average weights of the calves in each group were plotted against time and are graphically represented in Figure 1. A study of these curves indicates that little error would result from the assumption of linearity. Therefore a simple regression coefficient was used, assuming that growth was linear during the entire range of ages included in the study. However, the growth curves were obtained from calves during the best years as far as weaning weight was concerned, and may not be typical of the curve under less favorable late summer grazing conditions.

To further check the assumption of linear growth during the period to which corrections were applied, weaning weights were corrected on the basis

Figure 1

Growth Curves of Five Groups of Calves



of the regression coefficients and also on the basis of average daily gain for those calves which had several weights available. The correlation between weights corrected by the two methods was .98, indicating that the two methods gave very nearly the same results. The only cases in which the deviation between weights corrected by the two methods was very large were for very young calves, 50 days or more younger than the average. For these calves, the regression coefficient was lower than the average daily gain, therefore weights corrected by means of the regression coefficient would be lighter than if they were corrected by means of the average daily gain. It appears from a study of Figure 1 and growth curves reported by Lush (1930) and Johnson and Dinkel (1951), that growth slows down in late Summer and Fall. If it is assumed that the young calves would follow the same trend as their age increases, correcting by means of average daily gain would result in an overcorrection, whereas correcting by means of regression coefficient would allow for a decrease in growth rate as these calves become older. However, it is possible that the use of regression may result in an undercorrection.

The data were divided into subclasses according to sex of calf, age of dam and year, and the regression coefficient calculated on an intraclass basis as shown in Table I.

Table I

Regression of Weaning Weight (Y) on Weaning Age (X).

Source of Variation	d.f.	$\sum x^2$	$\sum xy$	b
Total	609	432,291	577,671	1.34
Subclass	110	138,235	148,943	
Intraclass	499	294,056	428,728	1.46

The average age was 217 days, and the average weight was 442 pounds. The average weaning weight was corrected to 210 days by the intraclass regression coefficient of 1.46, and the corrected average used in the formula for the age intercept which is shown in the following paragraph.

The weights of the calves were corrected to a standard age of 210 days according to the following series of formulas, as outlined by Whatley and Quaife (1937):

$$\text{Age Intercept} = \text{Average Age} - \frac{(\text{Average Weaning Weight})}{(\text{Regression Coefficient})}$$

$$\text{Age Intercept} = 210 - \frac{(432)}{(1.46)} = -86$$

The correction for weaning weight is:

$$\text{Corrected Weight} = \text{Actual Weight} \times \frac{(\text{Standard Age} - \text{Age Intercept})}{(\text{Actual Age} - \text{Age Intercept})}$$

$$\text{Corrected Weight} = \text{Actual Weight} \times \frac{(296)}{(\text{Age} + 86)}$$

In using this method, a table can be made of the correction factors for the various ages. A partial table is shown in Table II. The correction factor for a certain age is multiplied by the actual weight of a calf of that particular age.

Table II

Correction Factors for Varying Ages of Calves at Weaning

Age	C.F.	Age	C.F.
209	1.0034	211	.9966
208	1.0068	212	.9933
207	1.0102	213	.9900
206	1.0137	214	.9867
205	1.0172	215	.9834

The Influence of Sex

Since the calves produced by any one cow may be all the same sex, or in many cases the number of males and females are unequal, some allowance may be necessary for differences between sexes when comparing the production of different cows. Knapp et al (1942) found a difference of 22 pounds between the weaning weight of males and females. The corresponding difference found by Koger and Knox (1945) was 32 pounds. Likewise, Koch (1950) found the average difference between males and females to be 23 pounds. The study reported by Gregory et al (1950) failed to show a significant difference in weaning weight due to sex. Sawyer et al (1949) found that heifers were heavier than steers at weaning. The difference between sexes at birth has been reported as 4 to 5 pounds by Dawson et al (1947), Gregory et al (1950) and Burris and Blunn (1952). The average difference in favor of male calves in the present study was approximately 25 pounds for weaning weight and about 4 pounds for birth weight, (Table III). The weaning weights in this table were adjusted to a 210 day standard age.

Table III

Differences between Males and Females for Birth and Weaning Weight.

Weaning Weight			Birth Weight		
Sex	No. of Calves	Ave. Wt.	Sex	No. of Calves	Ave. Wt.
Male	306	444.2#	Male	314	74.8#
Female	301	419.6#	Female	311	70.4#
Difference		24.6#	Difference		4.4#

All the male calves were castrated each year during late April, but the few calves which were born in May usually were not castrated until weaning time. Therefore, the males at weaning include a few bulls, but not in great enough numbers to be considered separately.

Since the difference between sexes apparently increases with weight and age, the most logical sex correction would be to convert the weight of one sex to the equivalent of the other by a percentage correction factor. However, the simplest correction and the one most likely to be useful to cattlemen would be to convert the weight of heifers to a steer equivalent weight by adding a constant amount to the weights of heifer calves or to convert steer weights to a heifer equivalent by subtracting the same amount from each steer's weight. For the purpose of this study, the weights were corrected to a male equivalent by adding 4 pounds to the birth weights of all heifers and 25 pounds to their weaning weights. Correction in this manner removes nearly all of the variance in birth and weaning weights due to sex differences.

Influence of Age of Dam

Knapp et al (1942) studied the effect of age of dam on weaning weights of calves and found that the weights increased with increases in age of dam up to six years and then declined quite markedly as the cows became older. They noted that the curve obtained was quite similar to the normal production curve for dairy cattle, except that the peak of production was reached about a year earlier. Knox and Koger (1945) obtained a similar curve with the peak of production occurring at seven years of age. Koch (1950) found the same general trend with the peak of production at six years. However, the ten year old cows produced heavier calves than expected according to the production curve. Sawyer et al (1949) found that the weaning weight of calves increased with increasing age of dam up to eight years of age and then declined. Preliminary studies of the data obtained at this station indicated that weaning weight increased with age of dam up to five years, then levelled off for about five years, and from there tended to go even higher. With the addition of another year's data, the same picture was present except that the 10 to 13 year old cows weaned calves weighing about the same as the 5 to 9 year old cows. For that reason calf weights were corrected to a mature equivalent age of dam using the 5 through 9 year old cows as the basis for maturity. Table IV shows the average weaning weights and birth weights of all calves produced by cows at the various ages. The weaning weights were corrected for age of calf and sex of calf, and birth weights were corrected for sex differences.

Table IV

Birth and Weaning Weights of Calves from Dams of Different Ages

Age of Dam	No. of Calves	Ave. Weaning Wt. in Pounds	No. of Calves	Ave. Birth Wt. in Pounds
3	119	419.1	127	72.4
4	121	439.7	121	73.7
5	104	446.4	106	76.8
6	87	456.3	89	74.8
7	72	461.3	73	76.2
8	41	453.5	44	76.2
9	29	446.3	30	76.8
10	17	451.1	17	72.8
11	8	466.1	9	73.8
12	7	495.7	7	83.0
13	2	451.0	2	72.0

It was first thought that the increase in weaning weights of calves from 10 through 13 year old cows was the result of culling the poorer producing cows from the herd at young ages. To determine this the cows were divided into age groups within each year, and the selection differentials were calculated for age of calf and sex corrected weaning weights. Within each year and age group of cows the selection differential was the difference between the cows retained in the herd for further use and the average for all cows in the group before culling. The selection differentials for each group are shown in Table V. An average of all the selection differentials was computed by weighting each one by the number of cows in that particular group. The average selection differential was one pound. The selected cows weaned calves which were only one pound heavier at weaning than calves produced by cows in the unselected group from which they came. Selection, then, can be ruled out as a factor affecting production of the old cows.

Three methods of determining age of dam differences were used: averages of all calves produced by cows of each age, comparison of weights of calves from the same cow at different ages, and intra-year weighted mean differences. In the latter method, each intra-year differences was weighted in proportion to the reciprocal of its variance, using the method suggested by Yates (1934). This method was used by Chambers (1950) for determining differences in performance due to differences in age of dam in swine.

The effect of age of dam is shown in Table VI, as determined by each method. The effects are expressed as deviations from the weaning weight of calves produced by mature cows.

Although the weaning weight of calves produced by the old cows (10, 11, 12 and 13 years old) was somewhat higher than that of calves produced by mature cows, no correction was made for this group of calves. Since the number is quite small - only 34 calves produced by cows ten years old

Table V

Selection Differentials for Weaning Weights of Calves

Year	Age of Cows in Years	No. of Selected Cows	No. of Total Cows	Av. Weaning Wt. (in lbs.) of Calves from Sel. Cows	Av. Weaning Wt. (in lbs.) of Calves from All Cows	Selection Differential in Pounds
1945	3	10	10	387	387	0
	4	10	10	406	406	0
	5	7	8	423	420	3
	7	7	8	440	433	7
	8	5	6	448	446	2
1946	3	12	12	423	423	0
	4	10	10	415	415	0
	5	8	8	429	429	0
	6	5	7	419	417	2
	8	7	7	485	485	0
	9	3	4	450	440	10
1947	3	28	28	372	372	0
	4	12	12	417	417	0
	5	11	11	400	400	0
	6	10	10	381	381	0
	7	4	5	431	427	4
	9	5	6	459	463	-4
	10	1	4	504	454	50
1948	3	12	12	428	428	0
	4	22	22	434	434	0
	5	13	13	480	480	0
	6	8	10	446	450	-4
	7	9	9	438	438	0
	8	2	2	485	485	0
	10	2	2	517	517	0
	11	1	1	519	519	0
1949	3	29	29	401	401	0
	4	11	14	389	386	3
	5	26	26	438	438	0
	6	12	14	418	419	-1
	7	7	8	423	421	2
	8	10	10	407	407	0
	9	4	4	428	428	0
	11	5	5	454	454	0
	12	1	1	436	436	0
1950	3	22	22	451	451	0
	4	24	25	447	445	2
	5	11	11	447	447	0
	6	27	27	482	482	0
	7	10	12	471	458	13
	8	6	7	441	441	0
	9	7	10	429	423	6
	10	4	4	434	434	0
	12	6	6	493	493	0
	13	1	1	456	456	0

Average Selection Differential = .82 Pounds

Table VI

Effect of Age of Dam on Weaning Weight of Calves (In Pounds)

Age of Dam in Years	Method of Determination: Averages	Intra-year Weighted Mean Difference	Calves by the Same Cow at Different Ages
3	-34	-27.5	-43.5
4	-14	-15.5	-12.0
Mature (5,6,7,8,9)	0	0	0
Old (10,11,12,13)	+12	+11.3	+ 2.5

or older - the apparent effect could very well be due to chance variation in sampling. At any rate, for the correction of data in this study, all cows five years or older were grouped together as mature cows, and the calves from three and four year old dams were corrected to a mature equivalent. The first method shown in Table VI was used for corrections, since it represents about an average of all three methods at least as far as three and four year old cows are concerned. The effect of age of dam as used for correction of the data is shown in Table VII, along with the correction for birth weight.

Table VII

Effect of Age of Dam as Used for Correction of the Data

Age of Dam	Ave. Weaning Wt.	Correction	Ave. Birth Wt.	Correction
3	419#	+35#	72.4#	+4#
4	439#	+15#	73.7#	+2#
Mature	454#	0	76.0#	0

Correcting the weaning weights by adding 35 pounds to the weight of calves by three year old dams and 15 pounds to the weight of calves by four year old dams removed 82 percent of the sum of squares due to differences in age of dam. For birth weight, adding 4 pounds to the weight of calves from three year old dams and 2 pounds to the weight of calves from four year old dams removed only 62 percent of the sum of squares due to age of dam differences.

The above corrections were applied only to the calves produced at the range area near Stillwater. Since there was a complete correspondence between age of dam and year for the cows at Fort Reno, the calf weights were corrected for year influences and no attempt was made to determine the influence of age of dam.

The Influence of Year

During the eight years included in the study, there was considerable yearly variation in the average weights of the calves; although the weights had already been corrected for age of calf, sex of calf and age of dam. Apparently, the weaning weight of calves depends somewhat on the amount of forage on the range, which in turn is dependent on the amount of rainfall. The annual rainfall at Stillwater during the eight year period varied from about 23 inches to 34 inches. However, a study of the monthly rainfall indicated that the amount of rain during July and August had the greatest influence on the weaning weight of the calves. The yearly variation in birth weight, although possibly due, in part, to differences in range conditions, more likely was due to differences in sires, or to unequal distribution of age of dam in the different years, since less than two thirds of the variation in birth weight due to age of dam was removed by corrections. Table VIII shows the average weights of calves over the eight year period after corrections were made for age of calf, sex of calf and age of dam. Also shown in Table VIII are the annual rainfall and the yearly rainfall during July and August.

Table VIII

The Effect of Year on Birth and Weaning Weights

Year	Annual Rainfall	July & Aug. Rainfall	No. of Calves	Ave. Weaning Wt. in Pounds	No. of Calves	Ave. Birth Wt. in Lbs.
1944	31"	4.3"	24	460	25	76.0
1945	34"	3.7"	42	438	41	74.2
1946	28"	4.0"	48	456	50	76.0
1947	27"	2.0"	76	425	78	75.9
1948	32"	8.4"	71	471	79	73.0
1949	30"	3.5"	111	437	115	76.9
1950	23"	9.5"	125	477	126	75.9
1951	(Not Available)		110	457	111	77.7

In the experiments from which these data were taken, death losses were low and only a few cows were culled. For the most part, experiments were begun with young cows and the same cows retained until removed because of death, injury or sterility. For any given year the number of cows of the various ages was not equal, so it was expected that some relationship would exist between year and age of dam. Therefore, controlling the two variables statistically by subtracting out the sum of squares due to each, would likely result in too great a reduction in variation, and the resulting error variance would likely be too small. The effect would be to increase the repeatability by decreasing the total variation without affecting the variance among cows. By correcting first for age of dam and then determining the remaining variation between the various years and correcting for year, no overcorrection should result. This method may cause some bias in the measures obtained for effect of age of dam, or year, or both; however weights corrected in this manner should be comparable regardless of the year in which the calf was born or the age of dam. The birth and weaning weights of the calves were corrected for the effect of year to bring the average of each year to the average of all years.

The Influence of Treatment

The calves included in this study were from dams subjected to different treatments. A preliminary analysis of variance indicated that there were significant differences in weaning weights of calves whose dams were on different treatments, even though all treatments would be considered good according to common range practice. In one set of experiments the cows were used to compare different wintering rations. This experiment was revised twice during the eight year period. Each year the cows were re-allotted and switched from one treatment to another. In 1951, half of the calves from cows on this experiment were creep fed. Treatment of the cows in this group would tend to cause the repeatability of weaning weights of calves by the same cow to be lower than if no treatment differences were involved. Variance between calves by the same cow would be increased, while changes in variance among cows would be slight. In the other set of experiments, the groups of cows were fed different levels of phosphorous during the first four years. Cows remained on the same treatments the entire four years. The following year, cows were re-allotted and fed different levels of manganese. Treatment effects on the cows in the latter group would tend to cause an increased variance among cows without materially affecting variance among calves by the same cow, thus causing repeatability to be increased. In the pooled data the net effect of treatment differences on repeatability of performance by the same cow is probably slight. To determine what might be gained by correcting for treatment (using correction factors to bring the average of each treatment to the average of all), an analysis of variance was made both before and after correcting for treatment. Total variance was reduced by the corrections for treatment, but the variance among cows was reduced almost as much as the variance between calves produced by the same cow. The correction for treatment increased the fraction of variance due to cow influences by only one percent. The value of using the corrections for treatment is thus insifnificant. The increase in repeatability was not enough to warrant the extra time and labor required for making such corrections. Also, the more times data are transferred, the greater the chance for mistakes to occur. Since very little was gained by correcting weaning weights for treatment, no attempt was made to determine the effect of treatment on birth weights.

After weaning weights had been corrected for age of calf, sex of calf, age of dam and year, and birth weights corrected for sex of calf, age of dam and year, the birth weights were subtracted from weaning weights to obtain the gains from birth to weaning.

ESTIMATES OF REPEATABILITY

Intraclass correlation and the regression of subsequent records on the first record were used to determine the repeatability of weaning weight, birth weight and gain from birth to weaning on the Stillwater data. For the data from Fort Reno, simple correlation coefficients were calculated between first and second records for all three traits.

Weaning Weight

The intraclass correlation coefficient between calves by the same cow, using uncorrected weaning weights, was .22.

After corrections for age of calf, sex of calf, age of dam and year, weaning weights were analyzed to determine the portion of variance due to permanent differences between cows. The analysis of variance is shown in Table IX.

Table IX

Analysis of Variance of Corrected Weaning Weights

Source of Variation	d.f.	Sum of Squares	Mean Square	Mean Square is An Estimate of
Total	602	1,093,312		
Cows	150	623,657	4,158	$\sigma^2_e + 4^* \sigma^2_c$
Calves by the Same Cow	452	469,655	1,039	σ^2_e

* The average number of calves per cow was 4.

The value of σ^2_e is 1,039, and this represents the variance between calves by the same cow. The increase in variance between calves having different dams, σ^2_c, was calculated to be 780, using methods described by Winsor and Clarke (1940) for computing variance components in a one way classification.

From Table IX repeatability of weaning weights of different calves from the same cow can be calculated as the ratio of the variance between cows to the total variance.

$$\text{Repeatability} = \frac{\sigma^2_c}{\sigma^2_c + \sigma^2_e} = \frac{780}{1819} = .43$$

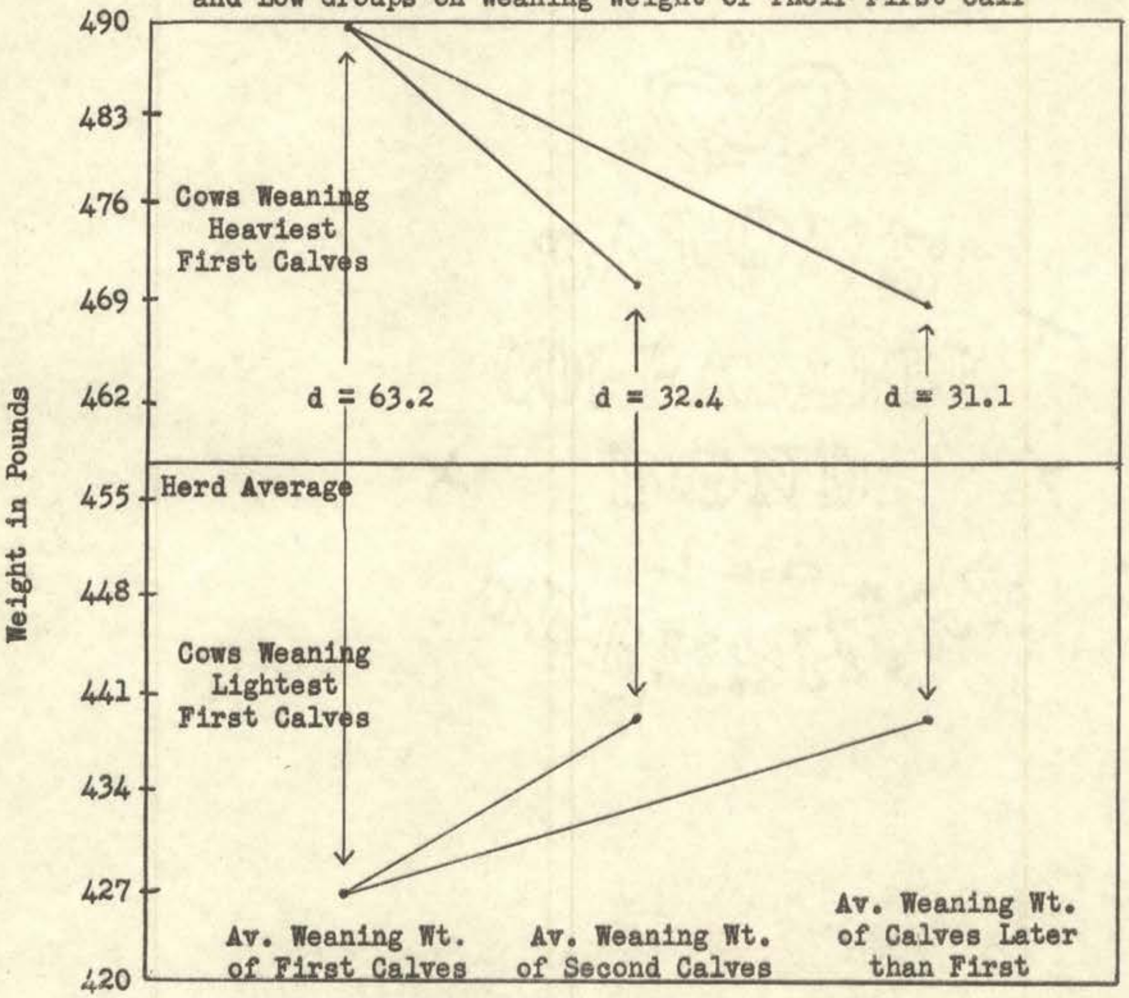
The fraction .43 is the intraclass correlation coefficient between the weaning weights of calves by the same cow. The upper and lower limits at the 5% confidence interval were calculated as outlined by Fisher (1936), and are .55 and .29 respectively.

To determine the effectiveness of selection on weaning weight of the first calf, the cows were divided equally into a high group and a low group on the basis of weaning weight of their first calves. A comparison of the differences between the weights of the first calves from these two groups of cows with the difference between the weights of their second or average of all calves raised after the first calf gives a measure of the permanent differences between these two groups of cows. The averages of the two groups of cows and the differences are shown in Table X. These are also shown in Figure 2.

From the data in Table X the repeatability of weaning weights of calves from the same cow can be calculated by dividing the difference between the weaning weights of the second calves from the two groups of cows by the difference between the weaning weights of their first calves.

Figure 2

Regression of Weaning Weight of Later Calves on the Weaning Weight of the First Calves. Dams Divided equally into High and Low Groups on Weaning Weight of Their First Calf



d = difference between average weaning weights of calves produced by the two groups of cows.

$$\text{Repeatability (First and Second Weights)} = \frac{32.4}{63.2} = .51$$

$$\text{Repeatability (First and Av. of Later Wts.)} = \frac{31.1}{63.2} = .49$$

Table X

Average Weaning Weights in Pounds of Calves from High and Low Groups of Cows Selected on the Weight of Their First Calf

	Total No. of Calves	High Cows	Low Cows	Difference
Average Weaning Wt. of First Calves	150	489.6	426.4	63.2
Average Weaning Wt. of Second Calves	150	471.2	438.8	32.4
Average Weaning Wt. of All Later than First	446	469.5	438.4	31.1

$$\text{Repeatability} = \frac{32.4}{63.2} = .51$$

Using the average weaning weight of all calves later than the first gives.

$$\text{Repeatability} = \frac{31.1}{63.2} = .49$$

Since some of the cows' first records were obtained when cows were from four to seven years of age, the data were restricted to include only those cows which produced their first calf as three year olds. The same procedure was followed with these three year old cows and the results were very nearly the same as above.

The correlation coefficient between the weaning weights of first and second calves from the cows at the Fort Reno station was .66. These cows produced their first calves at two years of age, whereas the cows at Stillwater produced their first calves at three years of age.

Birth Weight

The analysis of variance of corrected birth weights is shown in Table XI. From this analysis the repeatability of birth weights of calves from the same cow is .18.

Table XI

Analysis of Variance of Corrected Birth Weights

Source of Variation	d.f.	Sum of Squares	Mean Square	Mean Square is an Estimate of
Total	619	37.916		
Cows	150	14,326	95.5	$\sigma^2_e + 4.1^* \sigma^2_c$
Calves by the Same Cow	469	23,590	50.3	σ^2_e

* The average number of calves per cow was 4.1.

$$\text{Repeatability} = \frac{\sigma^2_c}{\sigma^2_c + \sigma^2_e} = \frac{11.0}{61.3} = .18$$

The upper and lower limits at the 5% confidence interval were .33 and .02 respectively.

Using uncorrected birth weights, the corresponding estimate of repeatability was .14. Correction of the birth weights for known variables increased the repeatability only a small amount.

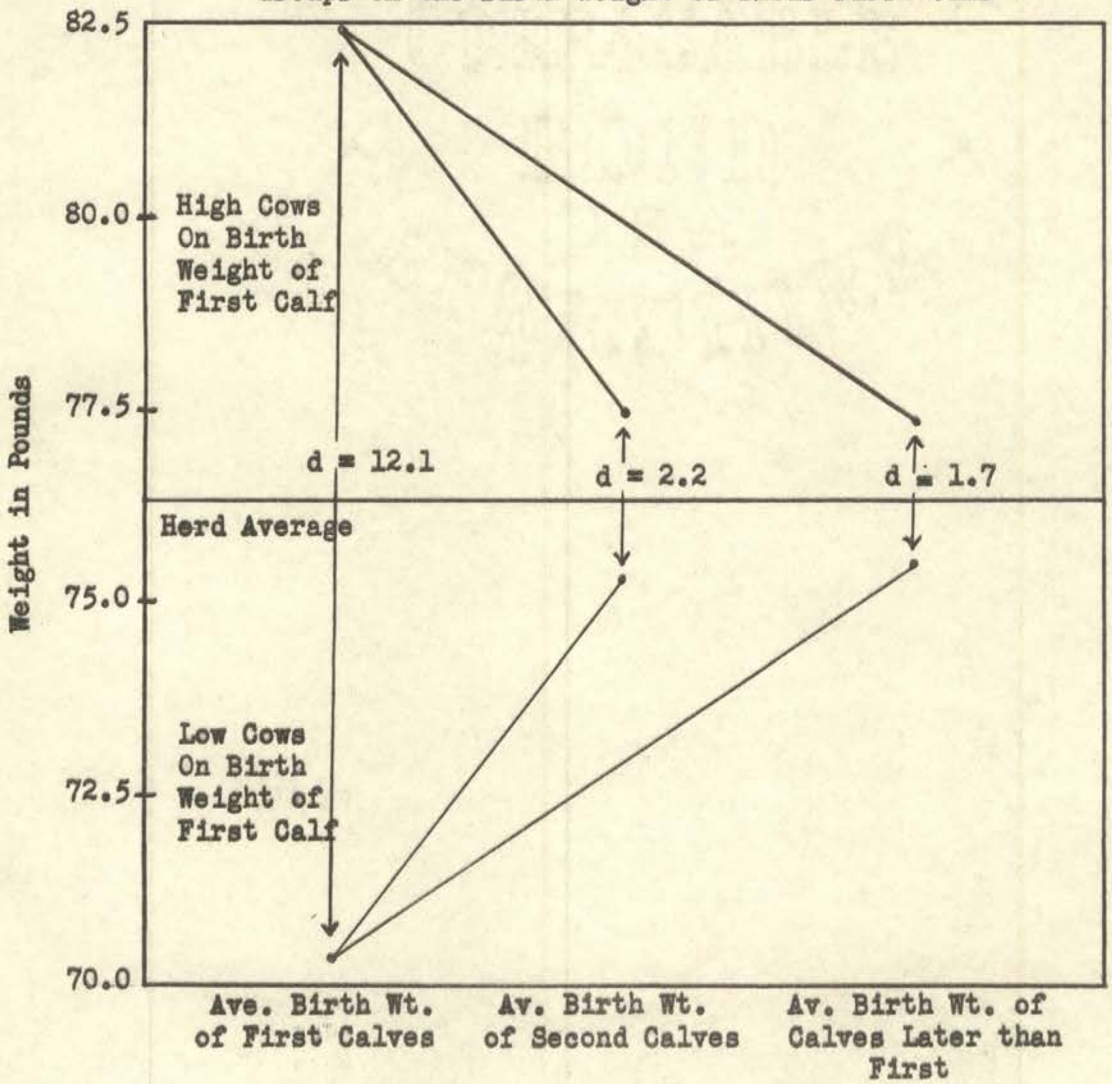
As was done with weaning weights, the cows were equally divided into high and low groups on the basis of the birth weight of their first calves, and the regression which later records showed toward the herd average was measured. Table XII shows the averages of the high and low groups and differences between the averages. The regression is shown graphically in Figure 3.

Repeatability was measured by regression of second birth weights from the first toward the herd average, and by regression of all later birth weights from the first toward the herd average.

$$\text{Repeatability (First and Second Weights)} = \frac{2.2}{12.1} = .18$$

Figure 3

Regression of Birth Weight of Later Calves on the Birth Weight of the First Calves. Dams Divided equally into High and Low Groups on the Birth Weight of Their First Calf



d = the difference between the average birth weights of calves produced by the two groups of cows.

Repeatability (First and Second Weights) $= \frac{2.2}{12.1} = .18$

Repeatability (First and Av. of Later Wts.) $= \frac{1.7}{12.1} = .14$

Table XII

Average Birth Weights in Pounds of Calves from High and Low Groups of Cows Selected on the Birth Weight of Their First Calf

	Total No. of Calves	High Cows	Low Cows	Difference
Average Birth Wt. of First Calves	150	82.4	70.3	12.1
Average Birth Wt. of Second Calves	150	77.4	75.2	2.2
Average Birth Wt. of All Later than First	463	77.2	75.5	1.7

$$\text{Repeatability (First and Average of Later Weights)} = \frac{1.7}{12.1} = .14$$

The correlation coefficient between birth weights of first and second calves from the group of cows at the Fort Reno station was .25.

Gain from Birth to Weaning

Gains from birth to weaning were analyzed similarly to weaning weights and birth weights, and the analysis of variance is shown in Table XIII. The average of the high and low groups and differences between averages are shown in Table XIV.

Table XIII

Analysis of Variance of Gains from Birth to Weaning

Source of Variation	d.f.	Sum of Squares	Mean Square	Mean Square is an Estimate of
Total	593	1,004,781		
Cows	149	538,905	3,617	$\sigma^2_e + 3.96^* \sigma^2_c$
Calves by the Same Cow	444	465,876	1,049	σ^2_e

* The average number of calves per cow was 3.96.

$$\text{Repeatability} = \frac{\sigma^2_c}{\sigma^2_c + \sigma^2_e} = \frac{648}{1697} = .38$$

The upper and lower limits at the 5% confidence interval were .51 and .23 respectively.

Table XIV

Average Gains from Birth to Weaning in Pounds of Calves from High and Low Groups of Cows Selected on the Gain of Their First Calf

	Total No. of Calves	High Cows	Low Cows	Difference
Average Gains of First Calves	150	411.3	345.9	65.4
Average Gains of Second Calves	150	390.4	365.5	24.9
Average Gains of All Later than First	445	390.3	365.6	24.7

$$\text{Repeatability (First and Second Gains)} = \frac{24.9}{65.4} = .38$$

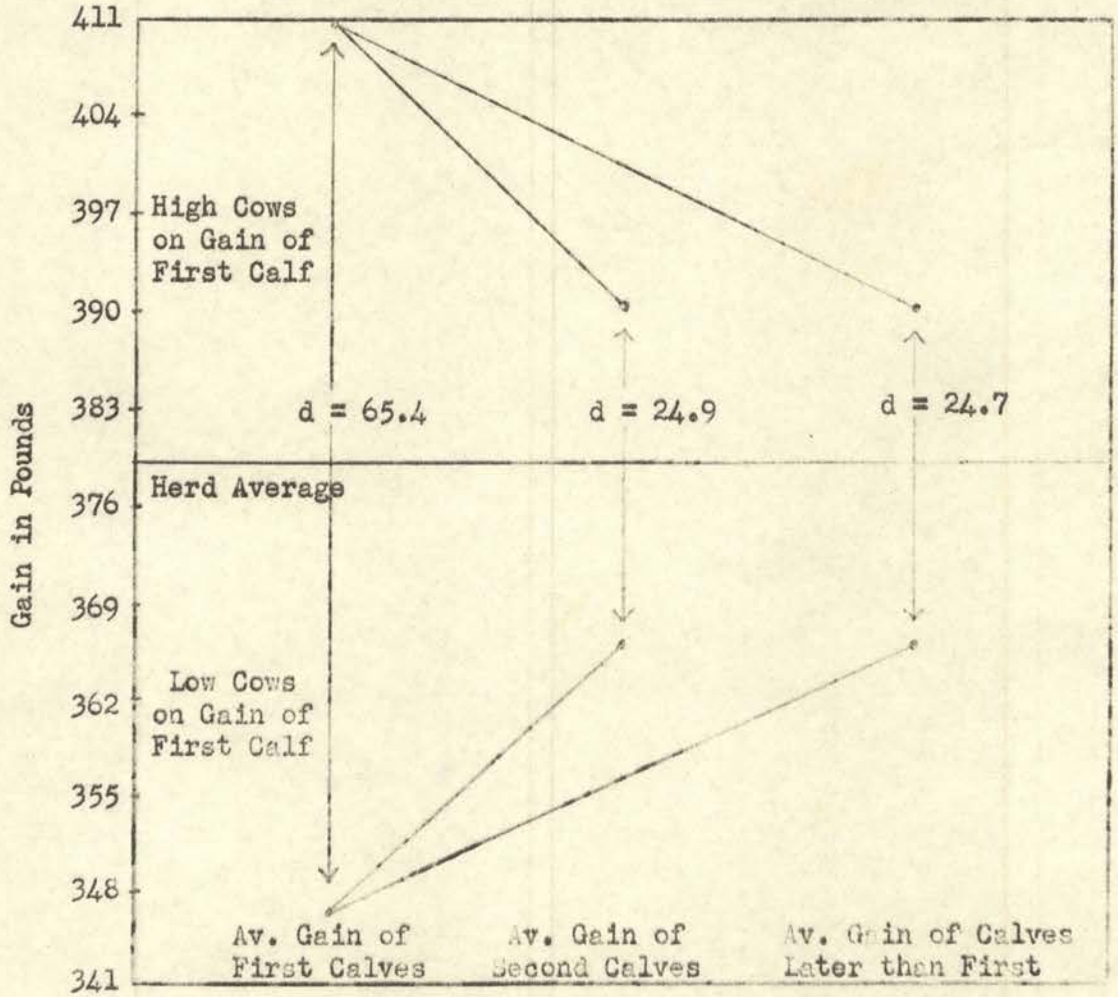
$$\text{Repeatability (First and Average of Later Gains)} = \frac{24.7}{65.4} = .38$$

The regression of later gains from the first toward the herd average is shown graphically in Figure 4.

Correlation between first and second records of gain from birth to weaning for the group of cows at the Fort Reno station was .69.

Figure 4

Regression of Gain from Birth to Weaning of Later Calves on the Gain of First Calves. Dams Divided equally into High and Low Groups on the Gain of Their First Calf



d = the difference between gains of calves produced by the two groups of cows.

Repeatability (First and Second Gains) $= \frac{24.9}{65.4} = .38$

Repeatability (First and Av. of Later Gains) $= \frac{24.7}{65.4} = .38$

DISCUSSION AND APPLICATION

Corrections for the effect of certain known variables on calf weights were made as simply as possible so as to be applicable under practical conditions and usable by cattlemen whose cattle are handled similarly to those in this study. The weights of the calves were corrected to a standard age of 210 days, because that is approximately the average age at which calves are weaned in this locality and is fairly near the average age of the calves included in this study. Figure 5 shows a nomograph which can be used as a quick method for correcting weaning weights to a constant age of 210 days. Although one weighing of calves varying as much as two months in age and correction to a standard age is not as accurate as weighing at a constant age, it saves considerable time, labor and handling of the cattle. The correction factors give results which undoubtedly are more accurate than if no corrections were made. Likely, the weight of calves at some younger age, such as 180 days or even 150 days, would more nearly measure the intensity of milk production of the cows. The amount of milk produced by a cow probably has less influence on weight of the calf as the age of the calf increases. However, selection of cows for weight of calves at an early age would overlook the persistency of lactation, which may be an important consideration.

From the data available, it would seem that a single weight at weaning, corrected by an appropriate correction factor, is about as accurate as correction on the basis of average daily gain between ages on either side of the standard age. Any increase in accuracy resulting from the use of two weights bracketing the standard age, therefore, is probably not

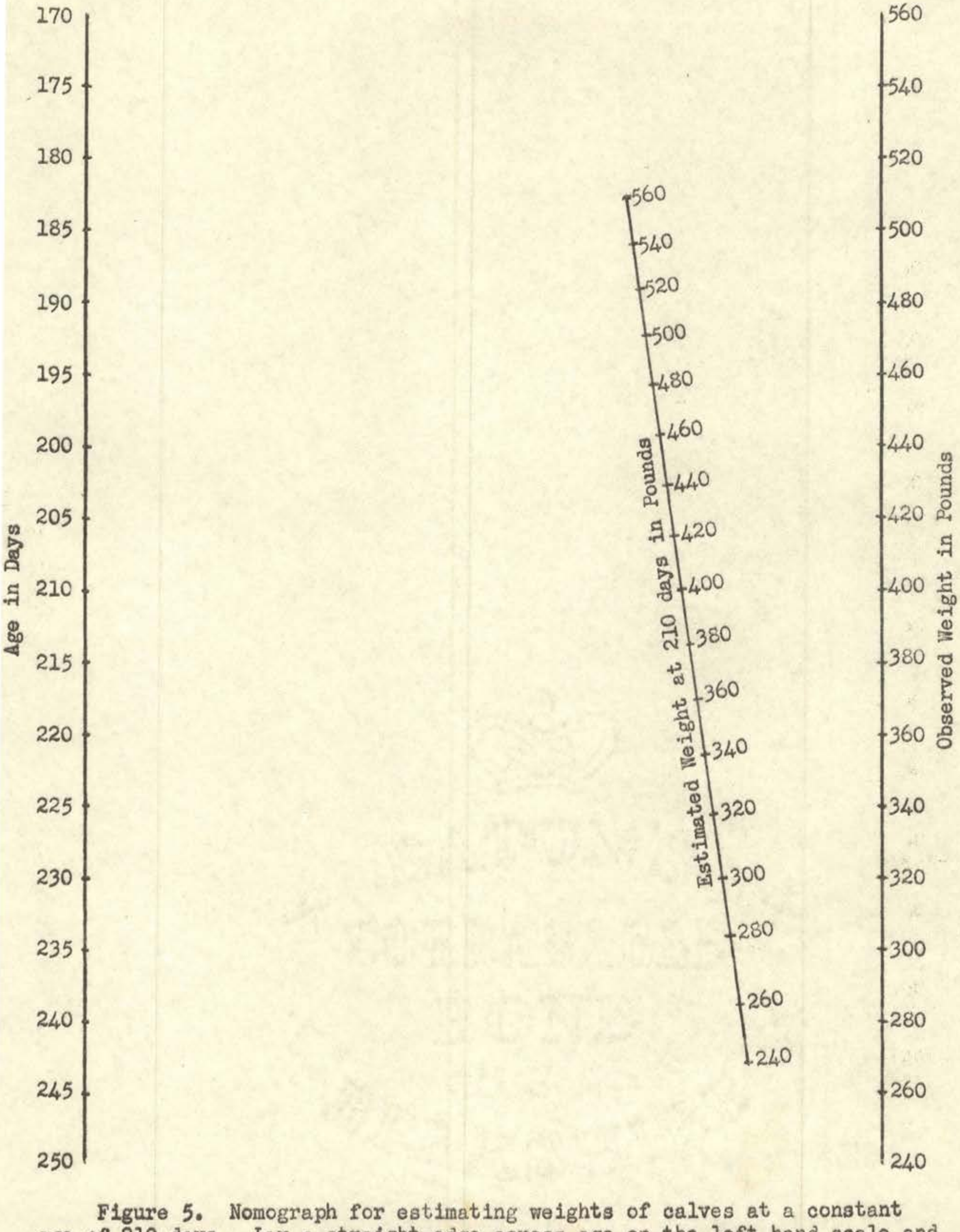


Figure 5. Nomograph for estimating weights of calves at a constant age of 210 days. Lay a straight-edge across age on the left hand scale and observed weight on the right hand scale and corrected weight is read directly from the center scale.

worth the extra time and effort required to obtain the additional weights under normal range conditions. Within a range of thirty days above or below the standard age, the corrections are fairly reliable. The main difficulty is the correction of the weights of extremely young calves. Less confidence can be placed in corrected weights if the age at weaning is much more than thirty days above or below the standard age. The use of correction factors obtained from the regression coefficient does not make allowance for variable circumstances which cause marked deviations from the linear growth pattern assumed in making the corrections. If there is a decided reduction in growth rate during late Summer in certain dry years, then correction of weights on the basis of average daily gain between weights obtained either side of the standard age would be more accurate than correction by means of the regression coefficient.

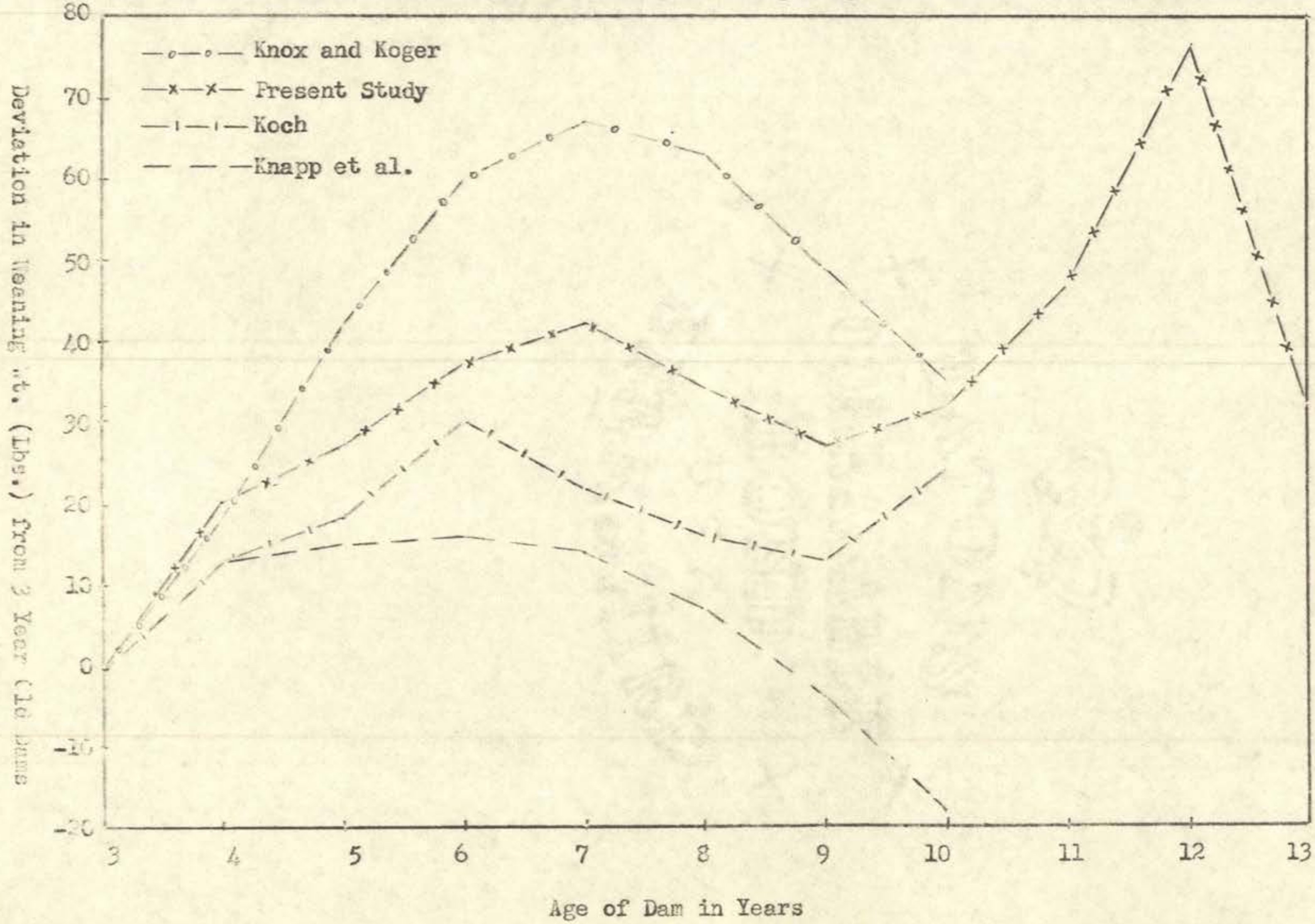
The regression of weaning weight on weaning age of 1.46 is intermediate between those obtained by other workers under different climatic conditions. Sawyer et al (1948) found that the regression of weight on age at weaning was 1.28 and that growth was uniform from 25 to 35 weeks of age. Koger and Knox (1945a) found a regression of 1.33 at 205 days of age. Johnson and Dinkel (1951) obtained two regression coefficients: 1.85 from 0 to 154 days, and 0.84 from 155 to 225 days. Koch (1950) obtained a regression coefficient of 2.27 for calves averaging 176 days in age.

In correcting for sex, the addition of 25 pounds to the weaning weight and four pounds to the birth weights of heifers to put them on a steer equivalent weight should be fairly applicable under even quite variable conditions. If bulls and steers are being compared, probably some correction is necessary, although not enough data are available to make this a certainty. Koch (1950) found considerable difference between bulls and steers at weaning, but attributed the difference largely to selection. The best males were saved for bulls. In any case where such a comparison can be made, selection is likely to be an important factor.

Production curves of cows at different ages are shown in Figure 6 for the present data, and for data presented by Knox and Koger (1945), Knapp et al (1942) and Koch (1950). Although age at weaning is not the same in the different sets of data and therefore averages are not comparable, the trends showing the effect of age of dam on weaning weight of calves can be compared. In each set of data represented in Figure 6 the weaning weights of calves for cows of each age are expressed relative to a base which is the weaning weight of calves from three year old heifers. Up to nine years of age the curves are quite comparable. In the present data the portion of the curve from three to nine years of age is more reliable than the period from nine to thirteen years of age because of the small number of cows in the older age groups. The tendency of the cows to maintain high production in later years could have been partially due to the fact that these older cows generally produced calves during the best years, but more likely this tendency was due to chance in sampling. Only a small group of cows, which were in the herd at the beginning of the study, remained in the herd long enough to produce calves at ten, eleven, twelve, or thirteen years of age. Therefore, the calves included in each of these age groups were produced by the same group of cows. Most of those cows were consistent in raising heavy calves. For the purposes of the present study, correction of only those calves from three and four year

Figure 6

Comparison of Four Studies on the Effect of Age of Dam on Weaning Weight of Calves. Effects Are Expressed as Deviation from the Average Weaning Weight of Calves from 3 Year Old Dams.



old dams was fairly effective, although it is realized that under different circumstances some correction may also be necessary for calves from the older cows. Trying to determine at what age cows should be culled from a herd is impossible from the information available, since production remained high as long as the cows were kept in the experimental herd. Even if it is assumed that the high production of the older cows was due to chance, and their production is extrapolated from the more reliable portion of the production curve, it does not seem that cows should be culled for age before they are about ten or eleven years old.

Correction factors used to eliminate the effects of yearly variation should be computed from the data or herds to which they are applied, as these values may vary even among herds in the same area. Correction factors for various years could be found by comparing yearly averages of records adjusted for age of calf, sex of calf and age of dam. These factors should be considered as approximations only, and subject to revision as more information becomes available. Keeping a running average of several years data - 8 or 10 years, if available - and dropping the oldest year's data as each additional year's data becomes available will furnish a good average for use in determining corrections for yearly variations in weight. In herds where about the same number of heifers go into the breeding herd as replacements each year, there should be no trouble from interactions between variables as was encountered in the present study.

Although the corrections used for the data in this study do not necessarily represent the most accurate corrections possible, they all are usable for herds under similar conditions of climate and management. For the purposes of determining estimates of repeatability, it is likely that more exact corrections would result in somewhat higher estimates; however, it is not thought necessary to attempt any more refinement of technique. Since an attempt is made to correct for several variables, the accuracy of correction for any single variable is somewhat limited.

The correlation between corrected birth weights and corrected weaning weights was .40, and the correlation between birth weight and gain from birth to weaning was .23. These figures are somewhat lower than similar correlations by other workers. Arizona workers (1937) found the correlation between birth weight and average daily gain from birth to weaning to be .60. Dawson et al (1947) found a correlation of -.58 between birth weight and number of days required to reach 500 pounds. Gregory et al (1950) obtained correlations of .07 and .44 between birth weight and gain from birth to weaning, and .27 and .60 between birth weight and weaning weight. Krasnov and Pak (1939) determined the correlation between birth weight and four months weight, and their estimates ranged from .39 to .58 for males and from .43 to .48 for females. They also found the correlation between birth weight and adult weight to be .56 for males and .41 for females. Dawson et al (1947) determined the correlation between birth weight and the number of days to reach 900 pounds to be -.62. Kusner (1936) found correlations between birth weight and eighteen months weight ranging from .43 to .68. It would appear that birth weight is about as accurate for predicting adult weight as for predicting weaning weight. The correlation between birth weight and weaning weight does not seem to be high enough to make birth weight a very good indicator of weaning weight.

The correlation between cow weight at weaning and weaning weight of the calf was found to be .14, and when the average of all the cow's weights and the average of all her calves' weights were correlated, the correlation was .17. Different cow-calf weight relationships have been studied by various workers. If the weight of the cow at any stage in development could be used as a good indication of her calf production, selection would be very simple. However, correlations between cow weight and calf weights do not indicate that such a high relationship exists. Knapp et al (1940) reported a correlation of .22 between birth weight and weight of dam at calving. Kusner (1936) found correlations of .30 and .42 between weight of dams and weight of daughters at birth. Krasnov and Pak (1939) found correlations of .56 for males and .42 for females between weight of dam and weight of calves at birth. Dawson et al (1947) found a correlation of .49 between birth weight and weight of dams. Gregory et al (1950) found correlations of .21 between birth weight and weight of cows immediately after calving at North Platte and .32 between birth weight and last weight of dam before calving at Valentine. Their correlations between calf gains and cow gains from birth to weaning were -.12 and -.34. Correlations between cow weight and calf weight at weaning were .20 and -.11.

The repeatability fraction includes all differences due to permanent differences between cows, and thus measures the accuracy of past production in predicting future production of the same cows. Since some of the permanent differences between cows are non-transmissible, the repeatability will be at least as great, and probably greater, than heritability. Thus, the repeatability can be used to indicate the immediate gain in future production of a herd by selection, but to the extent that it contains non hereditary differences between cows it tends to overestimate what can be gained in future generations by selection. No data are available in this study to get an estimate of what portion of repeatability is transmissible or heritable in the narrowest sense. The estimate of repeatability is almost as useful as an aid in selection as a heritability estimate would be. It is not profitable to keep the very poor producers in a herd even though their transmitting abilities may be somewhat better than their records of production indicate.

With an estimate of repeatability, the producing ability can be estimated from the first record, or from all records available. If any variation is due to temporary conditions, then producing ability can be more accurately estimated from an average of several records than from a single record. Any deviation due to temporary conditions is likely to be random in direction. Therefore, when averages are used, the deviations due to temporary circumstances tend to cancel each other somewhat. Figure 7 is a diagram showing how the repeatability of differences between averages increases as the number of records in each average increases. Repeatability as shown in Figure 7 is that portion of the variance in weaning weights which is due to permanent differences between cows. The permanent portion includes variance due to the additive effects of genes (σ^2G) and variance due to dominance, epistasis and permanent environment all of which are included in σ^2P.

According to Lush (1949), the most probable producing ability of the cow equals the herd average plus $\frac{nr}{1 + (n-1)\,r}$ times (her own average minus

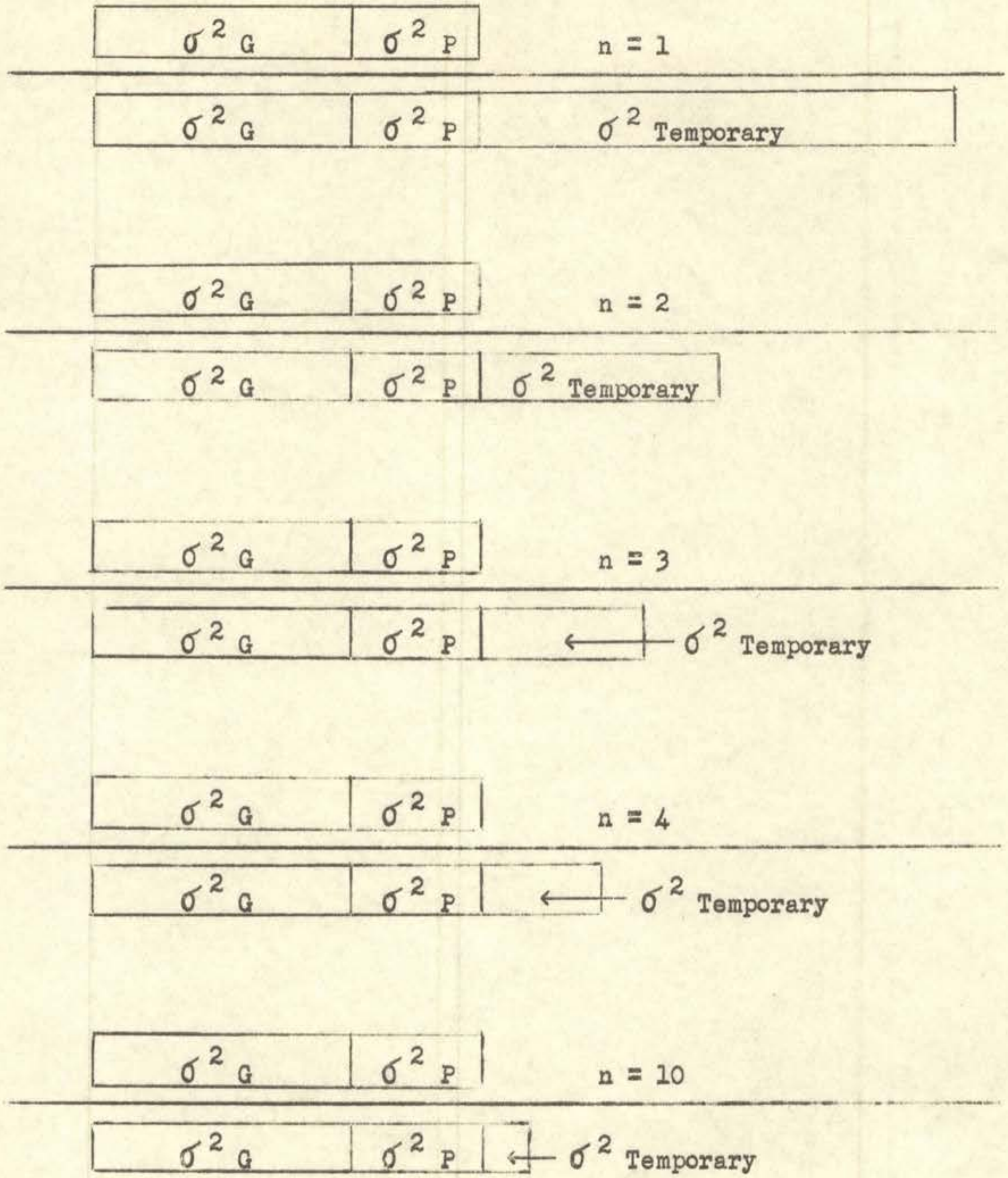


Figure 7. Diagram showing how the repeatability of differences between averages increases as the number (n) of records in each average increases. Drawn to scale for the case in which heritability is .30 when n is 1 and repeatability of single records is .45. σ^2 G is the additively genetic variance between individuals, σ^2 P the variance due to permanent but nontransmissible differences. As n increases, the variance due to temporary things falls to one-n'th of its value in single records. (1)

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(1) Lush, Jay L. 1949. Animal Breeding Plans. p. 174.

The herd average). Here n is the number of records and r is the repeatability of the trait under consideration. The fraction $\frac{nr}{1 + (n-1)\,r}$ shows how much confidence is placed in the cow's average as an indication of her producing ability. The amount of gain which can be expected from selection for production is the repeatability times the selection differential. Table XV shows the comparitive progress from selection with varying numbers of records for several selected values of repeatability.

Table XV

Progress When Selecting between Animals with n Records Each, as a Multiple of the Progress Which Could Be Made by Selecting Between Them when They Had Only One Record Each (1)

	r								
n	.1	.2	.3	.4	.5	.6	.7	.8	.9
2	1.35	1.29	1.24	1.20	1.15	1.12	1.08	1.05	1.03
3	1.58	1.46	1.37	1.29	1.22	1.17	1.12	1.07	1.04
4	1.75	1.58	1.45	1.35	1.26	1.20	1.14	1.08	1.04
6	2.00	1.73	1.55	1.41	1.31	1.22	1.15	1.10	1.04
10	2.29	1.89	1.64	1.47	1.35	1.25	1.17	1.10	1.05

Considering the estimates obtained for weaning weight and gain from birth to weaning, the repeatability is high enough that considerable confidence can be placed in the first record. The addition of more records would increase the accuracy in predicting future production; the greatest increase would occur with the addition of one more record. The addition of more records in the initial measurement for birth weight would markedly increase the accuracy of prediction, since one record is not a very good indication of future performance.

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(1) Lush, Jay L. 1949. Animal Breeding Plans. p.175.

The actual estimates of repeatability obtained are in fairly close agreement with other studies. For weaning weight, estimates of .43 and .49 were obtained, as compared to an estimate of .49 by Koger and Knox (1947), .52 by Koch (1950), and estimates varying from .37 to .50 by Gregory et al (1950). The only other estimates of repeatability of gain from birth to weaning are those of Gregory et al (1950) varying from .38 to .57, as compared to estimates of .38 obtained from the present study. Estimates of repeatability of birth weight are .14 and .18, as compared to those of Gregory et al (1950) ranging from -.12 to .24. The repeatability of weaning weight and of gain from birth to weaning was considerably higher than that of birth weight. Not only is weaning weight a better measure of a cow's production than birth weight, but also future production in weaning weights of calves can be more accurately predicted.

The estimate obtained by regression of later records from the first toward the herd average was higher than that obtained by means of an intraclass correlation coefficient for weaning weight. This would indicate that perhaps the first record was a little better indication of future production than later single records. Gregory et al (1950) found a higher correlation between first and second records than between first and third or second and third. Koger and Knox (1947) found the correlation between weaning weights of calves from cows at three and four years of age to be higher than adjacent records made at other ages. In their study, the first calves were from the same sire and from dams which had received identical treatment. In this study, the first calves were not all by the same sire, but undoubtedly the environmental conditions were much more nearly alike for all cows before their first calf was weaned than was the case before weaning later calves. If a group of cows were all subjected to the same treatment throughout their life, then one record should be as good as another for indicating future production.

The correlations between first and second weaning weights, birth weights, and gains from birth to weaning from the calves at the Fort Reno station were all higher than the corresponding estimates from the larger group at the Stillwater area. Estimates for the three traits were .66, .69 and .25 for weaning weight, gain from birth to weaning, and birth weight respectively. Since the calves were produced in consecutive years, the estimates would be expected to be higher than those from the larger group. Also, any cows which calved very late the first year, also calved late the second year, and any error in correcting the weights for age at weaning would tend to be in the same direction both years.

When using weaning weight of the first calf as the basis for selecting cows to keep in the breeding herd, either estimate of repeatability can be used: .43 or .49, or even an average of the two which would be .46. The difference in the estimate of producing ability using either estimate of repeatability would be small, even if a cow weaned a calf 100 pounds above or below the herd average. Since the percentage of cows saved is normally fairly high, the selection differential is necessarily rather small, and when the selection differential is multiplied by either of these two estimates, the difference would be of little consequence. Actually, the regression which later records show from the first toward the herd average is the most applicable in a breeding program since it indicates what part of the selection practiced, results in improved performance the next year.

Direct comparisons of repeatability and heritability can be made only if both estimates come from the same population. Therefore, no definite estimate can be made from this study as to what portion of repeatability is heritable. Lush and Arnold (1937) obtained both estimates from the same data for butterfat production in dairy cattle. The estimates were .43 for repeatability and .28 for heritability. Thus, in their study, heritability was about two-thirds of the repeatability. If the estimates of .30 and .28 for heritability of weaning weight obtained by Knapp and Nordskog (1946) and Knapp and Clark (1950), respectively, are used and compared with repeatability estimates of weaning weight of the known studies, it would seem that in beef cattle about two-thirds of the repeatability of weaning weight of calves from the same cow is due to hereditary influences in the cow. However, the same sort of comparisons for birth weight do not follow the same pattern. Estimates of repeatability obtained here and by Gregory et al (1950) are considerably lower than estimates of heritability obtained by Knapp and Nordskog (1946) or Knapp and Clark (1950). Even when Gregory et al (1950) obtained repeatability and heritability estimates from the same data, the heritability estimates were higher than those obtained for repeatability. The only heritability for birth weight comparable to known repeatability estimates is the estimate of .11 obtained by Dawson et al (1947). Since theoretically, the heritability cannot be greater than repeatability, apparently the heritability estimates on birth weights are subject to considerable sampling error. It may be possible that sires have nearly as great, if not as great an influence on the birth weight of the calf as does the dam. The intra-sire correlations between half-sibs seem to be as high or nearly as high as intra-dam half-sib correlations. This at least indicates that dominance, epistasis and permanent environment do not contribute much to the repeatability of birth weight.

With repeatability of weaning weight as high as reported here, the very low producers can be culled after the first record, with little danger of culling good cows. The cows at either extreme, either very high or very low producers, contribute much more to the repeatability of weaning weight than those which are fairly near the average. Very few of the cows which produced small calves their first year ever produced calves above the herd average. Therefore, if only a few are to be culled, the first record should be fairly accurate. If finances, labor and equipment are available so that cows can be kept until they have produced two calves, selection will be more accurate, but likely not enough can be gained by obtaining more than two records to compensate for the extra time and labor necessary to obtain them. In many cases, where facilities are limited, the extra gain even from the inclusion of a second record is hardly worth waiting for. In most selection programs, much of the emphasis is placed on factors other than cow productivity, thus limiting the effectiveness of selection for productivity. Since the weight of calves increases as the cows increase in age up to five or six years, it may be that the breeder wishes to keep the cows long enough to take advantage of this increase in productivity to help pay for the cost of raising the cows in the first place. The ideal as far as effectiveness of selection is concerned would be some method of determining producing ability of the cows before they are old enough for breeding. However, no criterion is available whereby selection at such an early age is very accurate.

In experimental work, in which the calf production of cows is being studied, the allotment of cows can be improved if something is known about their producing ability before the experiment is begun, particularly if the differences between treatments are fairly small. When weaning weight of the calves is used as a measure of the cows' performance, considerable gain can be expected in the efficiency of an experiment if previous knowledge is utilized. If cows are equalized in lots for productivity, the mean differences will be more precise, and more confidence can be placed in differences obtained even though the within-lot variation tends to be increased and thus the test is less sensitive for picking up small differences. By assigning cows to outcome levels on the basis of past production, the test can be made more sensitive by reducing the size of the resulting error term. The most efficient method of taking into account previous knowledge is the use of a covariance analysis and the adjustment of the lot means for past production. Approximately 16 to 25 percent of the variance in calf weaning weights can be removed, since the correlation between past and future production seems to be somewhere around .4 to .5. When birth weight is used as a measure of performance, such an increase in efficiency of an experiment can not be expected, as only a small portion of the variance in future production can be removed by allotment on past production. In many cases where weaning weight is to be used as the measure of cows' performance, it may be worth while to delay the start of an experiment by one year in order to obtain information to be used in allotting the cows. The cost of such a procedure should be relatively small, because the calves can be sold usually for enough to pay the cost of their production. This practice should increase the efficiency of the experiment by enabling more information to be obtained per dollar spent, unless treatment differences are large and easy to pick up by random allotment.

Any estimate of repeatability is merely a description of a certain population under certain conditions of environment. The repeatability of any trait is not a biological constant. The application of the estimate, therefore, is limited to those situations where cattle are handled under conditions similar to those from which the estimate was obtained, and the weights corrected for the same sources of variation. The similarity between different estimates of repeatability of the various traits in beef cattle indicates that the same estimate can be used with confidence under quite a variety of conditions.

SUMMARY AND CONCLUSIONS

Data investigated were 603 weaning weights and 620 birth weights of calves produced by 151 range Hereford cows in the experimental herd at Stillwater. The weights were collected during the eight year period from 1944 through 1951. Also, weaning weights and birth weights of 98 calves from 49 cows in the experimental herd at the Fort Reno experiment station were analyzed.

The effect of various factors on both birth and weaning weights were studied and correction factors were devised to adjust weights to a comparable basis. The average age of all calves at weaning was 217 days, and the average uncorrected weaning weight was 442 pounds. The average uncorrected birth weight was 72.6 pounds. The regression of weaning weight on age at weaning was 1.46, calculated on an intra-subclass basis. Weaning weights of all calves were corrected to a standard age of 210 days. Steer calves averaged 25 pounds heavier than heifers at weaning and bull calves averaged 4 pounds heavier than heifers at birth. Weights were standardized for sex differences by adding 4 pounds to the birth weight of heifers and 25 pounds to their weaning weights. Weaning weight increased with increasing age of dam up to seven years, declined to nine years, and then increased again. Birth weights increased with increasing age of dam up to five years, levelled off up to nine years, and tended to decline thereafter, but were somewhat erratic. The only corrections made for age of dam were the addition of 35 and 15 pounds to the weaning weights of calves from three and four year old dams respectively, and the addition of 4 and 2 pounds to the birth weights of calves from three and four year old dams respectively. Variation due to year was eliminated by correcting the weights of calves in each year to the average of all years. Although treatment of the cows had some influence on weights, corrections did not increase the repeatability very much, so treatment was not considered in the final analysis. Gain from birth to weaning was determined for all calves by subtracting corrected birth weights from corrected weaning weights.

From the group of cows at Stillwater, repeatability estimates were determined for birth weight, weaning weight, and gain from birth to weaning by two methods: the intraclass correlation coefficient and regression which later records showed from the first record toward the herd average.

Estimates for repeatability of weaning weight by the two methods were .43 and .49; the corresponding estimate obtained by using uncorrected weaning weights was .22. Estimates of repeatability of birth weight were .18 and .14, whereas the estimate made from uncorrected birth weights was .14. The estimates obtained for repeatability of gain from birth to weaning were .38 by both methods.

Corrections for the effect of variables considered in this study approximately doubled the repeatability of weaning weight, but had little influence on repeatability of birth weight. Repeatability of weaning weight and of gain from birth to weaning were considerably higher than that of birth weight. Moreover, weaning weight and gain from birth to weaning are much better measures of production for range beef cows than is birth weight.

The correlation between corrected birth weight and corrected weaning weight was .40 and that between corrected birth weight and gain from birth to weaning was .23. The correlation between cow weight at weaning and weaning weight of her calf was .14. The correlation between the average of a cow's weights at weaning and the average of her calves' weaning weights was .17.

Simple correlation coefficients were determined for all three traits between first and second records of the cows at Fort Reno. The correlations obtained were .66, .69 and .25 for weaning weight, gain from birth to weaning and birth weight respectively.

The use of the various estimates of repeatability in estimating the producing ability of cows with varying numbers of records is discussed, as well as their use for allotting cows for making group comparisons in experimental work.

These results indicate that considerable progress can be made in selecting cows on the basis of their first record, particularly in the case of weaning weights, and that differences in inherent producing ability should often be considered in allotment of cows for experimental work.

More information is needed to determine what portion of repeatability is due to the additive effects of genes in order to more accurately predict what gain can be expected in future generations from selecting cows for productivity.

PART II

CORRELATIONS BETWEEN WEIGHTS AND GAINS OF BEEF CATTLE AT DIFFERENT TIMES

Introduction and Review of Literature

Selection of young animals, either for breeding stock or for feeders, is often influenced quite largely by the size of the animals. Therefore the relationship between early weights and subsequent performance should be of interest to all beef producers. Weight is usually one of the factors considered in the allotment of cattle for experimental work. How much attention should be paid to initial weight depends on the correlation between initial weight and subsequent performance.

Miranda et al (1946) stated that initial weight is an important factor in allotment of pigs only when there is a wide range in weights. Lush (1931) found the correlation between initial weight of steers and gain in the feedlot to be .24. Several reports have indicated that growth prior to the feeding period in cattle was positively correlated with gain in the feedlot. Hultz (1927) found that rangy steers gained faster than lower set animals which were smaller. Similarly Woodward et al (1942) reported that large type steers gained more rapidly than smaller type steers. Knox and Koger (1946) found that rangy steers gained more rapidly than smaller compact steers, and suggested that the differences in gain were likely due to differences in size. Lush (1932) found that heavy initial weight was associated with large gain. He also found a positive correlation between skeletal size and rate of gain in the feedlot. Stanley and McCall (1945) likewise found a positive correlation between skeletal size and feedlot gain. In their study, weaning weight and subsequent daily gain in the feedlot were highly correlated. Koger and Knox (1951) found a positive relationship between performance on the range as measured by weaning weight and performance in the feedlot after weaning. The correlation between weaning weight and gain in the feedlot was increased considerably by corrections of weaning weight for age of calf and age of dam.

Black et al (1938), however, found height at withers and body length to be negatively correlated with feedlot gain. Black and Knapp (1936) reported a correlation of -.36 between average daily gain from birth to weaning and average daily gain from weaning to slaughter.

Mott and Miles (1946) found that less than one percent of the variation in gains made by steers on pasture was accounted for by differences in initial weight. Ruby et al (1948) reported correlations for various weights and gains of calves on wintering rations and on pasture during the summer. The correlations between initial weights and subsequent gains were relatively low, whereas correlations between weights at different times were relatively high. Winter and summer gain were negatively correlated. Koger and Knox (1951) found that growth on the range at different periods was positively correlated. However, weaning weight showed a low and in some cases a negative correlation with growth at later periods. The low correlation between weaning weight and growth at other periods was accounted for by the fact that growth of calves up to weaning was influenced by the milk supply of their dams.

Knapp and Clark (1947) analyzed gains of steers during three consecutive 84 day periods. Correlation between gains in periods one and two was .26, between gains in periods one and three was .18, and between gains in periods two and three was .39. Genetic influences accounted for 10, 54 and 84 percent of the variation in gains for the three periods, genetic influences becoming greater as the feeding period progressed. According to reports by Knapp and Nordskog (1946) and Knapp and Clark (1950), the influence of heredity on economic traits in beef cattle is quite important. The performance of animals, then, is a fairly good indication of the performance of their offspring.

Reports at this station (Oklahoma Miscellaneous Publications 11, 13, 15 and 17) have indicated that lots of steers which made the greatest gains in winter made the lowest gains during the summer on grass. It is the purpose of this study to determine the correlation between winter gain and summer gain of individual calves, as well as to determine the relationship between growth at different periods and the use of such relationships in selection of breeding stock.

Materials and Methods

Weights and gains were obtained from 386 Hereford steer calves wintered at the range area near Stillwater during the period of 1944 through 1950. Likewise, weights and gains were obtained from 219 Hereford heifer calves some of which were wintered at Stillwater and some at Fort Reno during the years 1948 through 1951. Weights were available over a two year period on most of the heifers. Also available were data on the feedlot performance of 470 Hereford steer calves on full feed at Stillwater from 1942 through 1951. The rations fed the various lots were different and the date of starting and ending the feeding periods varied somewhat from year to year. Therefore, all comparisons were made on an intra-lot, intra-year basis.

Measurements taken were as follows:

1. Initial weight, taken at time calves were divided into experimental lots.
2. Spring weight, taken at the close of the wintering period.
3. Final weight, taken at the close of the summer grazing period, about one year after the initial weight.
4. Winter Gain, the difference between 2 and 1.
5. Summer gain, the difference between 3 and 2.
6. Early Summer Gain, the gain during about the first 100 days of summer grazing period.
7. Total Gain, the sum of 4 and 5, or the difference between 3 and 1.
8. Yearling weight, the same as 3, about 18 months of age.
9. Two year old weight, one year later than 8, about 30 months of age.

10. First year gain, the same as 7.

11. Second year gain, the difference between 9 and 8.

12. Feedlot gain, gain during about 170 to 180 days on full feed.

Results and Discussion

Table XVI shows the means, standard deviations and coefficients of variation for the various groups.

Table XVI

Intra-lot means, standard deviations, and Coefficients of Variation

Description	Measurement	n	Mean	s	C.V.
All Calves in Wintering Lots, 386 Steers, 219 Heifers	Initial Wt.	605	444	43.6	9.8
	Spring Wt.	605	551	48.5	8.8
	Final Wt.	605	783	64.4	8.2
	Winter Gain	605	106	33.2	31.3
	Summer Gain	605	234	31.1	13.3
	Total Gain	605	340	39.2	11.5
Summer grazing divided into two Phases; Some lots were full fed during late Summer	Winter Gain	239	151	33.6	22.2
	Early Summer Gain	239	136	24.3	17.9
Steers Wintered for Two Winters, Some Lots Fed Corn During the Second Summer	1'st Yr. Gain	88	266	34.4	12.9
	2'nd Yr. Gain	88	347	39.0	11.2
Heifers Wintered, and Grazed During Summer for Two Years	1'st Yr. Gain	113	293	35.7	12.2
	2'nd Yr. Gain	113	294	38.9	13.2
	Yearling Wt.	113	736	45.8	6.2
	2 Yr. Old Wt.	113	1030	65.3	6.3
Steers in the Feedlot	Initial Wt.	470	495	36.5	7.4
	Feedlot Gain	470	354	43.0	12.1

As measured by the coefficient of variation, gains were more variable than weights in all cases. The winter gains were considerably more variable than summer gains. This is likely due to the competition between individual steers within a lot for the limited feed during the winter.

According to Ross et al (1947) steer calves wintered at a level which will produce 1.25 to 1.50 pounds per head per day are considered by cattlemen as "well wintered". "Medium wintered" steers are those which have gained approximately one pound per head per day and those gaining less than .75 pound per day are considered wintered at a low level. The lots of steers were divided on this basis to see if level of wintering had any effect on the correlation between winter gain and summer gain of individual steers. The three groups were each redivided into those grazed all summer and those grazed in early summer and full fed during the latter part of the summer period. Some of the heifers were bred during the summer, so the heifers were divided into two groups: open and bred. Judging by the gains, the heifers were all wintered at a medium level or low level. Table XVII shows the intra-lot correlations between winter and summer gains of the different groups.

Table XVII

Intra-lot Correlations between Winter and Summer Gains for Different Groups

	n	r
High Level of Wintering, Grazed all Summer	25	-.40*
High Level of Wintering, Full Fed Late Summer	44	.09
Medium Level of Wintering, Grazed all Summer	113	-.24*
Medium Level of Wintering, Full Fed Late Summer	55	-.29*
Low Level of Wintering, Grazed all Summer	129	-.22*
Low Level of Wintering, Full Fed Late Summer	20	.16
Heifer Calves, Open	113	.02
Heifer Calves, Bred	106	-.23*

* Signifies Probability of Chance Occurrence $<.05$

The correlations varied from -.40 to +.16. The numbers in each group were small, however, and considerable variation in correlations could be expected. It would appear that there is some tendency toward positive correlation between winter and summer gain for those calves which were full fed during late Summer. The results do not seem to indicate that level of wintering has a consistent effect on the correlation between winter and summer gain.

Considering the entire group of calves in wintering lots, there was some tendency for calves within a lot that made the largest gains during the winter to make the smallest gains during the summer (Table XVIII). This tendency was more pronounced during the early summer grazing period, indicating that the thinner calves were better able to utilize the lush grass of the early summer grazing period than calves in higher condition. The effect of competition between calves within lots for the limited feed in wintering lots, whereas no such competition was present while grazing, may have been partly responsible for the negative correlation between winter gains and summer gains. For those calves full fed in late summer, competition was reintroduced, so it would be expected that the negative correlation would be reduced, or even become positive.

Ruby et al (1948) obtained a higher negative correlation, -.28, between winter and summer gain, however none of the calves in their study were fed during the late summer, so it might be expected to be higher than that obtained in the present study. Correlations between initial weight and winter gain and between initial weight and summer gain were the opposite of those obtained by Ruby et al. In the present study correlations

Table XVIII

Intra-lot Correlations between Various Measurements

	n	Correlation Coefficient
Winter Gain and Early Summer Gain	239	-.23**
Winter Gain and Summer Gain	605	-.12**
Initial Weight and Winter Gain	605	-.14**
Initial Weight and Summer Gain	605	.08
Initial Weight and Total Gain	605	-.05
Spring Weight and Summer Gain	605	.45**
Initial Weight and Spring Weight	605	.78**
Initial Weight and Final Weight	605	.73**
Spring Weight and Final Weight	605	.84**
First Year Gain and Second Year Gain (Steers)	88	.08
First Year Gain and Second Year Gain (Heifers)	113	.44**
Yearling Weight and Two Year Old Weight	113	.81**
Initial Weight and Gain in the Feedlot	470	.24**

** Signifies Probability of Chance Occurrence <.01

were -.14 between initial weight and winter gain, and .08 between initial weight and summer gain. The corresponding correlations reported by Ruby et al were .23 and -.14 respectively. In both studies the correlation between initial weight and total gain was in the same direction as correlation between initial weight and winter gain, but smaller. Spring weight was correlated with summer gain .45 as contrasted to -.37 as obtained by Ruby et al. In their study, spring weight accounted for 13.5 percent of the variation in summer gain, whereas in the present study, spring weight accounted for about 20 percent of the variation in summer gains. Mott and Miles (1946) found that spring weight accounted for only one percent of the variation in summer gains of steers on pasture.

Weights at different times were highly correlated. The correlation between initial weight and spring weight was .78, between initial weight and final weight was .73, and between spring weight and final weight was .84. This would indicate that initial weight accounts for a large part of the variation in later weights. These results are in agreement with those of Ruby et al.

The correlation between initial weight and gain in the feedlot of .24 is in agreement with results reported by Lush (1931).

Correlation was .44 between first and second year gain for the heifers, but only .08 for the steers. However, some of the steers were fed corn during the second summer, and that may be partly responsible for the apparent difference between heifers and steers.

The correlation between yearling weight and two year old weight was .81, and was quite comparable to correlations between initial weight and later weights.

Although the numbers are limited, there is at least some indication of a positive relationship between growth during different periods. The high correlations between weights taken a year apart would indicate that selection for weight at 12 or 18 months of age would be effective. Koger and Knox (1951) indicated that selection for size had been highly successful.

From the results reported, it seems that initial weight is not a very good indication of subsequent gains. If rate of gain is the only item considered in experimental work, then little can be gained by control of initial weight. However, if final weight is considered as a factor, then initial weight becomes very important. Complete control of initial weight would remove 50 percent or more of the variation in subsequent weights, but less than 5 percent of the variation in gain.

SUMMARY AND CONCLUSIONS

Data from 1075 Hereford calves were analyzed to determine the relationship between weights and gains at different times. There was a rather low negative correlation between winter gain and summer gain for those calves on wintering rations. A higher negative correlation existed between early summer gain and winter gain than between total summer gain and winter gain. The correlation between weights and subsequent gains were low, indicating that initial weight does not account for much of the variation in gain. Correlations between weights at different times, however, were all high. Selection of cattle for size at early ages should be very effective. Initial weight and feedlot gain were positively correlated, the correlation being .24.

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THESIS TITLE: Repeatability of Weights and Gains in Range Beef Cattle.

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The content and form have been checked and approved by the author and thesis adviser. "Instructions for Typing and Arranging the Thesis" are available in the Graduate School office. Changes or corrections in the thesis are not made by the Graduate School office or by any committee. The copies are sent to the bindery just as they are approved by the author and faculty adviser.

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