SIRE INFLUENCE UPON WEIGHTS AND GRADES

OF BEEF CALVES

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INTRODUCTION

Feeder calf production is an economically important industry in the range areas of the west and southwest. More than a million cows over two years of age are being maintained in Oklahoma alone. The majority of calves produced by these cows are marketed at weaning as feeder and stocker calves.

In a range beef herd a calf's performance at weaning is doubly important since it is a measure of the calf's inherent growth potential and of the dam's producing ability. The brood cow influences traits such as weaning weight and grade both by the genes that she contributes and by the maternal environment she provides. The sire's effect upon the performance of his offspring is limited to the genes which he transmits.

Since the use of superior herd sires is the most efficient method of increasing the production of an individual herd, the importance of evaluating the breeding potentialities of males at an early age has long been recognized. The success of selecting breeding animals at a young age depends largely on the animals retaining the characteristics for which they were selected. If phenotype at an early age is an expression of genotype, it should be possible to select superior individuals on their weaning performance. On the other hand, if the phenotype of an individual is dependent largely on factors other than genotype, an animal's performance would be of little value as a criterion of selection.

Significant differences have been found to exist among average weaning weights and grades of offspring by bulls which were bred to cows of similar producing ability. These differences are known to exist among average post-weaning gains and final test weights. To produce permanent improvement in any characteristic the observed differences between individual animals must have a heritable basis. The marked changes in size, form, and quality of cattle since the time of Robert Bakewell serve as an indication that these traits are heritable. With this fact in mind, an accurate estimate of the heritability of a trait is the most important single genetic parameter needed to make effective breeding plans for the improvement of economic characters in beef cattle.

The primary purpose of this study was to obtain estimates of heritability for the direct effect of the sire upon the weaning weight, grade, post-weaning daily gain, and 12 month weight of his offspring by the regression of the offspring's average performance on the sire's performance. An analysis using the regression of offspring on parent for these traits was desired since records were available on the individual performance of a considerable number of sires, and also because less bias is incorporated in estimates of heritability by this method than with half-sib correlation methods, according to Lush (1940). Other purposes of this study were to obtain estimates of heritability for the direct effect of sire on his progeny for these same traits by paternal half-sib intraclass correlations, to obtain phenotypic correlations and regressions among these traits, and to obtain offspring-sire regressions. This study was also intended to compare the effectiveness of selecting sires on their performance at 7 and at 12 months of age.

REVIEW OF LITERATURE

Knapp and Nordskog reported the first genetic study on the variations in beef cattle weights and gains in 1946. Studies had been reported by various workers with other species of livestock prior to this time. The long generation interval in beef cattle and the expense of maintaining experimental herds might well be responsible for the lack of information on the importance of heredity on the performance of beef cattle.

Knapp and Nordskog (1946a) presented preliminary estimates of heritability of various weights and gains. They analyzed the records of 177 steer calves from 23 sires. All calves were dropped on the range during a period of approximately 8 weeks in April and May each year. After weaning in late October eight steers from each sire, if available, were placed on full feed in individual feeding stalls. The feeding period ranged from 252 to 273 days with all steers being fed the same period of time in any one year. From these data they reported the heritability estimates given below. Three methods of analysis were used. The authors postulated that the most probable cause of the high heritability estimates was that the population was too restricted to give reliable estimates.

Method of Analysis	Weaning Weight	Final Weight	Gain
Inter-year correlation between half-sibs	.12	.81	.99
Regression of progeny average on sire total variance	.00	.69	.46
Regression of progeny average on sire within year of sire	.30	.94	.48

Knapp and Nordskog (1946b), utilizing the same data reported by Knapp and Nordskog (1946a), estimated the heritability of score at weaning. The calves were scored at weaning by a committee of 3 men working independently. The average of the 3 scores was used as the score for each animal. Heritability of score at weaning was estimated to be .53 by paternal half-sib correlation. The regression of progeny score at weaning on sire score was negative (b = -.07), and was not significantly different from zero. The writers stated that in view of the fact that only 20 degrees of freedom were involved this low heritability might be due to sampling errors.

Knapp and Clark (1947) made an analysis of the gains of 422 steers by 43 different sires at the U. S. Range Livestock Experiment Station, Miles City, Montana, and at the North Montana Branch Station, Harve, Montana. All steers used were fed at least 252 days. The correlation between the genetic influence and the observed growth for the entire 252 day period was .85. When squared, this value would yield a heritability estimate of .72 for gains made during the entire feeding period.

√Patterson et al. (1949) reported on 7 years' feeding experiments in Texas where 6 to 10 progeny per sire were fed growing rations under similar conditions. From records on 814 young bulls and 104 heifers they obtained intra-year half-sib correlations of .26 for the bulls and .30 for the heifers. These half-sib correlations would yield heritability estimates over 100 percent. Since the animals in this study came from several different ranches, it was expected that the high correlation was at least partially due to the greater similarity of pretest environmental conditions within sire groups as compared with those between sire groups.

Correlations between initial weight and gain and between initial grade and initial weight were estimated to be .063 and -.243, respectively.

Gregory et al. (1950) used data collected at the North Platte and Valentine Substations of the Nebraska Agricultural Experiment Station to estimate the heritability of weaning weight. By paternal half-sib correlation they obtained estimates of heritability of weaning weight of .26 and .52 for North Platte and Valentine, respectively. The North Platte data were collected over two periods. Thirty-three weaning weights were collected during 1936, and a total of 237 weaning weights were collected from 1944 through 1947. Data on 69 weaning weights were available from the Valentine Substation during the years 1935 and 1936. The paternal half-sib correlation technique was the only method used in estimating heritability since no weaning records were available on the sires and dams. Differences between sires were not significant for weaning weight in either set of data.

Knapp and Clark (1950) reported a revision of the earlier heritability estimates published by Knapp and Nordskog (1946a, 1946b). The revised heritability estimates were considered to be more reliable since they were based on more than four times the number of steers in the original report. By paternal half-sib correlation heritability was estimated to be .28, .28, .65 and .86 for age-corrected weaning weight, weaning score, gain in the feedlot and final feedlot weight (15 months), respectively. These estimates were based on the progeny of 64 to 110 Hereford sires. Heritability estimates of weight at 15 months and rate of gain in the feedlot were also made by offspring-sire regression. These estimates, based on 72 sires and their offspring averages, were .92 and .77 for weight at 15 months and rate of gain, respectively. The bulls used in this study were fed for a period of 196 days after weaning and the steers were fed for 224 to 273 days, but all steers were fed the same length of time in any one year.

In a study to determine the most economical length of feeding period to obtain genetic growth differentiation, Knapp and Woodward (1951) estimated heritability of live weight at 28-day intervals during the feeding period where all animals were *ad libitum* fed. These workers estimated heritability to be fairly high at birth and stated that it dropped to .28 at weaning, and that it was still .28 at the end of the first 28-day period on feed. They further stated that the heritability rose sharply from the end of the first period to the end of the sixth period, and that there was little change from the end of the sixth period to the end of the ninth period. The heritability estimates ranged from .80 to .99 during the last three periods. The results were interpreted as indicating that feeding periods as short as 112 days would indicate heritable growth differences where *ad libitum* feeding was practiced. The method by which these heritability estimates were obtained was not given.

Knapp and Clark (1951) estimated heritability of weaning score and of feedlot gain to be .31 and .70, respectively. These estimates were obtained from an analysis of the records of 613 steers by 83 Hereford sires in an experiment conducted to determine the correlation between feeder grade at weaning and subsequent feedlot gains.

The scores were obtained each year by a three-man committee scoring independently. The average of the three scores for each animal was used as the score for that animal. They stated that the same points were scored as for feeder grade, and that score and feeder grade were essentially the same. Scores ranged from 52 to 94 which would be comparable to feeder grades of Common to Fancy. After scoring the steers were placed on feed for 224 to 270 days.

From these same data a gross correlation of .0001 was observed between score at weaning and gains in the feedlot. A genetic correlation of .300 and an environmental correlation of -.304 were obtained. These workers thought that the negative environmental correlation might have been due to some compensating increased gains in the feedlot for the relatively poorer conditions of environment before weaning, or that it might have been caused by a negative correlation which might exist between milk production and feedlot gains. From the study it was concluded that there was little value in selecting feeders for rapid gain if sole dependence was placed on the visual method of selection.

By the paternal half-sib correlation technique Koger and Knox (1952) estimated the heritability of weaning grade to be .30 and .24 for an Angus and a Hereford herd, respectively. The Angus data consisted of the weaning grades of 715 calves by 15 sires. Records were available on 1,257 weaning grades in the Hereford herd.

All the Angus calves were graded by one man. A committee of three or more people working independently graded the Hereford calves at weaning time. The Hereford calves averaged 205 days of age at weaning. The average of the committee members' grades for each calf was used as that calf's grade.

The authors suggested two possible reasons for the heritability estimate of weaning grade being higher from the Angus herd than from the Hereford herd. First, only one person graded the Angus cattle while a committee graded the Herefords. Since the range in grades by one individual is greater than the range of a committee grade, the committee grade has the advantage of being less subject to large errors, but also has the disadvantage of reducing variation in scores. Also, individual scores are more likely to reflect variation of a single trait than that of a committee. They further suggested that the Angus herd might not have been as highly selected at the beginning of the study as the Hereford herd. If a character is heritable, selection for that character would reduce its heritability within a group of animals.

Kincaid <u>et</u> <u>al</u>. (1952) obtained direct estimates of heritability of growth rate in beef cattle through progeny tests of sires which had been individually fed on record of performance tests for at least 168 days after weaning. Matings for the progeny tests of equal numbers of paired fast and slow gaining sires were as follows: 2 pairs in 1948, 4 pairs in 1949, and 5 pairs in 1950. The number of bulls fed on record of performance tests from which these selections were made and the average daily gains of the fast and slow gainers selected for progeny tests were: 8, 1.93 and 1.75 in 1948; 24, 2.09 and 1.45 in 1949; and 30, 2.09 and 1.59 in 1950. Samples of steers from these matings were full-fed on individual record of performance tests for at least 200 days while the heifers were tested on pasture alone after limited feeding during their first winter.

Estimates of heritability of postweaning growth rate based on differences between fast and slow gaining sires and their steer progenies were .33, .42 and .00, respectively. The steer progeny tests included 15 steers in 1949-50, 30 in 1950-51 and 36 in 1951-52. The heifer progenies which completed tests on pasture, 16 in 1950 and 39 in 1951, yielded heritability estimates of postweaning growth of .00 and .20. The average estimates of heritability of rate of gain weighted by numbers of pairs of sires progeny tested in each year were, for the steers and heifers, .22 and .12, respectively.

Dawson _et al_. (1954) estimated heritability of six-month weight to be zero from both offspring-sire regressions and paternal half-sib correlations of immediate offspring. These estimates were based on the six-month weights of 446 calves produced during the years 1945-1950 at the U. S. Livestock Experiment Farm, Jeanerette, Louisiana in a strain of cattle derived from a Brahman-Angus crossbred foundation.

The regression coefficient for the six-month weight of the offspring on the six-month weight of the sire was slightly but not significantly negative (b = -.18). The authors interpreted this as indicating that there was no apparent effect of the sire on the six-month weight of his offspring. They further stated that the fact that the sires used in this study were a highly select group so far as their own six-months' weight was concerned might have been a factor in reducing their apparent effect on the six-months' weight of their offspring.

An attempt was made to calculate the paternal half-sib correlation but the analysis of variance showed more variance within the offspring of the same sires than between offspring of different sires.

They concluded again that the sires on the average were having very little effect on the six-months' weight of their offspring. It appeared probable to the authors that the lack of sire effects in these data might have been due to sampling variation or perhaps to the fact that the sires used were relatively uniform in their transmitting ability.

Warwick and Cartwright (1955) reported heritability estimates of postweaning gain obtained by the gain ratio method of determination. The gain ratio technique is a relative measure obtained by dividing an individual's gain by the average of his sex, breed, year and ration group. The data analyzed were collected during four gain evaluation tests over a four-year period. The animals in the first three tests were on feed for a period of 154 days following a two week adjustment period after weaning. The fourth test was for only 140 days. The data were from 853 head consisting of two breeds, one cross and three sex classifications. Paternal half-sib correlation analyses using the gain ratio technique yielded heritability estimates of postweaning gain ranging from .33 to .51 for different classifications of breed or cross and pretest history. Since a more reliable estimate of heritability was considered to be that obtained by the method of regression of average offspring on parent, this also was calculated using gain ratio. From 73 pairs including 291 offspring, heritability was estimated to be .54 by the regression of offspring average on sire phenotype. These workers maintained that although estimates obtained from gain ratio were not true estimates of heritability, the high estimates encountered in this study added overwhelming support to the conclusion that selection for rate of gain would be effective when the individual's own record was used.

The correlation between initial weight and final gain ratio based on the 853 animals in this study was .11, and was statistically significant. Between initial age and final gain ratio the correlation was .00. Therefore, difference in initial weight accounted for only 1 percent of the variation in subsequent gain, and age apparently had no effect.

Shelby et al. (1955) estimated heritability of weaning weight, rate of gain in the feedlot and final weight by paternal half-sib correlation to be .23, .60 and .84, respectively. The data for this study consisted of the records of 635 Hereford steers fed in record of performance tests from 1942 to 1951, inclusive. The steers were by 88 sires from 9 inbred lines of different pedigree origin. The steers were individually fed through 1946, and were group fed thereafter. The length of feeding trial varied from 252 to 273 days. The effects of differences between years, between lines within years, and between sires within lines were separated by analysis of variance, while the effects of age at weaning, and of age and final weight at the completion of the feedlot test were removed by covariance.

Koch and Clark (1955a) analyzed data consisting of 4553 weaning weights, 3831 weaning scores, and 1694 fall yearling weights. The weaning and fall yearling weights were collected over the period 1929-1951 from 137 different sires, while the weaning scores were accumulated over the years 1936-1951 and involved 124 different sires. The data were adjusted for sex to a heifer basis, corrections were made for age of dam, and the weaning weights were adjusted to a standard age of 182 days. Sire differences were determined on a within year and line basis. The general management policy was to keep the cows on native range throughout the year, with supplemental feed consisting of alfalfa hay or cottonseed cake being fed during periods of severe winter storms or drought. Paternal half-sib correlations yielded heritability estimates of .24, .18 and .47 for weaning weight, weaning score, and yearling weight, respectively. Phenotypic correlations among the paternal half-sibs were also determined. Weaning weight was correlated .64 and .47 with weaning score and yearling weight, respectively.

Koch and Clark (1955b), utilizing part of the same data reported by Koch and Clark (1955a), estimated heritability of weaning weight and weaning score by the regression of offspring on sire method. Weaning weights were available on 85 sires and their progeny. Weaning scores were available on 77 sires and their offspring. The data were grouped into subclasses according to the year the sire was born and the year the calves were born. Grouping in this manner removed the average effects of years. The progeny average was then regressed on the sire's record. Heritability estimates obtained were .25 for weaning weight and .15 for weaning score.

Rollins and Wagnon (1956a) estimated heritability of weaning weight in two herds subjected to different environmental conditions. The data consisted of the weaning weights of 577 calves produced by 2 grade Hereford herds maintained by the University of California at the San Joaquin Experimental Range. One herd received supplements during the late summer, fall, and winter until adequate green forage became available, while the other herd received no supplements except in emergency to stop death losses. The data were standardized for differences due to year of birth, sex, age of dam and pasture. In the supplemented herd heritability of weaning weight was estimated to be .09 by paternal half-sib correlation, while it was estimated at .54 in the unsupplemented herd. Since there was no evidence that the heritability estimates for the two herds were significantly different, the workers considered an average of the two paternal half-sib estimates to be the best estimate of heritability of weaning weight that these data afforded. This estimate was .30.

Rollins and Wagnon (1956b) reported heritability estimates of weaning grades computed from the same data described by Rollins and Wagnon (1956a). All grading was done at weaning each year by the same man. The grading system used was that developed by Guilbert (1951). On the basis of paternal half-sib relationships heritability estimates were made within each of three generations for each herd. The estimates for the supplemented herd were consistently higher than those for the unsupplemented herd. However, these differences were not statistically significant. Heritability was therefore estimated for the paternal half-sibs within each herd and then pooled over both herds. The pooled estimate of heritability of weaning grade was .36. Within years a correlation of .42 was found to exist between weaning grade and weight. Thus 18 percent of the variance in weaning grade within years was due to variation in weaning weight.

Shelby et al. (1957 and 1960) analyzed the records from 542 bull calves tested in record of performance tests from 1940 to 1954, inclusive, at the U. S. Range Livestock Experiment Station, Miles City, Montana. These bull calves were by 116 sires from 11 inbred lines of different pedigree origin. All bulls were individually fed for a period of 196 days following a preliminary feeding period of about 14 days immediately after being weaned at an average age of 180 days. Weaning weights were adjusted to 180 days of age and were corrected for age of dam. Corrections for age of calf or dam were not made on weaning scores. The data were analyzed on a hierarchal type of classification to separate the variance into component parts. By paternal half-sib correlation the following estimates of heritability were obtained: weaning weight .43, weaning score .60, feedlot gain .46, actual final weight .77, and adjusted final weight .55. Actual final weights would have been taken at approximately 13 months of age, while adjusted final weights were computed from the 180-day weights and the 196-day feedlot gain. The authors concluded that weight at 13 months was the most valuable criterion for selection.

In a study to determine the relative economic importance of traits affecting net income in beef cattle, and to develop a selection index designed to attain maximum genetic progress toward increasing net income per hundred weight of finished product, Lindholm and Stonaker (1957) analyzed the records of 118 Hereford steers by 19 sires. These steers were raised by the Colorado Experiment Station in the 6-year period 1946-1951. The heritability estimates obtained by the use of paternal half-sib correlations in this study were higher than reasonably could be expected. The heritability estimate for unadjusted weaning weight was .81, and was near the maximum limit. Unadjusted weaning weights were used because it was felt that adjusted weights might bias the true biological relationships. Heritability of rate of gain in the feedlot was estimated to be 1.57. This estimate was greater than the maximum limit of heritability. The writers felt that the estimate of heritability of weaning weight was probably biased upward since an intra-class correlation of .38 indicated a difference in the weaning age of calves in the different sire groups. No explanation was given for the excessive magnitude of the heritability estimate of feedlot daily gain.

Phenotypic correlations among some traits were also computed. Correlation between weaning weight and weaning grade was .59. Feedlot daily gain was correlated .07 and -.35 with weaning weight and grade, respectively.

Kincaid and Carter (1958) using the three years' data reported by Kincaid <u>et al</u>. (1952) plus an additional three years' data, reported estimates of heritability of growth rate in beef cattle obtained by the direct method of dividing the weighted average difference between the offspring of paired high and low gaining sires by the difference between the sires and doubling the resulting regression. A study of this nature was desired by the writers in order to make some test of the "high" heritability estimates (in excess of 0.5) of post-weaning gains arrived at by indirect estimates. Nineteen high-gaining bulls that averaged 2.24 pounds per day and 19 low-gaining bulls that averaged 1.65 pounds per day were selected from the 131 bulls on test over a 6-year period. The bulls were individually full-fed for an average feeding period of 168 days. The difference between high and low gaining bulls, 0.59 pound per day, was slightly more than two standard deviations. For their progeny test the selected bulls, 22

Hereford, 12 Angus and 4 Shorthorn, were paired by breed and mated at random to equal numbers of grade Hereford cows. The steer progeny, totaling 192 head, were full-fed for 200 days following weaning, while the heifers, 196 head, were wintered largely on roughage and were tested by gains made on pasture their yearling summer. The differences between the progeny averages of the high and low gaining sires were 0.1 pound per day for the steers and 0.06 pound per day for the heifers. Heritability estimates based on these differences ranged from .26 to .34 for the steers and from .21 to .26 for the heifers, depending on the method used to adjust for differences in progeny numbers. When adjusted for differences in variance among the sires and within the progenies, i.e., when converted to standard measure, the estimates were .38 to .49 for the steers and .31 to .35 for the heifers. The authors felt that these adjusted estimates were more realistic. The authors suggested that previously reported heritability estimates in excess of 0.5 obtained from half-sib analyses were probably too high, and further that the true value of heritability of postweaning gains was positive, that it was between zero and 0.5 and was probably in the neighborhood of one third.

Carter and Kincaid (1959a), using the same data that Kincaid and Carter (1958) had used previously to estimate directly heritability of postweaning growth rate in beef cattle, reported estimates of heritability of a number of traits derived from offspring-parent regressions and paternal half-sib comparisons. Heritability estimates obtained from paternal half-sib correlations were, for the steers: weight at 6 months, .08; feeder grade, .41; and daily gain in the feedlot, .38.

For the heifers the heritability estimates were .69 and .51 for weight at 6 months and feeder grade, respectively. By regression of progeny average on sires' records heritability estimates of .16 for feeder grade and .21 for daily gain in the feedlot were calculated for the steer progeny. Feeder grade of the heifer progeny at weaning was estimated to be 63 percent heritable by offspring-sire regression.

In these data the average difference in weight at 6 months between the progeny of the high and low gaining sires was 10 pounds for the steer calves and 19 pounds for the heifers. Heritability of weight at 6 months was estimated at .69 for the heifers and .08 for the steers. To the knowledge of the authors such a difference between the sexes in heritability of weaning weight as they obtained had not previously been reported. They offered the slower growth rate and presumably lower nutritive requirements for optimum growth of heifers compared to steers as a possible explanation to this difference in heritability of weaning weight between the sexes. If their explanation was valid, then perhaps the available feed, milk, and grass was more nearly adequate for maximum expression of heritable differences in growth rate among the heifers than the steers.

Wagnon and Rollins (1959) analyzed the weaning and long yearling weights of 305 heifers. The heifers were raised in two experimental range beef cattle herds of similar breeding and managed alike except that one herd was supplemented during the fall and winter when the range was nutritionally deficient, while the cows and heifers in the other herd were not supplemented. The history and a more detailed description of the constitution and management of these herds was presented by Rollins and Wagnon (1956a). The weaning weights were adjusted to a standard age of 240 days and the long yearling weights to a standard age of 600 days (roughly 20 months) prior to analysis by the paternal half-sib correlation method. Heritability of weaning weight was estimated to be .42 and .57 for the supplemented and unsupplemented herds, respectively. This difference was not statistically significant. Estimates of heritability of long yearling weight were .44 for the supplemented herd and -.19 for the unsupplemented herd. While the estimates were not significantly different at the 5 percent level, the writers postulated that the difference between these estimates was not entirely due to sampling error, and suggested the possibility of the existence of a difference in heritability of long yearling weights under the two management conditions.

Kieffer (1960) estimated the direct effect of the sire upon his offspring for weaning weight and weaning score from the intraclass correlations of paternal half-sib calves. The data analyzed consisted of 1880 weaning weights and 1502 weaning scores from calves sired by 120 different bulls. These data were collected from 4 different herds, and where necessary the data were standardized for age of calf, sex of calf, age of dam, year effects, and level of winter nutrition. All analyses were made within herds and years in which the calves were weaned. Estimates of heritability obtained from the sums of squares pooled over all herds were .24 for weaning weight and .14 for weaning score.

Carter and Kincaid (1959b) estimated genetic and phenotypic correlations among various traits in beef cattle using the data from

195 steers and 190 heifers born over a 5-year period, the progeny of 36 bulls. Details of the performance and progeny tests from which these animals were obtained were presented in detail in a previous paper (Kincaid and Carter, 1958). From the data in this study there appeared to be little relationship between grades and subsequent gains. In the steer progeny the phenotypic correlation between feeder grade at weaning and daily feedlot gain was slightly negative (-.07) but a small positive genetic correlation was found (.28). These correlations in the heifers were -.02 and -.004, essentially zero, for phenotype and genotype, respectively. A fairly high positive correlation was found in this study between gain from birth to weaning (indicated by weight at 182 days) and postweaning gains. The genetic correlation between weight at 6 months and feedlot gain was .69 in the steers. In the heifers the genetic correlation between 6 month weight and yearling gain on pasture was .51. The respective phenotypic correlations were .27 and .20. These estimates were quite different from some reported by other workers, and the writers suggested that this study should be of sufficient importance to justify further investigation with independent data to verify or refute their findings.

Knapp _et al_. (1941) estimated phenotypic correlations among various traits both on a total population and a between-animals-in-the same-year basis. Data used were the records of animals raised from 1935 to 1940, inclusive, either at the U.S. Range Livestock Experiment Station, Miles City, Montana, or at the North Montana Branch Station, Harve, Montana. Correlations between weaning weight and daily gain in the feedlot were -.059 in the total population and .088 between animals in the same year. Score at weaning and gain in the feedlot were correlated .092 in the total population and .025 between animals in the same year. The writers concluded that neither weaning weight nor score was correlated with daily gain in the feedlot.

MATERIALS AND METHODS

The data used in this study were the weaning weights, weaning grades, condition scores at weaning, 12-month weights, postweaning average daily gains, and 18-month heifer weights obtained in various combinations from 3 different herds. Two of these herds (Projects 670 and 650) were owned by the Oklahoma Agricultural Experiment Station and were located at the Fort Reno Livestock Experiment Station, El Reno, Oklahoma. The third herd was owned by the Federal Government and was also located at El Reno, Oklahoma. Because the management practices varied considerably for each herd, all statistical analyses were made on an intra-herd basis. Therefore, the data are described separately for each herd. The statistical procedures and methods were common for all herds and are discussed under the same heading for all herds.

PROJECT 670

Description of the Data

Foundation stock for 4 unrelated lines of breeding designed to study the inheritance of economically important traits in beef cattle was purchased in 1949. One line was established from the Angus breed and three lines were established from the Hereford breed. A detailed description of this project has been reported by Kieffer (1960).

It was from this herd that all sires used in the regression studies were obtained. The general management of this cow herd has been that which is normally imposed under range conditions. Spring calving is the general pattern although three Angus sires used in this study were born in the fall of 1956. The calves were weighed at approximately 28-day intervals until weaned in the early fall at an average age of 210 days. Creep feeding was not practiced in this herd. All calves were given a score for condition at weaning. This scoring was done by the same man each year. The scoring system used consisted of 9 numerical classifications. Scores of 1 indicated calves in a very unthrifty condition and were culls. Calves scoring 9 were considered to be comparable in condition to that obtainable with a nurse cow.

At weaning the males were placed on postweaning gain tests each year. These bulls were full-fed a growing ration for 154 days and at the end of this feeding period the individuals with superior performance were selected for progeny tests. These individuals were the sires used in the regression study.

Twenty-five different Hereford sires from this herd were used in the 650 cow herd over the 4-year period covered by this study. Three of the 25 different sires were used twice, thus making a total of 28 sire progeny groups. The performance of each of the Hereford sires is given in Table I. Thirteen Angus bulls were used in the Federal Reformatory cow herd over the 3-year period of this study. Table II shows the performance of these sires.

Correction of the Data for Known Variables

Age of calf

The average age at weaning was approximately 210 days. This age was taken as a standard and the weaning weights for all bull calves

TABLE I

SIRE'S PERFORMANCE GROUPED BY BIRTH YEAR OF SIRE AND OF OFFSPRING (PROJ. 650)

Birth year of Sire	Birth year of Offspring	Sire No.	Adj. Grade	Adj. 210-Day Wt.	Postwean. ADG	12-Mo. Wt.
1952	1956	2-19	7.9	467	2.06	709
1952	1956	2-42	8.0	533	2.12	791
1953	1956	3-11	7.4	515	2.01	764
1953	1956	3-43	7.0	581	2.01	841
1953[a]	1956	3-09	7.4	487	1.79	708
1953[a]	1956	3-11	7.4	515	2.01	764
1954	1956	4-08	8.4	581	2.66	908
1954	1956	4-16	5.4	431	2.56	767
1954	1956	4-25	6.4	505	2.89	890
1954	1956	4-50	7.4	468	3.15	968
1954	1957	4-68	6.4	450	2.86	903
1954	1957	4-50	7.4	468	3.15	968
1954	1957	4-34	7.4	509	3.12	964
1954[a]	1957	4-20	7.4	499	2.18	760
1954[a]	1957	4-16	5.4	431	2.56	767
1955	1958	5-02	7.0	507	2.27	822
1955	1958	5-16	7.9	684	2.56	1,003
1955	1958	5-20	6.0	562	2.47	924
1955	1958	5-23	8.0	565	2.44	917
1955	1958	5-26	8.0	597	2.60	970
1955	1958	5-33	7.9	643	2.53	939
1956	1959	6-05	8.0	592	2.29	903
1956	1959	6-09	8.0	635	2.56	955
1956	1959	6-29	8.0	606	2.62	988
1956	1959	6-44	8.0	558	2.63	936
1956	1959	6-47	8.0	556	2.60	940
1956	1959	6-62	7.5	504	2.02	791
1956	1959	6-93	7.0	493	2.40	867

[a]Bred to yearlings to calve as 2-year olds.

TABLE II

SIRE'S PERFORMANCE GROUPED BY BIRTH YEAR OF SIRE AND OF OFFSPRING (FED. REF.)

Birth year of		Sire	Adj.	Adj. 210-	Postwean.	12-
Sire	Offspring	No.	Grade	Day Wt.	ADG	Mo. Wt.
1954	1957	114	8.0	530	2.69	930
1954	1957	264	8.0	571	3.31	1,090
1955	1958	115	7.0	523	2.56	913
1955	1958	155	6.9	521	2.53	841
1955	1958	175	8.0	491	1.98	789
1955	1958	185	8.0	559	2.56	961
1956	1959	046	8.0	522	2.36	901
1956	1959	066	6.0	533	2.39	894
1956	1959	096	8.0	598	2.69	991
1956	1959	196	7.0	571	2.90	1,048
1956[F]	1959	406	8.5	533	2.65	913
1956[F]	1959	426	7.4	495	2.62	902
1956[F]	1959	436	8.0	608	2.43	985

[F]Fall-dropped bulls.

were adjusted to it. This adjustment was made by prorating gains made by each calf during the 28-day weigh period bracketing the standard age of 210 days. For calves which were less than 210 days of age at weaning, their weights were adjusted to the standard age by adding to their weight the product of their weight per day of age and the deviation of their age from 210 days.

All bull weights were adjusted to 365 days by proration of gains made by each bull during the 14-day weigh period bracketing the standard age of 365 days. For the few bulls which were not 365 days of age at the end of the test, their weights were adjusted to 365 days by adding to their weights the product of the average daily gains made during the last 14-day weigh period and the deviation of their ages from 365 days.

The influence of age of dam

The weaning weights and condition scores of the sires were corrected for the effects of age of dam by the correction factors established for this herd by Kieffer (1960). These age of dam correction factors are given in Table III. The method used by Kieffer to correct weaning weight and condition score for the effects of age of dam was to compare average records made at each age of dam over all lines.

The influence of year

The method of analysis used in the offspring-sire regressions made adjustments of the data for year effects unnecessary. The comparisons were made on a contemporary group basis, with the data being grouped within year of birth of the sire and of the offspring. Grouping in this manner eliminated the effects of years from the data.

TABLE III

CORRECTION FACTORS FOR AGE OF DAM

Age of Dam	Grade (units)	Weaning Weight: Proj. 650 (lbs.)	Weaning Weight: Fed. Ref. (average daily gain) 1957 and 1958	Weaning Weight: Fed. Ref. (average daily gain) 1959
2	1.0	88	.36	
3	.9	62	.22	.29
4	.5	32	.13	.19
5	.4	11	.08	.13
6				.11
7				.07

PROJECT 650

Description of the Data

In the fall of 1948, a long-time experiment was initiated with 120 weanling Hereford heifers to study the effects of low, medium, and high levels of supplementary winter feed on the lifetime performance of range beef cows grazing native grass throughout the year. Since 1954, 4 additional replications of the experiment have been added using the 1954, 1955, 1956, and 1957 daughters of the foundation cows for the new replications.

A detailed description of the experimental treatment of this herd has been reported by Zimmerman et al. (1959). The foundation cows were divided into 8 lots of 15 each, and these 8 lots were randomly assigned to receive 3 different levels of supplementary winter feed. Half of these cows calved first at 2 years of age in the spring of 1950, whereas the remainder calved first at 3 years of age in the spring of 1951. Prior to 1954 all cows were mated as a single group to multiple sires. From 1954-1959 the cows were divided into breeding groups on the basis of their previous productivity. Each breeding group contained cows with like records of previous productivity.

The heifers constituting the additional replications were divided into 3 lots of 15 animals each, except in 1957 when there were 4 lots of 15 each. The lots were then assigned at random to receive low, medium, or high levels of supplemental winter feed. The heifers which received the different levels of supplemental feed were fed the first winter as weanlings to make the following gains: low level, no gain during the winter period; medium level, 0.5 pound gain per day; and high level, 1.0 pound gain per day. The fourth lot added in 1957 was considered to be the very high level. The heifers in this lot were full-fed a 65 percent concentrate mixture. All of these heifers were bred to calve first as 2-year olds. They were divided into breeding groups of equal numbers with each group having been balanced according to the sire of the heifers, production of the heifer's dam, and the heifer's own level of supplementary winter feeding.

The management followed in regard to the calves was the same for all replications each year. The calves were weighed and identified within 24 hours of birth. Bull calves were castrated at 6 to 8 weeks of age and all calves were weaned in early October. Each year at weaning the calves were given feeder grades. Prior to 1959 the calves were scored by 2 men working independently, and the average of the 2 scores constituted the score for each calf. In 1959 the calves were scored by 1 man only. The scoring system and corresponding feeder grades were: 15-13, fancy; 12-10, choice; 9-7, good; 6-4, medium; and 3-1, common. None of the calves were creep-fed. The heifer calves saved at weaning to make up the later replications of this experiment were weighed at approximately monthly intervals throughout the year.

Regression of the Offspring's Average Performance on the Sire's Performance

The offspring-sire pairs were grouped by the birth year of the sire and of the offspring. The average performance of the offspring within groups was regressed on the sire's performance. All offspring in each sire-birth-year group were contemporaries, as were the sires. There was a total of 28 offspring-sire groups. These 28 groups contained the weaning weights and grades of 398 calves and the 18-month weights of 113 heifers. The records used in this phase of the study were collected over the 4-year period 1956-1959. Table IV shows the average performance of the offspring for these traits grouped by the birth year of the sire and of the offspring.

Paternal Half-Sib Correlations of Weaning and Postweaning Traits

The paternal half-sib correlations were computed for weaning weight, grade, and 18-month heifer weight on a within-year basis. The records used in this phase of the study were the same as were used in the regression analysis. The average performance of the offspring of the 28 sire groups by years and sires is shown in Table V.

Phenotypic Correlations and Regressions of Adjusted 210-Day Weight and 18-Month Heifer Weight

Phenotypic correlations of adjusted 210-day weight and 18-month weight were computed intra-year and sire, intra-sire, intra-year, and on a gross basis for the 113 daughters which had 18-month weights over the 3-year period from 1956-1958. Regressions of 18-month heifer weights on adjusted 210-day weights were computed for the same data in same manner. The adjusted 210-day weights and 18-month heifer weights were 510 and 798 pounds and their standard deviations were 33.4 and 61.6 pounds, respectively.

TABLE IV

AVERAGE PERFORMANCE OF OFFSPRING USED IN THE REGRESSION ANALYSIS GROUPED BY BIRTH YEAR OF SIRE AND OF OFFSPRING (PROJ. 650)

Birth year of Sire	Birth year of Offspring	Sire No.	No. Calves	Adj. Grade	Adj. 210-Day Wt.	No. Daughters	18-Mo. Wt.
1952	1956	2-19	19	10.5	510	12	791
1952	1956	2-42	10	10.3	524		
1953	1956[a]	3-11	15	10.1	498	6	718
1953	1956[a]	3-43	4	9.4	485		
1953	1956	3-09	16	10.2	501	7	774
1953	1956	3-11	12	10.4	504	4	725
1954	1956	4-08	6	9.4	529		
1954	1956	4-16	2	11.0	532		
1954	1956	4-25	9	10.7	523	3	820
1954	1956	4-50	14	10.7	522	6	829
1954	1957	4-68	15	9.5	485	4	868
1954	1957	4-50	13	10.2	488	5	862
1954	1957	4-34	9	7.7	479	4	852
1954	1957[a]	4-20	13	7.9	445	4	830
1954	1957[a]	4-16	14	7.5	447	8	788
1955	1958	5-02	20	11.0	488	7	801
1955	1958	5-16	21	11.0	512	9	823
1955	1958	5-20	23	11.2	502	7	807
1955	1958	5-23	21	11.1	479	6	793
1955	1958	5-26	20	10.6	482	12	783
1955	1958	5-33	16	11.0	504	9	801
1956	1959	6-05	18	11.4	468		
1956	1959	6-09	14	11.0	447		
1956	1959	6-29	14	11.0	479		
1956	1959	6-44	17	11.4	489		
1956	1959	6-47	13	11.5	490		
1956	1959	6-62	15	11.6	457		
1956	1959	6-93	15	11.4	481		

[a]Calves out of 2-year old heifers.

TABLE V

AVERAGE PERFORMANCE OF CALVES USED IN THE PATERNAL HALF-SIB CORRELATION ANALYSIS BY YEARS AND SIRES (PROJ. 650)

Year	Sire No.	No. Calves	Adj. 210-Day Wt.	Adj. Grade	No. Daughters	18-Mo. Wt.
1956	2-19	19	510	10.5	12	791
1956	3-11	15	498	10.1	6	718
1956	4-25	9	523	10.7	3	820
1956	4-50	14	522	10.7	6	829
1956	3-09[a]	16	501	10.2	7	774
1956	3-11[a]	12	504	10.4	4	725
1956	2-42	10	524	10.3		
1956	3-43	4	485	9.4		
1956	4-08	6	529	9.4		
1956	4-16	2	532	11.0		
1957	4-16[a]	14	447	7.5	8	788
1957	4-20[a]	13	445	7.9	4	830
1957	4-34	9	479	7.7	4	852
1957	4-50	13	488	10.2	5	862
1957	4-68	15	485	9.5	4	868
1958	5-02	20	488	11.0	7	801
1958	5-16	21	512	11.0	9	823
1958	5-20	23	502	11.2	7	807
1958	5-23	21	479	11.1	6	793
1958	5-26	20	482	10.6	12	783
1958	5-33	16	504	11.0	9	801
1959	6-05	18	468	11.4		
1959	6-09	14	447	11.0		
1959	6-29	14	479	11.0		
1959	6-44	17	489	11.4		
1959	6-47	13	490	11.5		
1959	6-62	15	457	11.6		
1959	6-93	15	481	11.4		

[a]Bred to yearlings to calve as two-year olds.

Correction of the Data for Known Variables

Age of calf

Since weights were not available on the calves in this project before weaning, adjustments of weaning weights to a standard age could not be made by the method of linear interpolation. The weaning weights of the calves in this herd were corrected to a standard age of 210 days with correction factors computed by Botkin and Whatley (1953). This method of adjustment assumes that the growth rate of calves is essentially linear during that portion of the growth curve to which the corrections are applied.

The weights of all heifers kept at weaning to make up future replications of the experiment were adjusted to 547 days by proration of gains made by each heifer during the monthly weigh period bracketing the standard age of 547 days, or 18 months.

The influence of sex

The weaning weights of heifer calves were adjusted to that of the steer calves by adding 25 pounds to the weaning weights of the heifers. Botkin and Whatley (1953) found that steers were on the average 24.6 pounds heavier than heifers at 210 days of age. Koch and Clark (1955c) reported steers to be an average of 26.2 pounds heavier than heifers at 182 days of age, while Koger and Knox (1945) found a sex difference of 32 pounds in favor of steers at 205 days of age.

The influence of age of dam

The weaning weights and grades of the calves in this project were corrected for the effects of age of dam by application of the correction factors computed by Kieffer (1960) for Project 670. These correction factors are shown in Table III. Although these correction factors were not computed from the herd to which they were applied in this instance, they were thought to have done an adequate job in correcting for the effects of age of dam in this study. It should also be noted that feeder grades at weaning were corrected for the effects of age of dam by using correction factors that were developed for condition scores. This was not thought to incorporate serious bias into the data since a positive relationship was thought to exist between grade and condition.

The influence of year

No adjustments were made for year effects since the analyses were made on a within-year basis in such a manner as to adequately discount these effects.

The influence of nutritional treatment

Zimmerman et al. (1959) reported a significant difference in the performance of the heifers receiving the different levels of winter treatment in Replications 2, 3, and 4. No significant difference was found in Replication 1.

The weaning weights and grades of all calves produced by heifers receiving the low, high, and very high levels of winter feeding in Replications 2, 3, 4, and 5 were adjusted to the average of the calves produced by heifers on the medium level of wintering. All adjustment factors were computed on an intra-year basis. The average performance of calves from these cows by years and dam's level of winter feeding are given in Table VI. It was from these averages that correction factors for dam's level of wintering were computed.

FEDERAL REFORMATORY

Description of the Data

This herd of Angus cattle consisted of approximately 250 registered and grade cows. Records were available over the 3-year period from 1957-1959 for weaning weights, feeder grades, postweaning average daily gains, and 12-month weights.

The majority of the cows calved over the 3-month period of February-April, with a few calving in May and June. The cows were bred as yearlings to calve first as 2-year olds. Bull calves were castrated in April toward the end of the calving season. In all years the calves were creep-fed from approximately 100 days of age until weaned during October. The calves were given a feeder grade at weaning. The 1957 and 1958 calves were graded by 2 men; however, the same men did not grade the calves each year. The average of the 2 grades was taken as the grade for each calf. The 1959 calves were graded by 1 man only. The grading system was the same as was used for the calves in Project 650. Each year after weaning representative samples of steers and heifers by most of the sires were placed on postweaning gain tests. Steers only were fed in 1959. The length of the feeding period was 159, 168, and 171 days for the 1957, 1958, and 1959 calves, respectively.

TABLE VI

AVERAGE PERFORMANCE OF CALVES FROM COWS OF LATER REPLICATIONS BY YEARS AND DAM'S LEVEL OF WINTERING (PROJ. 650)

Trait	Birth year of calf	Dam's Level of Supplemental Winter Feeding							
		No.	Low	No.	Medium	No.	High	No.	Very High
Wean. Wt. (lbs.)	1956	8	402	10	414	10	442		
	1957	13	374	15	384	22	395		
	1958	26	370	32	415	31	432		
	1959	33	375	36	411	40	428	9	393
Grade (units)	1956	8	9.3	10	9.3	10	9.8		
	1957	13	8.7	15	7.1	22	7.6		
	1958	26	9.4	32	10.2	31	10.6		
	1959	33	10.4	36	10.8	40	11.2	9	11.0
18-Mo. Heifer Wt. (lbs.)	1956	15	708	15	775	14	807		
	1957	13	756	12	822	12	819	13	861
	1958	14	738	14	794	15	859	15	894

Regression of the Offspring's Average Performance on the Sire's Performance

The average performance of the offspring was regressed on the sire's performance within-birth-year of sires and of offspring. There was a total of 13 offspring-sire groups. These 13 groups contained the weaning weights and grades of 239 calves and the postweaning average daily gains and 12-month weights of 103 steers and heifers. The sires' performance and the average performance of their offspring for all traits, grouped by birth year of the sire and of the offspring, are given in Tables II and VII, respectively.

Paternal Half-Sib Correlations of Weaning and Postweaning Traits

The paternal half-sib analyses were computed on a within-year basis. Data were available on 421 weaning weights and grades and 176 postweaning average daily gains and 12-month weights. The calves used in this phase of the study were the progeny of 24 sire groups made up of 20 different sires. These 24 sire groups and their offspring included the 13 sires used in the regression phase of the study plus 11 other sire groups. Most of these additional sires were owned by the Federal Reformatory and no performance data had been obtained for them. Table VIII shows the average performance, by years and sires, of the calves used in this phase of the study.

Phenotypic Correlations and Regressions of Various Traits

Phenotypic correlations of weaning weight and feeder grade were computed on an intra-year and sire, intra-sire, intra-year, and on a

TABLE VII

AVERAGE PERFORMANCE OF OFFSPRING USED IN THE REGRESSION ANALYSIS GROUPED BY BIRTH YEAR OF SIRE AND OF OFFSPRING (FED. REF.)

Birth year of Sire	Birth year of Offspring	Sire No.	No. Calves	Adj. Grade	Adj. 210-Day Wt.	No. Calves	Postwean. ADG	12-Mo.Wt.
1954	1957	114	23	11.3	462	12	2.24	887
1954	1957	264	19	10.4	497	14	2.39	970
1955	1958	115	21	11.3	486	10	2.14	920
1955	1958	155	22	11.0	465	10	2.08	847
1955	1958	175	19	11.5	446	10	2.06	837
1955	1958	185	12	11.7	438	7	2.17	858
1956	1959	046	17	11.0	460	6	2.19	817
1956	1959	066	14	10.0	473	3	2.33	831
1956	1959	096	22	10.4	489	6	2.51	895
1956	1959	196	21	10.7	512	7	2.55	927
1956	1959	406	14	10.9	464	4	2.13	808
1956	1959	426	19	9.9	496	8	2.55	917
1956	1959	436	16	10.1	514	6	2.50	937

TABLE VIII

AVERAGE PERFORMANCE OF CALVES USED IN THE PATERNAL HALF-SIB CORRELATION ANALYSIS BY YEARS AND SIRES (FED. REF.)

Year	Sire No.	No. Calves	Adj. 210-Day Wt.	Adj. Grade	No. Calves	Postwean. ADG	12-Mo. Wt.
1957	2	12	443	11.1	6	2.10	860
1957	5	17	425	9.1	10	2.39	898
1957	7	15	442	11.1	6	2.30	880
1957	15	15	430	11.0	6	1.89	796
1957	17	13	445	11.1	6	2.32	922
1957	114[a]	23	462	11.3	12	2.24	887
1957	264[a]	19	497	10.4	14	2.39	970
1958	5	14	458	10.0	5	2.05	866
1958	6	21	438	10.8	10	2.33	880
1958	7	19	463	11.3	5	2.21	863
1958	115[a]	21	486	11.3	10	2.14	920
1958	155[a]	22	465	11.0	10	2.08	847
1958	175[a]	19	446	11.5	10	2.06	837
1958	185[a]	12	438	11.7	7	2.17	858
1959	6	16	486	10.6	5	2.54	917
1959	21	18	462	10.4	7	2.19	809
1959	264	22	509	10.1	7	2.58	946
1959	046[a]	17	460	11.0	6	2.19	817
1959	066[a]	14	473	10.0	3	2.33	831
1959	096[a]	22	489	10.4	6	2.51	895
1959	196[a]	21	512	10.7	7	2.55	927
1959	406[a]	14	464	10.9	4	2.13	808
1959	426[a]	19	496	9.9	8	2.55	917
1959	436[a]	19	514	10.1	6	2.50	937

[a]Sires used in regression analysis.

gross basis for 472 calves sired by 30 bulls. Regressions of feeder grade on weaning weight were computed for the same data in the same manner. The means, standard deviations, and coefficients of variation were 430 pounds, 73.1 pounds, and 17.2 percent respectively, for weaning weight, and were 10.6 units, 1.34 units, and 12.6 percent respectively for feeder grade.

Correlations of postweaning average daily gain with age at weaning, weaning weight, adjusted 210-day weight, and feeder grade were determined from the records of the 176 calves that were tested for postweaning growth rate. Postweaning average daily gain was also regressed on these same traits. These correlations and regressions were made on an intra-year and sire, intra-sire, intra-year, and gross basis. The traits studied, their means, standard deviations, and coefficients of variation were: age at weaning, 205 days, 20.7 days, and 10.1 percent; weaning weight, 470 pounds, 55.5 pounds, and 11.8 percent; adjusted 210-day weight, 486 pounds, 48.2 pounds, and 9.9 percent; feeder grade, 10.8 units, 1.75 units, and 16.2 percent; and postweaning average daily gain, 2.28 pounds, 0.267 pounds, and 11.7 percent.

Correction of the Data for Known Variables

Age of calf

In these data average daily gains were used instead of an age-standardized weaning weight since the ages at weaning varied from an average of 186 days in 1959 to 210 days in 1958. The age ranges at weaning for the 1957, 1958, and 1959 calves were from 134-245, 162-245, and 118-228 days respectively. The standard deviations of age at weaning were 26, 20, and 22 days for the 1957, 1958, and 1959 calves respectively, whereas the coefficients of variation were 13.0, 9.6, and 11.7 percent.

All weights were adjusted to 365 days by proration of the gains made by an animal during the 14-day weigh period bracketing the standard age of 365 days. For the few animals that were not 365 days of age at the end of the test, their weights were adjusted to 365 days by adding to their weight the product of the average daily gain made during the last 14-day weigh period and the deviation of their age from 365 days.

The influence of sex

The weaning weights of the 1957 and 1958 calves were corrected for the effects of sex by the use of the multiplicative factor computed for these data by Kieffer (1960). The 210-day weights of the heifers were made equivalent to those of the steers by multiplying the 210-day weights of the heifers by 1.082. The 1959 heifer weaning weights were made equivalent to those of the steers by adding .12 to the average daily gains from birth to weaning of the heifer calves. This correction factor was established by subtracting the mean heifer average daily gain from the mean steer average daily gain in 1959.

Steers and heifers were full-fed on postweaning gain tests in 1957 and 1958. Steers only were fed in 1959. The average daily gains and 12-month weights of the heifers were made equivalent to those of the steers by adding to the heifer gains and weights the difference between the mean average daily gains and 12-month weights of all the steers and heifers fed over the 2 years 1957 and 1958. The average performance of the steers and heifers on postweaning gain tests is shown by years in Table IX.

TABLE IX

AVERAGE PERFORMANCE OF STEERS AND HEIFERS IN THE FEEDLOT (FED. REF.)

Year	Days on Feed	Steers			Heifers		
		No.	ADG	12-Mo. Wt.	No.	ADG	12-Mo. Wt.
1957	159	45	2.24	898	15	2.09	827
1958	168	28	2.17	861	29	1.88	801
1959	171	59	2.43	887			

The influence of age of dam

The 1957 and 1958 weaning weights were corrected for age of dam by the application of the correction factors computed for these data by Kieffer (1960). The method used was to compare averages of records made at each age of dam. The weaning weights of the 1959 calves were corrected for age of dam by comparing average records made at each age of dam in that year. Feeder grades at weaning for the calves in this herd were corrected for age of dam in the same manner as described for the calves in Project 650. Table III contains the correction factors used to correct weaning weights and feeder grades of calves in this herd for the effects of age of dam.

The influence of year

Since all analyses were on a within-year basis, the effects of year were adequately removed without the use of correction factors.

Heritability Estimates

Regression of the offspring's performance on the sire's performance

All methods of estimating heritability rest on measuring how much more closely animals with similar genotypes resemble each other than less closely related animals do (Lush, 1945).

In order to obtain an estimate of heritability by the offspring-sire regression method, it is necessary to compute the offspring-sire regression coefficient. Snedecor (1956) has presented the requisite formulas for the computation of the regression coefficients used in this study. In terms of X and Y the regression coefficient b is an estimate of B and is computed by the following formula:

$$b_{yx} = \frac{\Sigma xy}{\Sigma x^2} \quad \text{where } \Sigma xy = \Sigma XY - \frac{(\Sigma X)\,(\Sigma Y)}{N} \text{ and } \Sigma x^2 = \Sigma X^2 - \frac{(\Sigma X)^2}{N}.$$

Here X is the observation on the sire, Y is the average of the observations on each sire's offspring, and N is the number of sire-offspring pairs. Since the average genetic relationship between offspring and sire is assumed to be .5, heritability is computed by doubling the offspring-sire regression coefficient.

The regression of offspring on sire is a parent-offspring resemblance, and is likely to include some environmental correlation between parent and offspring. Also it will include something from the resemblance of the offspring to the other parent, if matings were not random (Lush, 1945). In the present study the sires were raised in one herd and their offspring in two different herds. Therefore, environmental correlations between parent and offspring should not have introduced any large biases into the data. Since the cows were allotted to breeding groups at random (as nearly as was possible on the basis of age, previous productivity, etc.) no systematic biases due to deviations of matings from randomness should have been introduced into the data.

Paternal half-sib correlations of weaning and postweaning traits

In order to obtain an estimate of heritability by the paternal half-sib correlation method, it was necessary to compute the components of variance due to sires and to error, the error term being the variance between half-sibs by the same sire. The variance components for sire were obtained by equating the expected mean squares to the calculated mean squares and substituting in the estimated coefficients of the expected mean squares.

The sire component of variance is important because it estimates the additive genetic portion of the variance. Under random mating genic values of half-sibs are correlated by 25 percent; dominance deviations are uncorrelated; and epistatic deviations are correlated by an undetermined but small amount. An estimate of heritability is $\frac{4\ \sigma_S^2}{\sigma_S^2 + \sigma_E^2}$.

Standard errors of estimates

The standard errors for heritability estimates obtained by paternal half-sib correlations were computed by the methods described by Hazel and Terrill (1945).

Correlations and Regressions Among Traits

The formulas used for computing correlation and regression coefficients in this study were those presented by Snedecor (1956). The formula for computing the correlations was: $r_{xy} = \frac{\Sigma\ xy}{\sqrt{(\Sigma x^2)\ (\Sigma y^2)}}$,

while the formula for computing the regressions was:

$b_{yx} = \frac{\Sigma\ xy}{\Sigma x^2}$.

RESULTS AND DISCUSSION

Because the management practices were different for each herd, heritability estimates of the direct effect of the sire upon weaning weight, feeder grade, postweaning average daily gain, 12-month weight, and 18-month heifer weight of his offspring were computed separately for each herd. Heritability estimates were then computed by pooling the data for both herds.

Heritability estimates for several traits were computed from intra-class correlations of paternal half-sib calves and from offspring-sire regressions. These estimates contain that fraction of additively genetic inheritance transmitted by the sire directly to his offspring. Heritability estimates for the direct effect of the sire upon his progeny may also contain non-additive inheritance. The extent to which the heritability estimates for the direct effect of sire may also contain non-additive inheritance has been discussed under the section on materials and methods.

Heritability Estimates of Weaning Weight Computed from the Regression of the Offspring's Average Performance on the Sire's Performance

From Project 650 a total of 28 sires and their 398 offspring were available for this phase of the study. These data were collected over the 4-year period 1956-1959. The data were analyzed within birth year of the sire and of the offspring. The average weaning weight of each sire's offspring was regressed on the sire's own weaning weight. The sire data were shown in Table I, while the average performance of the offspring and the number of calves by each sire grouped by birth year of the sire and of the offspring was shown in Table IV. Table X shows the heritability estimate for weaning weight based upon this method. Weaning weight was estimated to be .03 heritable. This estimate was lower than expected, but could be due to the nature of the various treatments imposed on the cows in Project 650. If the correction factors applied to these data failed to accurately adjust for such variables as age and sex of calf, age of dam, and dam's level of supplemental winter feeding, the phenotypes of offspring would have been misjudged. Much more likely to be involved, however, is the small number of rather closely related sires selected for progeny tests within each season. Their individual phenotypes are estimated from a single record and are thus subject to large sampling errors.

Weaning weight was estimated to be .64 heritable in the Federal Reformatory herd. This estimate was based on the records of 13 sires and their 239 progeny. These data were collected over the 3-year period from 1957-1959 and were analyzed within birth year of the sire and of the offspring. The sires' performance and the average performance of the offspring grouped by birth year of the sire and of the offspring were shown in Tables II and VII, respectively. All calves in the Federal Reformatory herd were creep-fed and the effects of creep feeding may have caused the heritability estimate of weaning weight to be increased. Creep feeding could have enlarged the between-sire differences by enabling calves with a greater inherent ability for preweaning gains to gain more than calves with a lesser genetic capability for preweaning gains.

TABLE X

HERITABILITY ESTIMATES COMPUTED FROM THE REGRESSION OF AVERAGE PERFORMANCE OF THE OFFSPRING ON THE SIRE'S OWN RECORD ON A WITHIN GROUP BASIS

			Weaning Weight		Postweaning ADG		12-Month Weight	
Herd	No. Groups	No. Sires	Average No. Calves/Sire	Herit.	Average No. Calves/Sire	Herit.	Average No. Calves/Sire	Herit.
Fed. Ref.	4	13	18.4	.64	7.9	.51	7.9	1.02
Proj. 650	8	28	14.2	.03				
Both herds (pooled)	12	41	15.5	.15				

At the same time, the small number of sires could undoubtedly account for the high estimate obtained here. For these reasons it was thought that the pooling of the data from both herds would give the best estimate.

Heritability estimates computed by the regression of offspring on sire were given for each herd separately and pooled in Table X. The heritability estimate of weaning weight computed from the pooled sums of squares and cross products from data of both herds was .15. Heritability estimates of weaning weight computed by regression of offspring on sire reported in the literature were: .30 and zero by Knapp and Nordskog (1946a) when computed on a within year of sire and sire total variance, respectively; zero by Dawson et al. (1954); and .25 by Koch and Clark (1955b).

Records were available on postweaning average daily gains and 12-month weights from the Federal Reformatory herd only. These records contained the gains and weights of 103 steers and heifers by 13 sires. Heritability of postweaning average daily gain was estimated to be .51. This estimate was in general agreement with those estimates of Knapp and Nordskog (1946a) and Knapp and Clark (1950). Their estimates were .48 and .77, respectively. Twelve-month weight was estimated to be 102 percent heritable which was unrealistic. Sampling error due to the restricted number of sire-offspring groups is the only explanation offered for this excessive estimate. Knapp and Nordskog (1946a) and Knapp and Clark (1950) published estimates of .94 and .92, respectively, for final test weight of steers at approximately 15 months of age.

Heritability Estimates of Weaning and Postweaning Traits
Computed from Paternal Half-Sib Correlations

The data for this section of the study consisted of the records of 28 sires and their progeny from the Project 650 herd and 24 sires and their progeny from the Federal Reformatory herd. The records from Project 650 were obtained over the 4-year period 1956-1959, while the records from the Federal Reformatory were collected over the 3-year period from 1957-1959. These data were analyzed on a within year basis. The number of calves by each sire and their average performance for the traits considered were given in Tables V and VIII for Project 650 and the Federal Reformatory herds, respectively. Tables XI and XII show the analyses of variance from which the estimates of heritability were obtained, and Table XIII shows the heritability estimates for each herd and the pooled estimate.

Heritability was estimated to be .19± .29 for weaning weight in Project 650. This estimate contained 398 weaning weights. Weaning weight was estimated to be .60 ± .20 heritable in the Federal Reformatory herd. This estimate was based on 239 weaning weights. Heritability of weaning weight derived from pooling the sums of squares over both herds was estimated to be .42 ± .17. Heritability estimates of weaning weight reported in the literature have ranged from zero (Dawson et al., 1954) to .81 (Lindholm and Stonaker, 1957). However, the majority of the estimates were in the range of .20 to .60.

Feeder grade was estimated to be .30 ± .27 and .55 ± .21 heritable for Project 650 and the Federal Reformatory herd, respectively. The pooled heritability estimate of feeder grade was .43 ± .17.

TABLE XI

ANALYSIS OF VARIANCE OF WEANING AND POSTWEANING TRAITS
(PROJ. 650)

Trait and Source of Variation	D/F	Mean Square	Expected Mean Square
Weaning weight			
Total	397		
Birth years of calves	3	36151.530**	
Sires within years	24	3314.159*	$\sigma_e^2 + 14.150\ \sigma_s^2$
Calves within sires	370	1946.884	σ_e^2
Grade			
Total	397		
Birth years of calves	3	109.380**	
Sires within years	24	4.112**	$\sigma_e^2 + 14.150\ \sigma_s^2$
Calves within sires	370	1.935	σ_e^2
18-mo. heifer wt.			
Total	112		
Birth years of calves	2	22568.700**	
Sires within years	14	6528.691*	$\sigma_e^2 + 6.583\ \sigma_s^2$
Calves within sires	96	3156.051	σ_e^2

*Significant at $P < .05$.

**Significant at $P < .01$.

TABLE XII

ANALYSIS OF VARIANCE OF WEANING AND POSTWEANING TRAITS
(FED. REF.)

Trait and Source of Variation	D/F	Mean Square	Expected Mean Square
Weaning weight			
Total	420		
Birth years of calves	2	58495.315**	
Sires within years	21	8019.682**	$\sigma_e^2 + 17.514\ \sigma_s^2$
Calves within sires	397	1962.715	σ_e^2
Grade			
Total	420		
Birth years of calves	2	16.835**	
Sires within years	21	5.248**	$\sigma_e^2 + 17.514\ \sigma_s^2$
Calves within sires	397	1.388	σ_e^2
Postweaning ADG			
Total	175		
Birth years of calves	2	1.108**	
Sires within years	21	.107**	$\sigma_e^2 + 7.293\ \sigma_s^2$
Calves within sires	152	.044	σ_e^2
12-month weight			
Total	175		
Birth years of calves	2	14217.975*	
Sires within years	21	17284.245**	$\sigma_e^2 + 7.293\ \sigma_s^2$
Calves within sires	152	4155.964	σ_e^2

*Significant at $P < .05$.

**Significant at $P < .01$.

TABLE XIII

HERITABILITY ESTIMATES COMPUTED FROM PATERNAL HALF-SIB INTRACLASS CORRELATIONS

Trait	Fed. Ref.	Proj. 650	Both Herds (Pooled)
Weaning weight			
No. sires	24	28	52
No. calves	421	398	819
Heritability	.60	.19	.42
Standard error	.20	.29	.17
Grade			
No. sires	24	28	52
No. calves	421	398	819
Heritability	.55	.30	.43
Standard error	.21	.27	.17
Postwean. ADG			
No. sires	24		
No. calves	176		
Heritability	1.12		
Standard error	.22		
12-month weight			
No. sires	24		
No. calves	176		
Heritability	1.21		
Standard error	.22		
18-month weight			
No. sires		17	
No. daughters		113	
Heritability		.56	
Standard error		.39	

Heritability estimates of weaning grade or score reported in the literature were .53 by Knapp and Nordskog (1946a), .28 by Knapp and Clark (1950), .31 by Knapp and Clark (1951), .30 and .24 by Koger and Knox (1952), .18 by Koch and Clark (1955a), .36 by Rollins and Wagnon (1956b), .60 by Shelby _et al_. (1957), and .14 by Kieffer (1960). The pooled heritability estimate for feeder grade in this study is in general agreement with those estimates in the literature.

Postweaning average daily gains and 12-month weights were available on 176 steers and heifers in the Federal Reformatory herd. Postweaning average daily gain was estimated to be 1.12 $\pm$ .22 heritable. The heritability estimate of 12-month weight was 1.21 $\pm$ .22. Heritability estimates of average daily gain reported in the literature have ranged from .46 (Shelby _et al_., 1957 and 1960) to 1.57 (Lindholm and Stonaker, 1957). The majority of the estimates have been upward of .60. No estimates of 12-month weight as such have been reported. However, Knapp and Nordskog (1946a) and Knapp and Clark (1950) estimated final test weight at approximately 15 months of age to be .81 and .86 heritable, respectively. Shelby _et al_. (1955) estimated final weight to be .84 heritable for steers fed 252 to 273 days. Weight at 13 months of age was estimated to be .55 heritable by Shelby _et al_. (1957 and 1960). The estimates of heritability of test average daily gain and 12-month weight in this study were above the maximum limit for heritability. The only explanation offered is sampling error as a result of the restricted population size.

Heritability of 18-month heifer weight was estimated to be .56 $\pm$ .39 for 113 heifers by 17 bulls in Project 650. Koch and Clark (1955a) reported yearling weight of heifers to be .47 heritable. Long yearling heifer weight was estimated to be .44 and -.19 heritable by Wagnon and Rollins (1959).

All the heritability estimates for the Federal Reformatory data, except that of weaning weight, were larger when computed by the paternal half-sib correlation method than when computed by offspring-sire regression. A possible explanation for the larger estimates by paternal half-sib correlation is the fact that 11 additional sires were used in the half-sib data that were not used in the regression analysis. These 11 sires were not related to the sires from Project 670 used in the regression analysis. The sires from Project 670 in any sire-birth-year group were half-sibs. The inclusion of the additional sires would tend to increase the genetic variance between sires.

Phenotypic Correlation and Regression Coefficients Among Various Traits

Phenotypic correlations were computed between 18-month weights and adjusted 210-day weights for the 113 heifers in Project 650 for which 18-month weights were available. The correlations computed intra-year and sire, intra-sire, intra-year, and gross were .63, .45, .62, and .47, respectively. All the coefficients were highly significant ($P < .01$) and positive. This was expected since 210-day weight is a part of the 18-month weight. The regression coefficients of 18-month weights on adjusted 210-day weights were computed in the same manner as the correlations. The regression coefficients were: intra-year and sire, 1.08; intra-sire, .78; intra-year, 1.13; and gross, .87.

The sums of squares and sums of cross products from which these coefficients were determined are shown in Table XIV. Both the correlation and regression coefficients are shown in Table XV.

From the Federal Reformatory data correlations between actual weaning weight and actual feeder grade were computed intra-year and sire, intra-sire, intra-year, and on a gross basis for 472 calves by 30 sires. From the same data correlations between postweaning average daily gain and age at weaning, actual weaning weight, adjusted 210-day weight, and actual feeder grade were computed from the records of 176 calves by 24 sires. These correlations were computed in the same manner as were those between actual weaning weight and actual feeder grade. Regression coefficients were computed for the same combinations of traits in the same manner. Actual feeder grade was regressed on actual weaning weight and postweaning average daily gain was regressed on age at weaning, actual weaning weight, adjusted 210-day weight, and actual feeder grade. The correlation and regression coefficients computed intra-year and sire were considered to be the most reliable and are the ones discussed. The sums of squares and the sums of cross products from which the correlations and regressions were computed are shown in Table XVI. The coefficients for these correlations and regressions are shown in Table XVII.

Actual feeder grade and actual weaning weight were positively correlated and highly significant ($P < .01$). The intra-year and sire correlation was .49 and the corresponding regression was .009. This would indicate a fairly close association between these two traits. An increase of approximately 1/3 of a grade could be expected with each 100 pound increase in weaning weight.

TABLE XIV

SUMS OF SQUARES AND SUMS OF CROSS PRODUCTS FOR THE PHENOTYPIC CORRELATIONS AND REGRESSIONS BETWEEN 18-MONTH HEIFER WEIGHT (Y) AND ADJUSTED 210-DAY WEIGHT (X) (PROJ. 650)

Traits and Source of Variation	D/F	Σx^2	Σxy	Σy^2
Adj. 210-day wean. wt. (X) and 18-month heifer wt. (Y)				
Total	153	170898.727	148562.455	579820.338
Bet. years	2	15505.883	- 27777.205	52985.549
Bet. sires in years	22	22955.496	33247.066	136578.081
Within sires in years	129	132437.348	143092.594	390256.708

TABLE XV

PHENOTYPIC CORRELATIONS AND REGRESSIONS BETWEEN 18-MONTH HEIFER WEIGHT (Y) AND ADJUSTED 210-DAY WEIGHT (X) (PROJ. 650)

Computed	Correlation between Adj. 210-day wt. and 18-month heifer wt.	Regression of 18-month heifer wt.(Y) on Adj. 210-day wt.(X)
Intra-Year and Intra-Sire	.63**	1.08
Intra-Sire	.45**	.78
Intra-Year	.62**	1.13
Gross	.47**	.87

**Significant at $P < .01$.

TABLE XVI

SUMS OF SQUARES AND SUMS OF CROSS PRODUCTS FOR THE PHENOTYPIC CORRELATIONS AND REGRESSIONS AMONG VARIOUS TRAITS (FED. REF.)

Traits and Source of Variation	D/F	Σx^2	Σxy	Σy^2
Act. wean. wt. (X) and Act. grade (Y)				
Total	471	2515357.997	22401.701	840.309
Bet. years	2	201224.729	3006.246	45.200
Bet. sires in years	27	566438.531	2990.199	147.024
Within sires in years	442	1747694.737	16405.256	648.085
Act. grade (X) and Postwean. ADG (Y)				
Total	175	536.396	-18.591	12.432
Bet. years	2	32.924	- 8.160	2.216
Bet. sires in years	21	251.043	- 3.880	3.576
Within sires in years	152	252.429	- 6.551	6.640
Act. wean. wt. (X) and Postwean. ADG (Y)				
Total	175	538233.948	158.307	12.432
Bet. years	2	18431.437	-175.322	2.216
Bet. sires in years	21	142297.085	198.527	3.576
Within sires in years	152	377505.426	135.102	6.640

TABLE XVI (Continued)

Traits and Source of Variation	D/F	Σx^2	Σxy	Σy^2
Adj. 210-day wt. (X) and Postwean ADG (Y)				
Total	175	406712.994	1072.888	12.432
Bet. years	2	53299.265	310.888	2.216
Bet. sires in years	21	109550.277	357.400	3.576
Within sires in years	152	243863.452	404.600	6.640
Age at wean. (X) and Postwean ADG (Y)				
Total	175	75273.977	-393.275	12.432
Bet. years	2	13721.999	-173.588	2.216
Bet. sires in years	21	22006.695	- 92.366	3.576
Within sires in years	152	39545.283	-127.321	6.640

TABLE XVII

PHENOTYPIC CORRELATIONS AND REGRESSIONS AMONG VARIOUS TRAITS
(FED. REF.)

Computed	Act. grade (Y) on Act. wean. wt (X)	Postwean. ADG (Y) on Act. grade (X)	Postwean. ADG (Y) on Act. wean. wt.(X)	Postwean. ADG (Y) on Adj. 210-Day wt. (X)	Postwean. ADG (Y) on Age at wean. (X)
Intra-Sire and Intra-Year					
Corr. coef.	.49**	-.16*	.09	.32**	-.25**
Reg. coef.	.009	-.026	.000	.002	-.003
Intra-Sire					
Corr. coef.	.53**	-.29**	-.02	.44**	-.44**
Reg. coef.	.001	-.052	.000	.002	-.006
Intra-Year					
Corr. coef.	.45**	-.15*	.14	.40**	-.28**
Reg. coef.	.008	-.021	.001	.002	-.004
Gross					
Corr. coef.	.49**	-.23**	.06	.48**	-.41**
Reg. coef.	.009	-.035	.000	.003	-.005

*Significant at $P < .05$.

**Significant at $P < .01$.

A negative and statistically significant ($P < .05$) association was found to exist between postweaning average daily gain and actual feeder grade. The correlation between these two traits was -.16 and the regression was -.026. This would indicate a decrease in postweaning feedlot average daily gain of approximately .03 pounds per day for each increase of 1/3 of a grade at weaning.

Little association was found between postweaning average daily gain and actual weaning weight. The correlation coefficient was .09 and not significant. The corresponding regression was zero. However, postweaning average daily gain and adjusted 210-day weight were positively correlated, the coefficient, .32, being highly significant. The corresponding regression coefficient was .002. According to these data, one could expect an increase of .20 pounds per day in postweaning feedlot average daily gain with each additional 100 pounds in adjusted 210-day weight. These data indicated adjusted 210-day weight to be a more reliable indicator of subsequent feedlot average daily gain than was actual weaning weight.

A highly significant ($P < .01$), negative association existed between postweaning average daily gains and age at weaning. The correlation was -.25 and the regression was -.003. Therefore, gains in the feedlot would be lowered approximately .09 pounds per day for each additional 30 days in the age of the calves. The younger cattle at weaning made faster gains in the feedlot than the older cattle in this experiment. Creep feeding could have influenced these data. All calves were creep-fed in this group. It is reasonable that the older calves should be able to make more rapid gains from a creep ration than the younger calves.

Therefore, the older calves were heavier and in higher condition at weaning when they were put in the feedlot to begin their postweaning growth test. Younger, lighter animals in lower condition would be expected to make faster gains for at least a period of time than older, heavier animals in higher condition.

These correlation coefficients indicate that the younger animals with high adjusted 210-day weights had the highest average daily gains on postweaning growth tests. They also indicate that actual feeder grade and actual weaning weight were closely associated.

Correlations between weaning weight and average daily gain in the feedlot reported in the literature were .063 by Patterson et al. (1949), .11 by Warwick and Cartwright (1955), .07 by Lindholm and Stonaker (1957), .20 and .27 by Carter and Kincaid (1959b), and .088 by Knapp et al. (1941). Correlations between feeder grade or score and average daily gains were -.243 by Patterson et al. (1949), .001 by Knapp and Clark (1951), -.35 by Lindholm and Stonaker (1957), -.07 and -.02 by Carter and Kincaid (1959b), and .025 by Knapp et al. (1941). Koch and Clark (1955a) and Rollins and Wagnon (1956b) published correlations between weaning weight and grade of .64 and .42, respectively.

Regression of the Average Performance of the Offspring on the Sire's Performance

From Project 650 data the averages of the feeder grades, adjusted 210-day weights, and 18-month heifer weights of the progeny for each sire were regressed on the sire's condition score, adjusted 210-day weight, postweaning average daily gain, and 12-month weight. The regression coefficients for these combinations computed within year of birth of the sire and of the offspring are shown in Table XVIII, whereas the coefficients for the same combinations computed ignoring years are shown in Table XIX. By comparing the regressions in these two tables it is easily seen that year exerted a large effect. The regressions computed on the within year basis were considered to be the most useful. The regressions of the offspring's average 210-day weight on the sire's adjusted 210-day weight, postweaning average daily gain, and 12-month weight computed on a within year basis were .016, 14.672, and .035, respectively. The regression of offspring's adjusted 210-day weight on sire's 210-day weight (b = .016) when multiplied by 2 yields an estimate of heritability of weaning weight. These data indicate that the sire's 12-month weight would be a more effective criterion in selection for increased weaning weight than his adjusted 210-day weight. Each additional 100 pounds in the sire's weight at 12 months of age would be expected to increase the adjusted 210-day weight of his calves 3.5 pounds as compared to 1.6 pounds for each additional 100 pounds in the sire's weight at 210 days.

From the Federal Reformatory data the averages of the feeder grades, adjusted 210-day weight, postweaning average daily gains, and 12-month weights of the offspring for each sire were regressed on the sire's condition score, adjusted 210-day weight, postweaning average daily gain, and 12-month weight. These regressions were computed both on a within year of birth of the sire and of the offspring and on a gross basis with years ignored. The regression coefficients computed on the within year basis are shown in Table XVIII, and the regression coefficients computed with years ignored are shown in Table XIX. Years

TABLE XVIII

REGRESSION OF THE AVERAGE PERFORMANCE OF THE OFFSPRING (Y) ON THE SIRE'S OWN PERFORMANCE (X) ON A WITHIN GROUP BASIS

Offspring (Y)	Sire (X)			
	Cond. Score	Adj. 210-day wt.	Postwean. ADG	12-Mo. wt.
Adj. Grade				
Fed. Ref.	.426	-.001	-.370	-.001
Proj. 650	-.242	-.005	-.324	-.003
Both herds (pooled)	-.060	-.004	-.346	-.002
Adj. 210-day wt.				
Fed. Ref.	-13.229	.322	44.829	.183
Proj. 650	- 1.268	.016	14.672	.035
Both herds (pooled)	- 4.513	.074	29.021	.094
Postwean. ADG				
Fed. Ref.	- .054	.002	.255	.001
12-mo. wt.				
Fed. Ref.	-17.475	.712	107.474	.511
18-mo. wt.				
Proj. 650	4.059	.082	-56.860	-.024

TABLE XIX

REGRESSION OF THE AVERAGE PERFORMANCE OF THE OFFSPRING (Y) ON THE SIRE'S OWN PERFORMANCE (X) WITH YEARS IGNORED

	Sire (X)			
Offspring (Y)	Cond. Score	Adj. 210-day Wt.	Postwean. ADG	12-Mo. wt.
Adj. Grade				
Fed. Ref.	.260	.005	-.515	-.002
Proj. 650	.390	.006	-.342	.003
Both herds (pooled)	.357	.005	-.384	.002
Adj. 210-day wt.				
Fed. Ref.	-7.159	.351	38.963	.186
Proj. 650	- .469	-.017	7.449	-.003
Both herds (pooled)	-2.155	.027	15.032	.046
Postwean. ADG				
Fed. Ref.	-.029	.003	.273	.002
12-mo. wt.				
Fed. Ref.	-1.195	.688	106.988	.453
18-mo. heifer wt.				
Proj. 650	-7.602	-.072	73.754	.230

again had a definite effect on these regressions. Coefficients computed within year for the regression of the offspring's average adjusted 210-day weight on the sire's adjusted 210-day weight, postweaning average daily gain, and 12-month weight were .322, 44.839, and .183, respectively. These results differed from those obtained from Project 650 and indicated that the sire's adjusted weight at 7 months would be a somewhat more effective selection criterion for increased weaning weights of his calves than the sire's 12-month weight. According to these data an increase of 100 pounds in the sire's adjusted 210-day weight would be expected to increase the adjusted 210-day weight of his calves 32 pounds as compared to 18 pounds for each additional 100 pounds in the sire's weight at 12 months of age. If this were true, selection based on the adjusted 210-day weight of the sire would be an advantage to breeders in improving the growth potential of their animals since selections could be made more economically at weaning time.

The regression coefficients obtained by pooling the information from both herds are shown in Tables XVIII and XIX, respectively, and they are considered to be more reliable than the individual regression coefficients for either herd. The pooled regression coefficients of the offspring's adjusted 210-day weight on the sire's 210-day weight, post-weaning average daily gain, and 12-month weight were .074, 29.021, and .094, respectively. These would indicate that the sire's 12-month weight was a slightly better criterion of selection for increased 210-day calf weights than was the sire's adjusted 210-day weight. However, there was little difference between the two traits. Selection of sires on the basis of superior weaning weights or 12-month weights should result in increased weaning weights of their progeny.

SUMMARY

The data for this study consisted of the weaning weights, feeder grades, postweaning average daily gains, 12-month weights, and 18-month heifer weights of calves from 2 different herds. All sires used in the regression phase of this study were bred and raised in a third herd. Where necessary the data were standardized for age of calf, sex of calf, age of dam, and level of winter nutrition.

The heritabilities of weaning weight, postweaning average daily gain, and 12-month weight were estimated by regressing the average performance of the offspring on the sire's performance within year of birth of the sire and of the offspring. Heritabilities for these same traits plus feeder grade and 18-month heifer weight were also obtained from the intraclass correlations of paternal half-sibs. The half-sib data were analyzed on an intra-year and intra-herd basis.

A total of 41 bulls and 637 of their progeny were available for the offspring-sire regression analysis. Twenty-eight of these groups were produced in Project 650 and the remaining 13 were from the Federal Reformatory herd. Because of limited amount of data, estimates of heritability computed from the pooled sums of squares and cross products over both herds were considered to be more reliable. The pooled estimate of heritability of weaning weight from offspring-sire regression was .15. Heritability estimates of postweaning average daily gain and 12-month weight were obtained from 103 steers and heifers by 13 sires produced in the Federal Reformatory herd by offspring-sire regression and were estimated to be .51 and 1.02, respectively.

Records of 819 calves by 52 sires were used to obtain estimates of heritability by paternal half-sib correlation from the sums of squares pooled over the 2 herds. These estimates were .42 ± .17 and .43 ± .17 for weaning weight and feeder grade, respectively. Heritability estimates of postweaning average daily gain and 12-month weight were computed from the records of 176 steers and heifers from the Federal Reformatory herd and were 1.12 ± .22 and 1.21 ± .22, respectively. Eighteen-month weight of 113 heifers from Project 650 was estimated to be .56 ± .39 heritable.

The correlation between actual grade and unadjusted weaning weight was .49 and highly significant ($P < .01$), while the correlation between actual grade and postweaning average daily gain was -.16 and significant ($P < .05$). No significant association ($r = .09$) was found between actual weaning weight and postweaning average daily gain, but adjusted 210-day weight and postweaning average daily gain were positively correlated ($r = .32$) and highly significant ($P < .01$). The correlation between age at weaning and postweaning average daily gain in the feedlot was -.25 and highly significant ($P < .01$).

From sums of squares and cross products pooled over both herds, regression coefficients of .074 and .094 were obtained when the adjusted 210-day weights of the offspring were regressed on the adjusted 210-day and 12-month weights of the sires, respectively. This would indicate that selection of sires on the basis of their weights at 12 months of age might be slightly more effective in increasing adjusted 210-day calf weights than would selection of sires based on their weights at 7 months of age.

LITERATURE CITED

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

Carter, R. C. and C. M. Kincaid. 1959a. Estimates of genetic and phenotypic parameters in beef cattle. II. Heritability estimates from parent-offspring and half-sib resemblances. J. Animal Sci. 18:323.

Carter, R. C. and C. M. Kincaid. 1959b. Estimates of genetic and phenotypic parameters in beef cattle. III. Genetic and phenotypic correlations among economic characters. J. Animal Sci. 18:331.

Dawson, W. M., E. H. Vernon, A. L. Baker and E. J. Warwick. 1954. Selection for increased weights of six-month-old beef calves in a Brahman-Angus population. J. Animal Sci. 13:556.

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

Guilbert, H. R. and G. H. Hart. 1951. California Beef Production. Manual 2. Calif. Agr. Exp. Sta. and Extension Service.

Hazel, L. N. and C. E. Terrill. 1945. Heritability of weaning weight and staple length in range Rambouillet lambs. J. Animal Sci. 4:347.

Kieffer, N. M. 1960. Inheritance of certain maternal traits in beef cattle. Ph.D. Thesis. Oklahoma State University.

Kincaid, C. M. and R. C. Carter. 1958. Estimates of genetic and phenotypic parameters in beef cattle. I. Heritability of growth rate estimated from response to sire selection. J. Animal Sci. 17:675.

Kincaid, C. M., R. C. Carter and J. S. Copenhaver. 1952. Heritability of rate of gain from progeny tests with beef cattle. J. Animal Sci. 11:741 (Abstract).

Knapp, B., Jr., A. L. Baker, J. R. Quesenberry and R. T. Clark. 1941. Record of performance in Hereford cattle. Mont. Agr. Exp. Sta. Bul. 397.

Knapp, B., Jr. and R. T. Clark. 1947. Genetic and environmental correlations between growth rates of beef cattle at different ages. J. Animal Sci. 6:174.

Knapp, B., Jr. and R. T. Clark. 1950. Revised estimates of heritability of economic characteristics in beef cattle. J. Animal Sci. 9:582.

Knapp, B., Jr. and R. T. Clark. 1951. Genetic and environmental correlations between weaning scores and subsequent gains in the feedlot with record of performance steers. J. Animal Sci. 10:365.

Knapp, B., Jr. and A. W. Nordskog. 1946a. Heritability of growth and efficiency in beef cattle. J. Animal Sci. 5:62.

Knapp, B., Jr. and A. W. Nordskog. 1946b. Heritability of live animal scores, grades, and certain carcass characteristics in beef cattle. J. Animal Sci. 5:194.

Knapp, B., Jr. and R. R. Woodward. 1951. Heritability of weights of beef steers by months during the feeding period. J. Animal Sci. 10:1026 (Abstract).

Koch, R. M. and R. T. Clark. 1955a. Genetic and environmental relationships among economic characters in beef cattle. I. Correlations among paternal and maternal half-sibs. J. Animal Sci. 14:775.

Koch, R. M. and R. T. Clark. 1955b. Genetic and environmental relationships among economic characters in beef cattle. II. Correlations between offspring and dam and offspring and sire. J. Animal Sci. 14:786.

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

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

Koger, M. and J. H. Knox. 1952. Heritability of grade and type in range beef cattle. J. Animal Sci. 11:361.

Lindholm, H. B. and H. H. Stonaker. 1957. Economic importance of traits and selection indexes for beef cattle. J. Animal Sci. 16:998.

Lush, J. L. 1940. Intra-sire correlations and regressions of offspring on dam as a method of estimating heritability of characteristics. Proc. Amer. Soc. Anim. Prod. p. 293.

Lush, J. L. 1945. Animal Breeding Plans. (3rd Ed.) Iowa State College Press, Ames, Iowa.

Patterson, R. E., J. H. Jones, J. J. Bayles and R. V. Turnbough. 1949. Performance-testing and progeny-testing of beef breeding stock as an aid to selection. J. Animal Sci. 8:608 (Abstract).

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

Rollins, W. C. and K. A. Wagnon. 1956b. Heritability of weaning grade in range beef cattle. J. Animal Sci. 15:529.

Shelby, C. E., R. T. Clark, J. R. Quesenberry and R. R. Woodward. 1957. Heritability of some economic traits in record of performance bulls. J. Animal Sci. 16:1019 (Abstract).

Shelby, C. E., R. T. Clark, J. R. Quesenberry and R. R. Woodward. 1960. Heritability of some economic characteristics in record of performance bulls. J. Animal Sci. 19:450.

Shelby, C. E., R. T. Clark and R. R. Woodward. 1955. The heritability of some economic characteristics in beef cattle. J. Animal Sci. 14:372.

Snedecor, G. W. 1956. Statistical Methods. (5th Ed.) Iowa State College Press, Ames, Iowa.

Wagnon, K. A. and W. C. Rollins. 1959. Heritability of postweaning growth to long yearling age of range beef heifers raised on grass. J. Animal Sci. 18:918.

Warwick, B. L. and T. C. Cartwright. 1955. Heritability of rate of gain in young growing beef cattle. J. Animal Sci. 14:363.

Zimmerman, J. E., L. S. Pope, A. B. Nelson and D. F. Stephens. 1959. Effect of different levels of wintering on the performance of spring-calving beef cows. Okla. Agr. Exp. Sta. Misc. Pub. MP-55:55.

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