SOME FACTORS AFFECTING WEANING WEIGHTS AND WEANING SCORES IN BEEF CALVES

Thesis for the Degree of M. S.
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by

James S. Brinks

AN ABSTRACT

Submitted to the College of Agriculture,
Michigan State University of Agriculture and Applied Science
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ABSTRACT

SOME FACTORS AFFECTING WEANING WEIGHTS
AND WEANING SCORES IN BEEF CALVES

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The relative importance of age of dam, sex, and age of calf as factors affecting the weaning weights and scores of beef calves was studied. The data used in the study were collected during the period of 1953 through 1956 at the Michigan State University Experiment Station and included one hundred and sixty Hereford and forty-two Angus calves sired by twelve Hereford and four Angus bulls. The data were analyzed by least square method of analysis.

The weaning weights of calves were found to increase with an increase in age of dam up to the five--six year old age group. The calves from seven year old dams showed a marked decrease followed by an increase in the weights of calves from eight year old and over dams. Correction values of 50, 25, and 15 pounds were calculated for two, three and four year old dams respectively. The weaning scores of calves increased with an increase in age of dam up to seven years of age and then declined slightly.

Steer calves tended to have heavier weaning weights than heifers each year. A correction value of 5 pounds was obtained by least squares analysis.

A value of .85 pounds per day was obtained by least squares analysis for an age of calf effect. However, using this correction factor left the younger calves lighter and the older calves heavier than the average. Therefore a value of 1.5 pounds was calculated by making the regression of weight on age equal to zero and this value was then used to put the calves on an equal age basis.

Heritability estimates of weaning weight and weaning score were calculated by the paternal half sib method of analysis. Estimates of .29 and .62 were obtained for weaning weight and weaning score respectively.

The genetic, environmental, and phenotypic correlations between weaning weight and weaning score were computed. Values of -.92, 1.46, and .36 respectively were obtained.

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INTRODUCTION

Research has shown that genetic and environmental factors affect the weaning weights and weaning scores of beef calves. The relative importance of these factors in causing differences in weaning weights and scores has considerable practical importance to the animal breeder. Many studies indicate that adjusted weaning weights along with weaning scores should be included in a selection index for beef cattle improvement. Correcting the actual weaning weights for known effects enables the researcher and breeder to compare the calves on an equal basis. One of the purposes of this study is to determine to what extent some of these factors affect the weaning weights and scores of beef calves and to obtain correction factors where needed.

Improving the performance of beef cattle for these economic traits through breeding depends on the effective use of genetic variation. One connected with animal breeding should understand the genetic and environmental relationships among these traits. Foremost of these relationships are heritability estimates of the characters and the genetic and environmental correlations between these traits.

Heritability estimates of economic traits are especially important since they represent the proportion of gain which

is transmitted to the offspring through selected parents (Lush 1948). These estimates are essential in planning efficient breeding programs and determining the relative emphasis due each of the traits when breeding animals are selected.

Genetic correlations between these traits are important because they point out whether the same genes are involved in the production of both traits. Consequently, one knows if when selecting for a character he is automatically selecting for another trait or against the other trait. Knowing this, one can guide the breeding program accordingly.

This study is an attempt to evaluate the relative importance of some factors affecting the weaning weights and weaning scores of beef calves under Michigan conditions.

OBJECTIVES

1. To determine the effect of the following factors on weaning weights and scores of beef calves:
   a) Age of dam
   b) Sex
   c) Age of Calf

2. To obtain heritability estimates for weaning weights and scores of beef calves.

3. To obtain an estimate of the genetic correlation between weaning weight and score in beef calves.

REVIEW OF LITERATURE

Factors Affecting Weaning Weights And Weaning Scores

Age of Dam

Research has shown that age of dam affects the weaning weights of beef calves. The cows may influence the weaning weights and scores of their calves by genes transmitted to the calves and by the maternal environment they provide.

Physiological changes in function, such as increased milk production and changes in size and weight which may accompany the aging process, might be expected to influence the calves' environment. This altered condition may directly affect the weaning weights and scores of beef calves.

Koch (1951) concluded that age of dam affects the weaning weights of calves presumably through changes in udder development, milking ability, and the cow's ability to withstand the rigors of range conditions.

Koch and Clark (1955a) reported that Hereford range cows' production increased steadily from three to six years of age and then declined with regard to birth weight, weaning weight and weaning score of their calves.

Botkin and Whatley (1953) calculated correction values for weaning weights of thirty-five and fifteen pounds for

three and four year old Hereford cows using five years and older as a mature equivalent basis.

Burgess et al. (1954) found the effects of age of dam as deviations from the average in Hereford cows to be: two year old cows, minus fifteen pounds; three to five year old cows, plus five pounds; six to eight year old cows, plus twenty-one pounds; nine years old and over, minus ten pounds.

Rollins and Guilbert (1954) found the optimum age of dam in regard to weaning weight to be six or seven to ten years of age.

Nelms and Bogart (1956) reported there was little or no effect due to age of dam even though large differences appeared to exist between two year old and older cows.

Rollins and Wagnon (1956a) reported that weaning weights of grade Hereford calves increased with an increase in age of dam up to seven or eight years and then declined.

Knapp (1942) reported the weaning weight of Hereford calves increased with age of dam to six years of age and then declined.

Knox and Kroger (1945) found that weaning weights of range calves increased with age of dam until cows were seven years old and then declined slightly.

<u>Sex</u>

In general, it has been observed that males of most species of domestic animals grow faster and reach a greater

mature weight than females. Most studies on the effect of sex on weaning weights of beef calves indicate that male calves tend to have heavier weaning weights than females.

Koch (1951) reported that Hereford bulls and steers were forty-four and thirteen pounds heavier than heifers at weaning and added that the heavier weights for bulls over steers may be partially due to more intense selection on weight for the bulls.

Koch and Clark (1955a) found males (bulls and steers) to be 26.2 pounds heavier than females based on 182 day weaning weights.

Kroger and Knox (1945a), working with data from 1936 to 1943, reported that high grade Hereford steers were heavier than heifers each year. The steers were thirty-two pounds heavier on an average over the years based on 205 day weaning weights which was highly significant. The data did not show sex differences to be greater for some sires.

Gregory *et al.* (1950) reported no significant difference due to sex in weaning weights but in general the mean difference was in favor of the male calves.

Botkin and Whatley (1953) reported the Hereford males were 24.6 pounds heavier than females at weaning based on 210 day weights.

Burgess et al. (1954) found the mean differences due to sex to be plus fourteen pounds for bull calves, minus six for steer calves and minus eight for heifer calves.

Rollins and Guilbert (1954) estimated that bull calves on the average gained .13 pounds per day more than heifers from birth to four months of age. Bull calves were sixty-eight pounds heavier than heifers based on 240 day weaning weights.

Nelms and Bogart (1956) reported that there was apparently no direct effect of sex on rate of suckling gain after correction was made for differences in birth weight.

Rollins and Wagnon (1956a) reported that Hereford steer calves weighed thirty-one and eighteen pounds more than heifer calves in two herds based on 240 day weaning weights.

Knapp and Black (1941) found sex to have a significant influence on rate of gain during the suckling period.

Koch and Clark (1955a) reported that male calves tended to score .13 units or .1 of a grade higher than females.

Rollins and Wagnon (1956b) found that heifers averaged slightly lower in grade than steers at weaning but concluded that the differences were probably due to differences in weight.

Age of Calf

Many times it is desirable to have the calves' weaning weights at a constant age for use in the comparison of animals. Since birth dates vary and it is not feasible to weigh the calves everyday, some correction factor is needed to put the calves on an equal basis. Usually an average regression coefficient of weight on age is calculated. Naturally, this value will vary with different herds and management practices.

Johnson and Dinkel (1951) gave a linear correction factor of 1.017 pounds per day based on 182 day weaning weights.

Botkin and Whatley (1953) reported a value of 1.46 pounds per day for Hereford calves.

Burgess *et al.* (1954) found a value of 1.67 pounds per increase in age of calf one day.

Kroger and Knox (1945a) found the regression of weight on age to be 1.21 pounds per day for grade Hereford calves. In a subsequent paper, they (1945b) reported that the average regression of weight on age within subgroups to be 1.33 pounds per day.

Heritability Estimates

Characteristics in beef cattle such as weaning weight and weaning score may be described as being highly or lowly heritable depending on how closely relatives resemble each other in regard to these traits. When the degree of heritability for a character is low, the rate of progress through

selection which can be expected is correspondingly low. Therefore, heritability estimates of this type are needed to determine how much emphasis should be placed on these traits in the breeding program.

Weaning Weight

Gregory *et al.* (1950) obtained heritability estimates of weaning weight of .26 and .52 for two range Hereford herds based on paternal half sib correlations.

Knapp and Nordskog (1946a) found heritability estimates for weaning weight in range Hereford cattle to be .12 from intra sire correlations and .0 from sire progeny regression estimates. After adjustment had been made for method of feeding they obtained an estimate of .30.

Knapp and Clark (1950) reported a revised heritability estimate of weaning weight in range Hereford calves of .28.

Tyler *et al.* (1948) obtained a heritability estimate of .15 for weight in Holstein cattle at six months of age and .20 to .35 for Ayrshires at the same age.

Dawson *et al.* (1955) reported a heritability estimate for days to weaning at 500 pounds of .451 in Milking Shorthorns using paternal half sib correlation.

Heritability of weaning weight in Hereford calves was estimated at .23 by Shelby *et al.* (1955) using paternal half sib correlation.

Koch and Clark (1955b) obtained estimates of .24 for weaning weight in registered and grade Herefords and .21 for gain from birth to weaning using paternal half sib correlations.

Heritability estimates of .11 for weaning weight and .07 for gain from birth to weaning were obtained by Koch and Clark (1955c) using regression of offspring on dam analysis. Estimates of .25 and .17 were found by regression of offspring on sire for the two traits respectively.

Koch and Clark (1955d), after adding an effect for maternal environment, reported a heritability estimate of .19 for weaning weight.

Rollins and Wagnon (1956a), analyzing two herds of grade Hereford cattle, reported estimates of .09 and .54 averaging .30 by paternal half sib correlations. Estimates of .84 plus or minus .23 and minus .13 plus or minus .24 were obtained by offspring dam regression for the same traits.

Hazel and Terrill (1945) reported an estimate of .30 plus or minus .04 for heritability of weaning weight in range lambs. Hazel and Terrill (1946b) estimated heritability to be .17 for weaning weight in lambs based on an average of half sib and offspring dam estimates.

Blunn et al. (1953) found estimates of heritability of gain from birth to weaning at fifty-six days of .22 and .02 in swine using paternal half sib correlations.

Weaning Score

Knapp and Nordskog (1946b) found heritability for weaning score to be .53 for Hereford calves using intra sire correlations.

Knapp and Clark (1950) obtained an estimate of .28 for weaning score and concluded that growth measures were more highly influenced by heredity than were measures of quality and conformation.

Kroger and Knox (1952) found heritability of weaning score to be .50 and .30 in Angus cattle using regression of offspring on dam and half sib correlation estimates. Estimates of .23 and .24 in range Herefords were obtained by using intra sire regression of offspring on dam and half sib correlations.

Knapp and Clark (1951) reported a heritability estimate of .31 for weaning score in Hereford steers and Koch and Clark (1955b) found heritability to be .18 for weaning score in Hereford calves using paternal half sib correlation.

Using regression of offspring on dam and regression of offspring on sire methods for computing heritability, Koch and Clark (1955c) obtained estimates of .16 and .15 respectively for weaning score. Later, (1955d) they reported an estimate for weaning score for Hereford calves of .16 after adding a part due to genic effects for a maternal effect.

Rollins and Wagnon (1956b) obtained estimates of .67 and .08 for weaning score using paternal half sib correlations for two Hereford herds. Pooling the estimates gave a value of .36. Heritability estimates on the basis of selection experiments over two generations gave values of .42 and .29 or an average of .36.

Tyler and Hyatt (1948) reported an estimate of .30 for heritability of official type ratings in Ayrshire cattle using regression of daughter on dam analysis.

Hazel and Terrill (1946b) found heritability estimates of body type in sheep varying from .28 to minus .07. The estimates for body type were smaller in each breed than corresponding estimates of heritability for weaning weight.

Hazel and Terrill (1946a), after averaging eight values, estimated heritability for body type in range lambs to be about .13 plus or minus .04.

Genetic Correlation

The genetic correlation indicates whether the same sets of genes are affecting both weaning weight and weaning score of the calf. A high positive genetic correlation indicates that when selecting for one trait, the other is automatically being selected for simultaneously, whereas a low or high minus genetic correlation indicates that selection is independant for each trait or in opposite directions. Therefore, genetic correlations are very useful in guiding a breeding program.

Knapp and Clark (1951), working with data from Hereford steers, obtained a genetic correlation between weaning score and gain in the feedlot of .30. The environmental and phenotypic correlations between the two traits were found to be minus .30 and .0001 respectively.

Koch and Clark (1955b) obtained estimates of .47, .68 and .64 for the genetic, environmental, and phenotypic correlations respectively between weaning weight and weaning score in Hereford calves.

Touchberry (1951) found the genetic correlation between weight and type in three year old Holstein cows to be zero.

Hazel (1943) estimated the genetic correlation between weight and score in swine derived from intrasire regressions of offspring on dam to be .519. A genetic correlation of zero was obtained between both weight and productivity and score and productivity.

METHOD OF PROCEDURE

Data

The data used in this study are the weaning weights and scores of forty-two registered Angus and one hundred and sixty registered and high grade Hereford calves raised at the Michigan State University Experiment Station at Lake City, Michigan, during the period of 1953 through 1956.

Four sires consisting of three purebred Hereford and one purebred Angus from breeders' herds in Michigan were used each year.

The weaning weights and scores were obtained around October 15th each year. A committee of three persons of the Michigan State University Animal Husbandry Department scored the calves using the five United States Department of Agriculture Feeder Cattle Grades as a basis. A scoring system consisting of one through fifteen units was employed with each unit corresponding to one-third of a grade. The three scores for a calf were averaged and the calf then was assigned a score corresponding to the nearest one-third of a grade. A score of fifteen would correspond to a grade of fancy plus whereas an average choice calf would score eleven.

The ages of dam studied were grouped as 2, 3, 4, 5-6, 7, and 8 years and over. A rough analysis of the data showed this breakdown to be satisfactory.

Procedure

The data were analyzed by the method of least squares using the procedure described by Henderson (1948). The equation used was:

$$Y_{ijklm} = \mathcal{M} + d_i + B_j + s_k + y_l + bX_{ijklm} + e_{ijklm}$$

where Y_{ijklm} = observed weaning weight (score).

$\mathcal{M}$ = an average or common effect.

d_i = age of dam effect.

B_j = breed effect.

s_k = sex effect.

y_l = year effect.

b = regression coefficient of weaning weight (score) on age.

X_{ijklm} = age of calf.

e_{ijklm} = an effect peculiar to the individual calf.

The procedure for obtaining the set of equations was as follows:

$$\Sigma(e_{ijklm})^2 = \Sigma(Y - [\mathcal{M} + d_i + B_j + s_k + y_l + bX_{ijklm}])^2$$

$$\frac{\partial \Sigma(e_{ijklm})^2}{\partial \quad d_i} = -2 \sum_{jklm} (Y - [\mathcal{M} + d_i + B_j + s_k + y_l + bX_{ijklm}])$$

$$= -2 \, (Y_{i....} - [n_{i...}(\mathcal{M} + d_i) + \sum_j n_{ij..}B_j + \sum_k n_{i.k.}s_k + \sum_l n_{i..l}y_l + \sum_{jklm} X_{ijklm}b])$$

Set = 0.

Normal equation for d_i is:

$$Y_{i....} = n_{i...}(\mathcal{M}+d_i) + \sum_j n_{ij..}B_j + \sum_k n_{i.k.}s_k + \sum_l n_{i..l}y_l + \sum_{jklm} X_{ijklm}b$$

The other equations were obtained in a similiar manner and are as follows:

Normal equation for B_j is:

$$Y_{.j...} = \sum_i n_{ij..}(\mathcal{M}+d_i) + n_{.j..}B_j + \sum_k n_{.jk.}s_k + \sum_l n_{.j.l}y_l + \sum_{iklm} X_{ijklm}b$$

Normal equation for s_k is:

$$Y_{..k..} = \sum_i n_{i.k.}(\mathcal{M}+d_i) + \sum_j n_{.jk.}B_j + n_{..k.}s_k + \sum_l n_{..kl}y_l + \sum_{ijlm} X_{ijklm}b$$

Normal equation for y_l is:

$$Y_{...l.} = \sum_i n_{i..l}(\mathcal{M}+d_i) + \sum_j n_{.k.l}B_j + \sum_k n_{..kl}s_k + n_{...l}y_l + \sum_{ijlm} X_{ijklm}b$$

Normal equation for b is:

$$\sum_{ijklm} Y_{ijklm}X_{ijklm} = \sum_{jklm} X_{ijklm}(\mathcal{M}+d_i) + \sum_{iklm} X_{ijklm}B_j + \sum_{ijlm} X_{ijklm}s_k + \sum_{ijkm} X_{ijklm}y_l + \sum_{ijklm}(X_{ijklm})^2 b$$

For ease in solving the equations μ was combined with the age of dam equations and placed first since this class had the greatest number of equations. This permits a number of zeros to drop out near the beginning.

Also, striking out the last equation of each class, except the class where μ is combined, reduces the number of equations to be solved from fifteen to twelve. This method gives an estimate of $B_1 - B_2$ for breeds, $s_1 - s_2$ for sex, etc. Table 1 shows the equations to be solved.

TABLE 1. TABLE OF EQUATIONS TO BE SOLVED

	Age of Dam*							Breed	Sex	Years			Weaning Weight	Weaning Score
	$\widehat{\mu+d_1}$	$\widehat{\mu+d_2}$	$\widehat{\mu+d_3}$	$\widehat{\mu+d_4}$	$\widehat{\mu+d_5}$	$\widehat{\mu+d_6}$	$\hat{b}$	$\widehat{B_1-B_2}$	$\widehat{s_1-s_2}$	$\widehat{y_1-y_4}$	$\widehat{y_2-y_4}$	$\widehat{y_3-y_4}$	ΣY	$\Sigma Y'$
$\widehat{\mu+d_1}$	23						3858	4	14	1	4	11	7344	251
$\widehat{\mu+d_2}$		31					5661	4	11	7	6	6	11656	356
$\widehat{\mu+d_3}$			33				6003	6	11	6	15	5	12516	400
$\widehat{\mu+d_4}$				49			8967	17	27	6	16	15	19505	591
$\widehat{\mu+d_5}$					18		3300	6	10	2	2	6	6715	214
$\widehat{\mu+d_6}$						48	9042	5	28	11	13	10	19556	570
$\hat{b}$	3858	5661	6003	8967	3300	9042	6864977	8166	18252	5955	9733	10026	14253523	433933
$\widehat{B_1-B_2}$	4	4	6	17	6	5	8166	42	23	2	12	12	16801	510
$\widehat{s_1-s_2}$	14	11	11	27	10	28	18252	23	101	17	28	25	38882	1180
$\widehat{y_1-y_4}$	1	7	6	6	2	11	5955	2	17	33			13428	431
$\widehat{y_2-y_4}$	4	6	15	16	2	13	9733	12	28		56		20512	680
$\widehat{y_3-y_4}$	11	6	5	15	6	10	10026	12	25			53	19633	586

* d_1, d_2, d_3, d_4, d_5, and d_6 correspond to 2, 3, 4, 5–6, 7, and 8 year old and over dams respectively.

RESULTS AND DISCUSSION

Age of Calf

Upon completion of the least squares method of analysis, a value of .85 pounds increase in weight per calf per day was obtained. Biologically this value seemed too low and other values were substituted to make the regression of the adjusted weights on ages equal to zero. A correction factor of 1.5 pounds per day was found to be satisfactory and was used to put the calves on an equal basis for age. This value is in close agreement with the values obtained by Kroger and Knox (1945b), Botkin and Whatley (1953), and Burgess *et al.* (1954).

Least squares analysis of score on age gave a value of -.002884 per day and is attributed to chance deviations. This value is not significantly different from zero and should be taken as such.

Age of Dam

Completion of the least squares method of analysis showed an increase in weaning weight with an increase in age of dam up to the five--six year age group. This is in close agreement with the work of Koch and Clark (1955a), Botkin and Whatley (1953), Knapp *et al.* (1942), and Knox and Kroger (1945). Table 2 lists the effects of age of dam on weaning weight and score as deviations from the average.

TABLE 2. INFLUENCE OF AGE OF DAM ON WEANING WEIGHT AND WEANING SCORE

Age of Dam	Number of Cows	Deviations From Average Weaning Weight	Deviations From Average Weaning Score
2	23	-41	-.48
3	31	- 4	-.34
4	33	+ 5	+.15
5-6	49	+21	+.28
7	18	- 6	+.29
8+	48	+24	+.10

The apparent large decrease in the weaning weights of calves produced by seven year old cows does not seem biologically realistic and is not in accord with the findings of other workers. Chance deviations or sampling errors play a larger part in this age group since it contains the smallest number of calves and this is the most probable reason for the apparent decrease in weaning weight. Marlowe and Gaines (1957), in a study at Virginia, found seven year old dams to have a marked decrease in weaning weights of their calves. If other experiment stations find these results the phenomenon should be studied further.

Weaning score increased with an increase in age of dam up to seven years of age and then declined slightly. These

results agree closely with the findings of Koch and Clark (1955).

In obtaining correction factors to be used in adjusting the calves' weights for age of dam effects, the five--six year age group was set equal to zero and others were found as deviations from this group. The results are shown in table 3.

TABLE 3. AGE OF DAM EFFECTS AS DEVIATIONS FROM 5-6 YEAR AGE GROUP

Age of Dam	Deviations From 5-6 Year Age Group
2	−62
3	−25
4	−16
5-6	0
7	−27
8+	+2

With this data as a basis, correction factors for age of dam effects were calculated. It was found that adding 60 pounds to the calves' weights for two year old dams gave them too high of an advantage. Correction factors of 50 pounds, 25 pounds, and 15 pounds for two, three, and four year old dams were found to be satisfactory by regression analysis.

Sex

Differences in weaning weight between the sexes showed the steer calves to have a 5 pound advantage as computed by least squares analysis. This value is in accord with Gregory (1950) but is lower than most values found in other studies. A correction factor of 5 pounds was found to be satisfactory to put the sexes on an equal basis for comparison. The

TABLE 4. INFLUENCE OF SEX ON WEANING WEIGHT*

Year	Number of Males	Average Weight	Number of Females	Average Weight	Average Difference
1953	17	422	16	417	5
1954	28	391	28	387	4
1955	25	376	28	373	3
1956	31	410	29	397	13
					6.25

* Corrected for age of dam and age of calf.

average differences between the sexes in weaning weight for each year are shown in table 4.

Heifers were found to score .299 units higher than steer calves by least squares analysis. This value corresponds to approximately .1 of a grade and is attributed to chance deviations.

HERITABILITY ESTIMATES

Procedure

Heritability estimates for weaning weight and weaning score were calculated by the paternal half sib method of analysis. Only the Hereford calves were included in the estimates to eliminate any breed differences that might exist. All data were adjusted for age of dam, sex, and age of calf as previously described. Three Hereford sires were used each year during the period of 1953 through 1956.

Heritability was calculated in the narrow sense--the fraction of the phenotypic variance that was due to the average effects of the genes of the individual members of the population. The formula used to estimate heritability, utilizing paternal half sib data, was as follows:

$$H = \frac{4\sigma^2_s}{\sigma^2_e + \sigma^2_s}$$

The σ^2_e term includes all the random environmental variance, three-fourths of the genic variance, all of the dominance variance, and a major part of the epistatic variance. The σ^2_s term contains one-fourth of the genic variance plus a small part of the epistatic variance.

Heritability estimates were computed each year and also, over the four year period on a between sires within years

basis. Conventional methods of analysis of variance and covariance were used to obtain the mean squares which are listed in table 5. The coefficient for the σ^2_s components were computed as described by Henderson (1953).

Results and Discussion

Results obtained by analysis of variance indicate a highly significant difference between sires for weaning weight in 1956. There was not a significant difference between sires during the first three years. This variation in results is attributed to having only three sires each year. Therefore chance would play a large part in determining how closely they resemble each other for these traits. Also, this variation in results may be expected since when only three sires are tested and heritability for a given trait is .5, one would have to have sixteen offspring per sire to expect to obtain a significant sire difference half of the time (Magee 1957).

There was a significant difference between sires for weaning score each year except in 1955.

TABLE 5. ANALYSIS OF VARIANCE AND COVARIANCE FOR WEANING WEIGHT AND WEANING SCORE, 1953 - 1956

		VARIANCES		COVARIANCE		
		Weaning Weight	Weaning Score	Weaning Weight–Weaning Score		
Source	Degrees of Freedom	Mean Squares	Mean Squares	Degrees of Freedom	Mean Squares	Expected Mean Squares
1953						
Between Sires	2	1629.31	10.66*	2	65.23	$\sigma^2_e + 10\,\sigma^2_s$
Within Sires	28	1792.32	2.74	27	37.28	σ^2_e
1954						
Between Sires	2	1297.96	9.38*	2	− 56.20	$\sigma^2_e + 14.64\,\sigma^2_s$
Within Sires	41	1671.67	2.74	40	42.84	σ^2_e
1955						
Between Sires	2	2574.46	5.39	2	29.37	$\sigma^2_e + 13.61\,\sigma^2_s$
Within Sires	38	1417.98	2.51	37	41.82	σ^2_e
1956						
Between Sires	2	8766.18**	9.91*	2	− 291.99	$\sigma^2_e + 14.48\,\sigma^2_s$
Within Sires	41	1665.82	2.35	40	17.98	σ^2_e

* Significant P(<.05)
** Significant P(<.01)

The σ^2_s components for weaning weight and weaning score were obtained from data in table 5 and are listed below:

TABLE 6. σ^2_s COMPONENTS FOR WEANING WEIGHT AND WEANING SCORE, 1953 - 1956

Year	Weaning Weight	Weaning Score
1953	−16.30	.792
1954	−25.53	.454
1955	84.97	.212
1956	490.36	.522

Using the data from tables 5 and 6, heritability estimates were calculated as follows:

$$1953 \qquad H = \frac{4\sigma^2_s}{\sigma^2_e + \sigma^2_s} = \frac{4(-16.30)}{1792.32 + (-16.30)} = -.04$$

Heritability estimates for weaning weight and weaning score for the four years are listed in table 7.

TABLE 7. HERITABILITY ESTIMATES OF WEANING WEIGHT AND WEANING SCORE, 1953 - 1956

Year	Weaning Weight	Weaning Score
1953	−.04	.90
1954	−.06	.57
1955	.23	.31
1956	.91	.73

The minus heritability estimates obtained for weaning weight in 1953 and 1954 are below what the true population value could be and should be thought of as zero. These are most likely due to sampling errors being multiplied by four in the numerator of the heritability formula. This is a disadvantage of using the paternal half sib method when few sires are involved and is a possible explanation of why the estimates are so low.

Heritability for weaning weight, as calculated over the four year period on a between sires within years basis, was found to be .29. This is a more reliable estimate since the

$$H = \frac{4\sigma^2_s}{\sigma^2_e + \sigma^2_s} = \frac{4(138.147)}{1746.20 + 138.147} = .29$$

data includes twelve sires and one hundred and sixty calves.

TABLE 8. ANALYSIS OF VARIANCE FOR WEANING WEIGHT AND WEANING SCORE

Source	d.f.	Weight M.S.	Score M.S.	Expected M.S.
Between Years	3	14886.33	36.04	
Between Sires Within Years	8	3566.98*	8.83**	$\sigma^2_e + 13.18\sigma^2_s$
Within Sires	148	1746.20	2.57	σ^2_e

* Significant P(<.05)
** Significant P(<.01)

A heritability estimate of .62 was obtained for weaning score.

$$H = \frac{4\sigma^2_s}{\sigma^2_e + \sigma^2_s} = \frac{4(.475)}{2.57 + .475} = .62$$

The estimate of .29 for weaning weight is in close agreement with values obtained by Gregory et al. (1950), Knapp and Clark (1950), Shelby et al. (1955), Koch and Clark (1955), and Rollins and Wagnon (1956).

Heritability of weaning score, calculated to be .62, is somewhat higher than values reported in other studies.

These heritability estimates indicate that rapid improvement may be made through individual selection for weaning score. Much improvement can also be made through selection based on weaning weight although it will be less rapid than improvement in weaning score in the herd.

GENETIC CORRELATION OF WEANING WEIGHT AND WEANING SCORE

Procedure

The genetic correlation between weaning weight and weaning score was calculated as described by Hazel et al. (1943) and was adapted for use in beef cattle data. The formula used was:

$$R_{G_iG_j} = \frac{\text{Cov } G_iG_j}{\sqrt{(\sigma^2_{G_i})(\sigma^2_{G_j})}}$$

where $\sigma^2 G_i = 4\sigma^2 s_i$

$\sigma^2 G_j = 4\sigma^2 s_j$

$\text{Cov } G_i\ G_j = 4 \text{ Cov } s_i s_j$

The genetic correlations in 1953 and 1954 were not calculated since the σ^2_s component for weaning weight in each case was negative and therefore its square root undefined. Only the Hereford calves, corrected for age of dam, sex, and age of calf were again used.

Results and Discussion

Using the variance and covariance data from tables 5 and 6, the genetic correlations between weaning weight and score were calculated in the following manner.

1955 $$R_{G_iG_j} = \frac{Cov\ G_iG_j}{\sqrt{(\sigma^2_{G_i})(\sigma^2_{G_j})}} = \frac{-.9148}{\sqrt{(84.97)(.212)}} = -.22$$

1956 $$R_{G_iG_j} = \frac{Cov\ G_iG_j}{\sqrt{(\sigma^2_{G_i})(\sigma^2_{G_j})}} = \frac{-21.4068}{\sqrt{(490.36)(.522)}} = -1.34$$

The 1.34 correlation estimate obtained in 1956 is larger than the true value could be and is attributed to the fact that only three sires were used in obtaining the σ^2_s and Cov s_is_j components. Chance deviations will therefore play a large part in the estimate of these components. Hence, a correlation estimate greater than minus one could be obtained but is not a valid estimate.

The genetic correlation between weaning weight and weaning score was also computed over the four year period on a within year basis. Variance and covariance components for weaning weight and weaning score were calculated from data in tables 5 and 6, and are summerized in table 9.

TABLE 9. GENETIC AND ENVIRONMENTAL VARIANCES AND COVARIANCES

Source	(V) Weaning Weight	(V) Weaning Score	(Cov) Weaning Weight and Score
Genetic	552.588	1.900	-29.7512
Environmental	1331.759	1.145	56.9434
Phenotypic	1884.347	3.045	27.1922

The genetic, environmental and phenotypic correlations were again calculated by dividing the appropriate covariance by the square root of the product of the two corresponding variances and are as follows:

$$R_{G_iG_j} = \frac{Cov\ G_iG_j}{\sqrt{(\sigma^2_{G_i})(\sigma^2_{G_j})}} = \frac{-29.7512}{\sqrt{(552.588)(1.900)}} = -.92$$

$$R_{E_iE_j} = \frac{Cov\ E_iE_j}{\sqrt{(\sigma^2_{E_i})(\sigma^2_{E_j})}} = \frac{56.9434}{\sqrt{(1331.759)(1.145)}} = 1.46$$

$$R_{P_iP_j} = \frac{Cov\ P_iP_j}{\sqrt{(\sigma^2_{P_i})(\sigma^2_{P_j})}} = \frac{27.1922}{\sqrt{(1884.347)(3.045)}} = .36$$

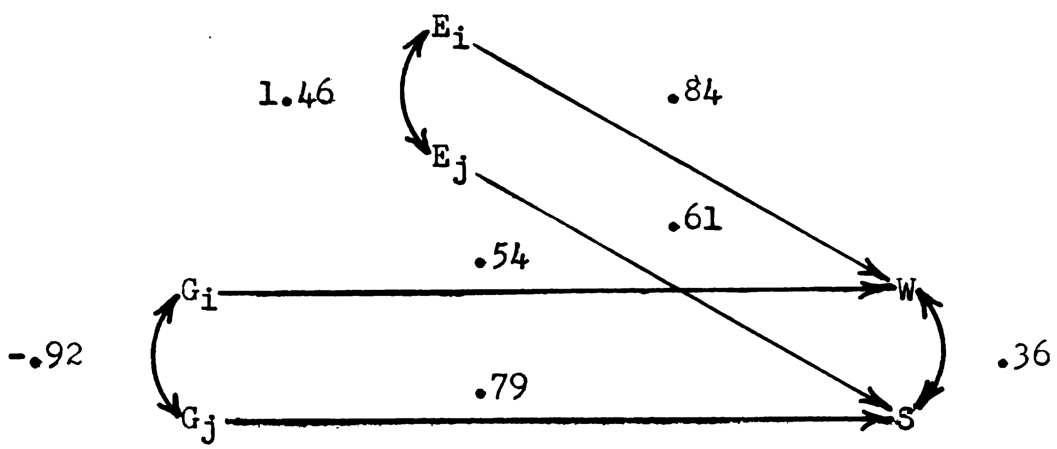
The minus genetic correlation is in opposition to the positive values found by Knapp and Clark (1951) and Koch and Clark (1955). The 1.46 environmental correlation is above the possible true value and is again attributed to sampling errors, as previously described.

Figure 1 presents a path coefficient diagram that illustrates the genetic and environmental relationships involved in the observed correlation between weaning weight and weaning score.

In the diagram below G_i and G_j are the genic values for weaning weight and weaning score respectively. The E_i and

E_j terms include the dominance and most of the epistatic deviations along with the environmental effects. W and S are the corrected weaning weights and weaning scores of the calves. The correlation coefficients are shown by the

FIGURE 1. GENETIC AND ENVIRONMENTAL RELATIONSHIPS BETWEEN WEANING WEIGHT AND WEANING SCORE



curved, double headed arrows whereas the path coefficients are indicated by the straight, single headed arrows. The path coefficients were calculated by dividing the square root of a particular variance by the square root of the corresponding phenotypic variance. For example, the path from G_i to W is as follows:

$$g_i = \frac{\sqrt{\sigma^2 G_i}}{\sqrt{\sigma^2 P_i}} = \frac{\sqrt{552.588}}{\sqrt{1884.347}} = .54$$

The remaining path coefficients were calculated in a similiar manner.

The phenotypic correlation then is the sum of the products of the paths or chains and is as follows:

$$R_{WS} = (.54)(-.92)(.79) + (.84)(1.46)(.61) = .36$$

The phenotypic correlation was also calculated directly on a within year basis and was found to be .40. The slight discrepancy is due to rounding errors.

The negative genetic correlation obtained probably is not nearly so high as the results indicate since the estimated environmental correlation is over one--the maximun true value. The results seem to indicate however, that selection for weaning weight and weaning score is in opposing directions in the herd even though a positive phenotypic correlation exists.

The negative genetic correlation found in this study is in opposition to findings in other studies. Research in this area on beef cattle is very sparse and more investigation is needed before a general statement can be applied to the cattle population as a whole.

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the relative importance of age of dam, sex, and age of calf as factors influencing the weaning weights and weaning scores of beef calves. Correction factors for these effects were calculated in order to put the calves on an equal basis for comparison.

Also, heritability estimates along with the genetic, environmental and phenotypic correlations between weaning weight and weaning score were calculated.

1. The weaning weights of calves were found to increase with an increase in age of dam up to the five--six year age class. A decrease in the weaning weights of calves from seven year old dams was exhibited followed by an increase in the eight year old and over age class.
2. The weaning scores of calves were found to increase with an increase in age of dam up to seven years of age and then decline slightly.
3. Correction factors for weaning weight obtained for calves from two, three, and four year old dams were 50, 25, and 15 pounds respectively.
4. Steer calves tended to have heavier weaning weights than heifer calves each year. An adjustment factor of 5 pounds was obtained and used to put the sexes on an equal basis.

5. A value of .85 pounds per calf per day was obtained by least squares analysis for an age of calf effect. However, correcting the weaning weights of calves using .85 pounds per day left the younger calves lighter and the older calves heavier than the average each year. Therefore a value of 1.5 pounds was calculated by making the regression of weight on age equal to zero and was used to put the calves on an equal age basis.

6. Heritability of weaning weight was estimated at .29.

7. Heritability of weaning score was found to be .62.

8. The genetic correlation between weaning weight and weaning score was estimated at -.92.

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