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To the Graduate Council:

I am submitting herewith a thesis written by William Lafayette Williams entitled "Variation in Beef Sires as Measured by Differences in Their Daughter Productivity." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science with a major in Animal Husbandry.

Charles S. Hobbs
Major Professor

We have read this thesis and recommend its acceptance:

John D. Smalling

Harold J. Smith

Lauren L. Christian

Accepted for the Council:

Hilton A. Smith
Dean of the Graduate School

VARIATION IN BEEF SIRES AS MEASURED BY DIFFERENCES IN THEIR DAUGHTER PRODUCTIVITY

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

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by

William Lafayette Williams

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CHAPTER I

INTRODUCTION

The profits realized from beef cattle herds depend upon the per cent calf crop weaned, the weight and grade of the calves weaned, the current market price, and the cost of production. The information obtained on the performance of the calves at weaning should be particularly useful in increasing profits through selection for increased weight and grade. These records can be used in culling cows from the herd, in selecting heifers for replacements, and in selecting prospective herd sires. Also, these records can be used in evaluating the herd sires, the dams of the calves, and the management program of the herd.

Sire sampling programs have been devised to maximize improvement in traits concerned with more efficient beef production. Primary emphasis in sire analysis should be given to those traits or qualities which will make the largest economic contribution through the performance of the daughters of selected sires. The improvement of these traits involved in beef production is the most important key to economic success.

In addition to economic considerations, the heritability of the traits is also important. The opportunity to select among sires should not be wasted on traits which give little promise of being responsive to selection.

Comparison of sires based on the initial production of their daughters could be very important in predicting future performance of the sires. At this time a major portion of the bull's productive life may be ahead of him, and he could be placed into heavy service without waiting for proof from additional daughters.

With reference to dairy cattle, the theory has been proposed that selection of sires on first lactation performance records of daughters fosters the development of animals with short productive lives. However, no direct support for this contention has been demonstrated. The evidence indicates that higher producers during the first lactation remain in the herd for a longer period and continue to produce at a higher level than animals with lower first records. (Parker et al., 1960).

The objectives of this study were: (1) To determine if sire differences can be measured through their daughter productivity; (2) To separate the direct effect of sires through genetic contribution to traits expressed in their daughters' progeny from the indirect effect as measured by their daughters' maternal performance; (3) To estimate the heritability of performance traits of calves from first calving heifers; and (4) To determine the phenotypic and genetic association between preweaning traits.

CHAPTER II

REVIEW OF LITERATURE

Rollins and Guilbert (1954) studied monthly weights to weaning of 159 purebred Hereford calves dropped during the years 1944 to 1951 at the University of California. They concluded that cows in the age range of seven to ten years produced calves that grew faster to four months of age and were heaviest at weaning (240 days). However, from four months of age to weaning, the calves from first-calf-heifers and to a lesser extent from second-calf cows grew faster than those from cows in the optimum age range. This is probably due to a greater persistency in lactation of young cows since several investigators have found this to be the case in dairy cattle.

These workers also reported the results of culling cows on the basis of their first calf's rate of growth to four months of age. It was indicated that this criterion could be used to predict the future production of a cow sufficiently well to warrant its use as a part of a system for selecting replacements. This agrees with the work of Botkin and Whatley (1953).

Koch and Clark (1955 a) used data from 5,952 Hereford calves raised at the U. S. Range Livestock Experiment Station, Miles City, Montana, during the period 1926 to 1951. Dams influenced the pre-weaning growth of their calves both by genes transmitted to the calf and by maternal environment provided the calf. The influence of

age-of-dam should be considered in a selection program because this measure of the maternal environment was shown to affect weaning weight, weaning score, and fall yearling weight. The production of the cow in relation to birth weight, weaning weight, and weaning score increases steadily from 3 to 6 years of age and then declined.

Koch and Clark (1955 b) analyzed the birth weights, weaning weights, weaning scores, and fall yearling scores of 4,553 registered and unregistered Hereford calves raised at the U. S. Range Livestock Experiment Station, Miles City, Montana, during the period 1926-1951. It was indicated that maternal environment had considerable influence on birth weight, gain from birth to weaning, and weaning score. Maternal environment appeared to be of little importance in yearling gain and score or was negatively associated with these traits. The heritability and repeatability (measured as a permanent characteristic of the cow) estimates were, giving heritability first and repeatability second: 0.35 and 0.26 for birth weight, 0.24 and 0.34 for weaning weight, 0.21 and 0.34 for gain from birth to weaning, and 0.18 and 0.22 for weaning score. They found a genetic correlation of 0.46 between birth weight and weaning weight which indicates that many of the same genes affected prenatal growth and postnatal growth to weaning.

These same workers (1955 c) found heritability estimates when maternal environment was taken into account to be as follows: birth weight, 0.42; weaning weight, 0.19; weaning gain, 0.12; weaning score, 0.16; yearling gain, 0.40 and yearling score, 0.27. Based upon these results they considered the consequences of selecting for traits shown

to be affected by maternal environment. Selecting for weaning gain increased genic value for growth response and slightly increased genic value for maternal environment. Part of the genetic gain made in growth response will be nullified by the fact that some of the genes which affect growth response favorably have an adverse effect on milking ability. Selection under a management system where differences in milking ability of the dam are masked, such as creep feeding the calves or placing the calves on nurse cows, favor the genic value for growth response at the expense of the genic value for milking ability. Greater emphasis will be placed on milking ability than on growth response when selecting dams which produce the heaviest calves. Similar results will also be true for weaning score.

The data in Marlowe and Gaines' study (1958) contained the records of 4,116 non-creep-fed and 2,007 creep-fed calves in the Virginia Performance Testing Program over a four-year period, 1953-56, inclusive. Sex-of-calf influenced growth rate significantly but had little effect on type score. Bull calves gained approximately 5 per cent faster than steer calves, and steer calves grew approximately 8 per cent faster than heifer calves. Season of birth had a significant influence on growth of non-creep-fed calves, but was of no significant importance on growth of creep-fed calves or type score in either group. The most important source of variation studied was age-of-dam with the largest differences occurring among the younger age groups. Maximum production was realized from cows in the six- to ten-year-old age groups.

Rollins and Wagnon (1956) estimated the heritability of weaning grade in two experimental range herds, A and B of similar breeding, that were managed alike except Herd A cows were supplemented during the fall and winter when the range was nutritively deficient while the cows in Herd B were not supplemented. The heritability estimates in Herd A was consistently higher than that of Herd B; however, the difference in the estimates was not statistically significant. The average heritability estimate of weaning grade for the two herds was 0.36. The heritability of weaning grade in Herd A was estimated to be 0.42 and 0.29 in Herd B on the basis of selection experiments extending over two generations.

Christian (1963) studied the weaning records of 253 Angus and 828 Hereford calves weighed and scored close to weaning time in 13 purebred Hereford and 5 purebred Angus herds in Wisconsin during the period from 1957 to 1961. The calves were sired by 54 Hereford and 18 Angus bulls. He estimated heritability, calculated by the paternal half-sib method, for weaning weight and score to be: 0.19 $\pm$ 0.15 and 0.79 $\pm$ 0.12, respectively, for the Herefords and 0.58 $\pm$ 0.30 and 0.34 $\pm$ 0.31 for the Angus. The genetic correlations between weaning weight and score were 0.16 $\pm$ 0.30 for the Herefords and -.42 $\pm$ 0.50 for the Angus.

Using a total of 1,987 calves, Lehmann *et al.* (1961) found that heritability estimates were: daily gain, 0.20 $\pm$ 0.03; weaning weight (203-day weight in this study), 0.21 $\pm$ 0.03; and type score at weaning, 0.33 $\pm$ 0.04. The estimates of genetic correlation between daily gain and type (.007) and between weaning weight and type (-.026), suggested

that growth and type are essentially genetically independent. On the other hand, the phenotypic correlations (0.42 and 0.39) led to the conclusion that weight (probably degree of finish) and type were positively correlated without cognizance by the graders.

Shelby et al. (1963) investigated the phenotypic and genetic relationships existing between and within various traits thought to be of economic importance in beef cattle in a 10-year block (1947-1956) of data collected at the U.S. Range Livestock Experiment Station at Miles City, Montana. Records of 616 Hereford steers from grade cows mated to 87 bulls representing 11 lines of breeding were used. The heritabilities and genetic, phenotypic, and environmental correlations were estimated for 18 traits. All weights and average daily gain (ADG) gave fairly high correlations. Thus, some evidence is provided that growth rate at different ages is controlled by many of the same genes. Weaning weight offered a better indication of the breeding value for ADG and final weight at slaughter than did birth weight. It was concluded that mass selection for ADG or final weight would be moderately effective. Scores and grades offered little promise of predicting future productivity of progeny but their relationship with contemporary criteria was large enough to be of some economic value. Heritability estimates given were: Birth weight = 0.54, 180-day weight = 0.24, weaning score = 0.23, and ADG = 0.48. Genetic correlations were found to be as follows: Birth weight with 180-day weight = 0.68; birth weight with weaning score = 0.99; birth weight with ADG = 0.29; 180-day weight with weaning score = 0.51; 180-day weight with ADG = 0.77, and weaning

score with ADG = -.02. Phenotypic correlations were: Birth weight with 180-day weight = 0.37; birth weight with weaning score = 0.29; birth weight with ADG = 0.30; 180-day weight with weaning score = 0.57; 180-day weight with ADG = 0.18; and weaning score with ADG = 0.03.

Carter and Kincaid (1959) estimated genetic and phenotypic correlations among various traits from data on 195 steers and 190 heifers. Positive genetic correlations were found between gains in a particular period and grade at the end of the period. These included weight at 6 months and feeder grade which were 0.49 and 0.31 for heifers and steers, respectively. Gains in a particular period and grade at the end of the period showed high positive correlations. Perhaps the most important genetic correlation found was that between preweaning growth rate and postweaning gains. This was estimated to be 0.51 for the heifers and 0.69 for the steers.

Gregory et al. (1950) used data collected at the North Platte and Valentine Substations of the Nebraska Agricultural Experiment Station to determine correlation coefficients. The simple correlation coefficients for birth weight with ADG from birth to weaning were 0.07 and 0.44 at North Platte and Valentine, respectively. The correlation coefficients for birth weight with weaning weight were 0.27 for North Platte and 0.60 for Valentine.

Lindholm and Stonaker (1957) applied price and cost data to 118 Hereford steer calves, bred and fed by the Colorado Agricultural Experiment Station, to obtain individual net income estimates. It was indicated by multiple correlation studies, using net income per hundred

weight as a dependent variable, that weaning weight was the most important trait affecting net income. They concluded that weaning weight alone was an accurate basis for selecting for increased net income in these Hereford calves. The heritability of weaning weight was estimated to be 0.81 and the heritability of daily gain was estimated to be 1.57. The large standard errors could not confine the parameter within the limits of zero to unity.

Pahnish et al. (1961) obtained weaning weights of 329 bull calves and 332 heifer calves over a period of 6 years (1949-1954) from 11 Hereford sires. Differences among sires were significant in the analysis involving male progeny and highly significant in the analysis involving female progeny. The heritability estimates for weaning weight were 0.28 $\pm$ 0.32 and 0.57 $\pm$ 0.41 for bulls and heifers, respectively. Although the difference was not significant the estimated heritability of weaning weight derived from the heifer data was higher than that derived from the bull data by the paternal half-sib method. If it were possible to establish that the heritability of weaning weight and/or other weaning traits is higher for heifers than for steers or bulls weaned at the same time, heifer progeny, rather than bull or steer progeny, might provide a better measure of the breeding merit of a sire. This could arise from heifers being influenced to a lesser extent than males by uncontrolled environment or be due to a sex-linked mechanism.

Additional heritability estimates for birth weight, weaning type, and ADG from birth to weaning are given in Table I.

Evidence for greater variability in steers than heifers was

TABLE I

SUMMARY OF HERITABILITY ESTIMATES OF WEANING AND PREWEANING TRAITS

Name of author and year	No. of animals*	Method of est.**	Birth weight	Wean. type	ADG, birth to weaning
Shelby (1957)	542 b.	P.H.S.	0.59	0.60	0.40
Brinks (1963)	3,548 h.	P.H.S.	0.38	0.28	0.40
Swiger (1961)	700+c.	P.H.S.	0.22±0.10		
Blackwell (1962)	499 s.	P.H.S.		0.38	
Blackwell (1962)	420 h.	P.H.S.		0.26	
Carter (1959)	190+s.	P.H.S.		0.41	
Carter (1959)	190+s.	S-O reg.		0.16	
Carter (1959)	190+s.	D-O reg.		0.07	
Carter (1959)	200+h.	P.H.S.		0.51	
Swiger (1962)	647 c.	P.H.S.	0.30±0.12		-.02±0.06[a]
Swiger (1962)	647 c.	P.H.S.			-.16±0.09[b]
Swiger (1962)	647 c.	P.H.S.			-.44±0.14[c]
Swiger (1962)	2,092 c.	P.H.S.	0.37±0.07		0.14±0.05[a]
Swiger (1962)	2,092 c.	P.H.S.			0.15±0.05[b]
Swiger (1962)	2,092 c.	P.H.S.			0.28±0.05[c]
Lasley (1961)	414 c.	P.H.S.	0.67±0.32		
Mahmud (1963)	1,306 c.	P.H.S.		0.36	0.26
M'hoeffer (1963)	908 h.	P.H.S.		0.11[d]	0.13[e]
M'hoeffer (1963)	908 h.	P.H.S.		0.20	0.39[f]
M'hoeffer (1963)	751 b.	P.H.S.		0.30[d]	0.28[e]
M'hoeffer (1963)	751 b.	P.H.S.		0.29	0.33[f]
Miquel (1963)	580 c.	P.H.S.	0.15		
Miquel (1963)	196 c.	P.H.S.	0.16		
Miquel (1963)	385 c.	P.H.S.	0.55		
Miquel (1963)	48 c.	P.H.S.	0.50		
Miquel (1963)	146 c.	P.H.S.	0.26		
Miquel (1963)	209 c.	P.H.S.	0.20		
Pahnish (1963)	b.	P.H.S.	0.32		0.32
Pahnish (1963)	h.	P.H.S.	0.14		0.16
M'hoeffer (1960)	1,682 c.	P.H.S.		0.27[d]	0.18[e]
M'hoeffer (1960)	1,682 c.	P.H.S.		0.21	0.25[f]
M'hoeffer (1960)	1,682 c.	P.H.S.			0.22
Thornton (1960)	c.	P.H.S.	0.13		

TABLE I (continued)

Name of author and year	No. of animals*	Method of est.**	Birth weight	Wean. type	ADG, birth to weaning
Thornton (1960)	c.	P.H.S.	0.13		
Thornton (1960)	c.	P.H.S.	0.21		

* b. = bulls
h. = heifers
s. = steers
c. = calves (both male and female)

** P.H.S. = paternal half sib.
S-O reg. = regression of offspring on sire.
D-O reg. = regression of offspring on dam.

[a] Gain from birth to weaning.

[b] ADG, birth to 130 days.

[c] Gain, 130 days to weaning.

[d] Midsummer type score.

[e] Daily gain from birth to midsummer.

[f] Daily gain from midsummer to weaning.

reported by Brinks et al. (1961). He analyzed the data from 2,151 heifers and 2,281 steer calves dropped from 1936 through 1958 at the United States Range Livestock Experiment Station, Miles City, Montana. The sex differences between bulls and heifers, and between steers and heifers were highly significant ($P<.01$) for birth weight, weaning weight, and preweaning gain. Heifer calves weighed 7 per cent less than bull calves at birth and 6 per cent less than bulls and 5 per cent less than steers at weaning. The variation among the steers and bulls were larger ($P<.05$) than the variation among heifers for birth weight, gain from birth to weaning, and weaning weight. The steers and bulls had slightly larger coefficients of variation than did the heifers for the three traits.

Neville (1962) analyzed data collected from 135 progeny of five Hereford sires born during the winters of 1957, 1958, and 1959. Sires effects were not significant when growth rate of the calves was considered. This lack of significance might have been due to the fact that the sires had been selected on the basis of their pre- and post-weaning performance.

Current dairy reports have indicated high genetic correlations between partial lactation records and complete records. Van Vleck (1962) found, in a study of the available 150-day records of all A I daughters which calved in New York between December, 1959 and August, 1960, that the otherwise high correlations indicate that selection on the basis of 150-day records does a satisfactory job of selecting for 305-day yield. He concluded that the chief advantages of sire

selection based on 150-day daughter records were:

1. Genetic progress is inversely proportional to the turnover rate in testing bulls.

2. Genetic progress is also related to the number of top bulls saved and the number of poor ones that are culled out of all those sampled. The more bulls tested with the same number saved for use, then the faster the progress which can be made. The shorter length of time which bulls have to be saved with 150-day record evaluation can allow up to 10 per cent more bulls to be tested with the same facilities.

3. Returning superior sires to service 5-6 months earlier will permit an increased service life of those sires.

CHAPTER III

MATERIALS AND METHODS

The data included the preweaning records of 223 Angus and 169 Hereford calves of first calf heifers from 1957 to 1962 at five of the Tennessee Agricultural Experiment Stations, Ames Plantation, and Alcoa farm. Fifty-seven sires were used in this study. The heifers calved at either two or three years of age. An adjustment for age of dam and for sex of calf was made when conducting the analysis.

The dependent variables considered in the analysis of these data were: birth weight, preweaning type score, preweaning condition score, adjusted average daily gain (AADG), and index. At approximately 110 days of age, the calves were weighed and scored for type and condition by a staff member of the University of Tennessee Animal Husbandry Department. Most all of the calves included in this study ranged between 65 and 155 days of age when preweaning information was obtained. The allowable range for type score was 3 to 17 with 17 corresponding to U. S. D. A. High Fancy, 14 to High Choice, 11 to High Good, 8 to High Medium, and 5 to High Common. A similar scale was used for condition score. The average daily gain (ADG) was calculated by subtracting the birth weight from the preweaning weight and dividing by the days of age at preweaning. The ADG from birth to preweaning was then multiplied by the appropriate correction factor to adjust all daily gains to a 6-10 year-old-dam and male calf equivalent. The

correction factors used were from an analysis of the preweaning weights of calves according to age of dam and sex of calf from the beef cattle records of the University of Tennessee Agricultural Experiment Stations and were:

Age of Dam	Correction Factor	
	Male	Female
2	1.15	1.22
3	1.10	1.17

The index of an individual calf was computed by multiplying AADG by 40, adding 5 times the type score, and subtracting 18. For example, the index of a calf with an AADG of 2.00 pounds per day and a type score of 10 would be computed in the following manner:
$40(2.00) + 5(10) - 18 = 112$.

The pastures consisted largely of orchardgrass-Ladino clover and fescue-Ladino clover mixtures. The winter ration for the heifers before calving consisted of silage, hay, and a small amount of concentrates. Corn silage made up the majority of the silage with some grass silage being used. The hay consisted predominantly of orchard grass, clover, and alfalfa. From 3 to 4 pounds of concentrates were fed once each day. Any variation among stations was removed because the analysis was conducted on a within station basis.

The calves were tattooed and weighed at birth. Only non-creep fed spring calves born from January to May were used in this study.

The I. B. M. 1620 Electronic Computer was used to conduct the analyses. Since the subclass numbers were not equal, nested

(hierarchal) analysis of variance according to Method 1 of Henderson (1953) was used with main classifications of stations and service sire, and sire of the dam nested within stations.

CHAPTER IV

RESULTS AND DISCUSSION

The results of this study show considerable differences in the preweaning performance of daughter progenies of different sires. A larger variation can be noted among the grand progeny (grandsons and granddaughters) of sires at some stations than among the grand progeny of sires at other stations. Part of this variability may be due to a greater variation within the cow herd at some stations than within the herd at other stations.

I. MEAN PRODUCTION OF DAUGHTERS BY SIRES

Angus

Only one Angus sire was included from Alcoa. As shown in Table II the average birth weight was 50.8 pounds, type score was 11.00, condition score was 6.84, and adjusted average daily gain (AADG) was 1.64 pounds.

Eleven Angus sires were included from Ames Plantation (Table III). The birth weight ranged from 56.3 pounds to 45.2 pounds, type score ranged from 14.50 to 9.82, condition score ranged from 11.50 to 8.28, and AADG ranged from 2.22 to 1.34 pounds. The sires that tended to appear in the top one-half in type score or in the lower one-half appeared in similar positions on AADG. The results from this station indicate that for the production traits studied sire 1011 was superior

TABLE II

SUMMARY OF DAUGHTER PERFORMANCE OF
ANGUS SIRES AT ALCOA

Sire No.	No. of calves			Birth weight (lb.)	Rank	Type score	Rank	Cond. score	Rank	AADG (lb.)	Rank
	Total	Male	Female								
1001	4	3	1	50.8	1	11.00	1	6.84	1	1.64	1

TABLE III

SUMMARY OF DAUGHTER PERFORMANCE OF ANGUS SIRES AT AMES PLANTATION

Sire No.	No. of calves			Birth weight (lb.)	Rank	Type score	Rank	Cond. score	Rank	AADG (lb.)	Rank
	Total	Male	Female								
1001	4	1	3	53.2	6T	9.88	10	8.28	9T	1.34	11
1002	20	10	10	54.3	4	12.12	4	9.65	4	1.94	4
1003	11	7	4	56.3	1	10.66	9	9.59	5	1.92	5
1004	6	3	3	51.2	8T	10.72	8	8.28	9T	1.52	9
1005	21	13	8	55.2	2	11.56	6	9.88	3	1.75	8
1006	6	2	4	45.2	11	9.82	11	-	-	1.35	10
1007	13	7	6	53.2	6T	10.92	7	9.26	7	1.76	7
1008	5	4	1	54.9	3	12.09	5	10.19	2	2.04	3
1009	14	8	6	54.0	5	12.46	2	8.94	8	2.07	2
1010	17	8	9	51.2	8T	12.20	3	9.55	6	1.78	6
1011	2	1	1	50.0	10	14.50	1	11.50	1	2.22	1

to the other sires and that sires 1001 and 1006 were inferior in these traits of production to the other sires.

Table IV is a summary of the thirteen Angus sires studied at the Plateau Experiment Station. The average birth weight was from 71.0 to 48.8 pounds, type score was from 11.92 to 10.80, condition score was from 8.88 to 7.29, and AADG was from 1.90 to 1.38 pounds. It should be noted that a high degree of variation for these traits does not exist among the grand progeny of sires used at this location. Sire 1016 was slightly superior to the other sires and sires 1013 and 1024 were consistently inferior for type score, condition score, and AADG.

Only two Angus sires were studied at the Main Experiment Station (Table V). Their respective averages were 58.4 and 51.4 pounds for birth weight, 11.79 and 11.62 for type score, 9.62 and 7.88 for condition score, and 2.09 and 1.78 for AADG.

Hereford

Fourteen Hereford sires were included from Alcoa (Table VI). The birth weight ranged from 78.2 to 58.2 pounds, type score ranged from 12.58 to 9.88, condition score ranged from 9.00 to 6.19, and AADG ranged from 2.18 to 1.26 pounds. These data show that sires were consistently either in the top one-half or the lower one-half of the group for type score, condition score, and AADG based on the offspring of the daughters. Sires 0005 and 0009 were superior to the other sires and 0016, 0018, and 0020 were consistently inferior to the other sires for these traits.

TABLE IV

SUMMARY OF DAUGHTER PERFORMANCE OF ANGUS SIRES
AT THE PLATEAU EXPERIMENT STATION

Sire No.	No. of calves			Birth weight (lb.)	Rank	Type score	Rank	Cond. score	Rank	AADG (lb.)	Rank
	Total	Male	Female								
1006	12	7	5	62.4	2T	11.57	5	8.17	10	1.90	1
1008	8	2	6	58.5	5	11.66	4	8.66	3T	1.82	4
1012	16	10	6	57.0	6	11.92	1T	8.88	1	1.78	7
1013	6	2	4	54.5	7	10.94	12	8.25	9	1.38	13
1014	7	5	2	61.0	4	11.05	11	7.29	13	1.80	5T
1015	6	3	3	62.4	2T	11.16	10	8.66	3T	1.56	11
1016	16	10	6	53.3	10	11.92	1T	8.82	2	1.84	3
1017	7	4	3	54.4	8	11.36	8	8.34	8	1.86	2
1019	4	2	2	53.5	9	11.75	3	8.62	5T	1.52	12
1021	6	2	4	50.2	12	11.56	6	8.00	11	1.60	9
1022	5	1	4	52.5	11	11.25	9	8.62	5T	1.80	5T
1023	8	6	2	48.8	13	11.54	7	8.58	7	1.66	8
1024	6	5	1	71.0	1	10.80	13	7.55	12	1.58	10

TABLE V

SUMMARY OF DAUGHTER PERFORMANCE OF ANGUS SIRES
AT THE MAIN EXPERIMENT STATION

Sire No.	No. of calves			Birth weight (lb.)	Rank	Type score	Rank	Cond. score	Rank	AADG (lb.)	Rank
	Total	Male	Female								
1000	8	3	5	58.4	1	11.62	2	7.88	2	2.09	1
1001	9	5	4	51.6	2	11.79	1	9.62	1	1.78	2

TABLE VI

SUMMARY OF DAUGHTER PERFORMANCE OF HEREFORD SIRES AT ALCOA

Sire No.	No. of calves			Birth weight (lb.)	Rank	Type score	Rank	Cond. score	Rank	AADG (lb.)	Rank
	Total	Male	Female								
0005	3	2	1	62.2	11	12.58	1	9.00	1	2.14	3
0007	5	2	3	72.0	3	10.80	8	7.71	5	2.00	5
0008	4	2	2	76.5	2	10.58	9T	8.00	3	2.16	2
0009	3	1	2	78.2	1	11.18	3	8.75	2	2.18	1
0010	4	2	2	69.8	5	10.58	9T	6.75	10	1.68	9
0011	4	1	3	71.2	4	10.42	11	6.66	11	1.64	10
0012	4	1	3	64.6	9	11.70	2	7.34	7	1.81	6
0013	10	3	7	67.3	6	11.02	4	7.16	8	1.75	8
0014	3	1	2	58.2	14	11.00	5T	7.38	6	1.78	7
0015	4	1	3	61.4	12	10.84	7	6.88	9	1.60	11
0016	3	2	1	66.0	7	9.88	14	6.25	13	1.50	12
0017	2	1	1	64.5	10	11.00	5T	7.75	4	2.04	4
0018	3	1	2	58.5	13	10.00	13	6.38	12	1.26	14
0020	6	4	2	65.0	8	10.32	12	6.19	14	1.48	13

Table VII is a summary of the five Hereford sires studied at the Tobacco Experiment Station. The average birth weight was from 66.6 to 58.3 pounds, type score was from 11.16 to 10.04, condition score was from 8.04 to 6.38, and AADG was from 1.82 to 1.64 pounds. Sires 0502 and 0503 were superior to the other sires for type score and AADG.

Five Hereford sires were included from the Middle Tennessee Experiment Station (Table VIII). The birth weight ranged from 71.5 to 57.3 pounds, type score ranged from 11.80 to 9.80, condition score ranged from 9.50 to 7.62, and AADG ranged from 1.91 to 1.44 pounds. When considering both type score and AADG, sire 0012 was superior to the other sires. It should be noted that sire 0017 had the lowest type score but the highest AADG and sire 0027 had the highest type score but the lowest AADG.

Table IX is a summary of the five Hereford sires at the Highland Rim Experiment Station. The average birth weight was from 68.5 to 59.8 pounds, type score was from 11.25 to 9.25, condition score was from 10.00 to 5.75, and AADG was from 2.47 to 1.38 pounds. Sire 0012 was superior to the other sires when both type score and AADG was considered. This sire was also superior in these traits at the Middle Tennessee Experiment Station. Sire 0017 was inferior to the other sires for type score, condition score, and AADG. It should be noted that the progeny of sire 0017 were the lowest in type score but were the highest in AADG at the Middle Tennessee Experiment Station. This difference in AADG may be due to a more superior maternal environment provided by the dams at the Middle Tennessee Experiment Station than

TABLE VII

SUMMARY OF DAUGHTER PERFORMANCE OF HEREFORD SIRES AT THE TOBACCO EXPERIMENT STATION

Sire No.	No. of calves			Birth weight (lb.)	Rank	Type score	Rank	Cond. score	Rank	AADG (lb.)	Rank
	Total	Male	Female								
0501	5	4	1	66.2	2	10.19	4	7.12	4	1.67	4
0502	8	4	4	66.6	1	10.88	2	7.44	3	1.70	2T
0503	6	3	3	58.3	5	11.16	1	6.38	5	1.70	2T
0504	8	1	7	63.2	3	10.04	5	8.04	1	1.82	1
0505	9	4	5	60.4	4	10.49	3	7.56	2	1.64	5

TABLE VIII

SUMMARY OF DAUGHTER PERFORMANCE OF HEREFORD SIRES
AT THE MIDDLE TENNESSEE EXPERIMENT STATION

Sire No.	No. of calves			Birth weight (lb.)	Rank	Type score	Rank	Cond. score	Rank	AADG (lb.)	Rank
	Total	Male	Female								
0012	7	4	3	58.4	3	11.19	2	8.25	4	1.86	2
0016	9	5	4	57.6	4	10.55	3	9.50	1	1.62	4
0017	6	1	5	57.3	5	9.80	5	9.00	2T	1.91	1
0027	3	1	2	71.5	1	11.80	1	7.62	5	1.44	5
0028	3	2	1	69.8	2	10.00	4	9.00	2T	1.76	3

TABLE IX

SUMMARY OF DAUGHTER PERFORMANCE OF HEREFORD SIRES
AT THE HIGHLAND RIM EXPERIMENT STATION

Sire No.	No. of calves			Birth weight (lb.)	Rank	Type score	Rank	Cond. score	Rank	AADG (lb.)	Rank
	Total	Male	Female								
0012	4	2	2	64.2	2	11.25	1T	8.92	2	2.47	1
0017	4	2	2	60.5	4	9.25	5	5.75	5	1.38	5
0022	3	2	1	64.0	3	10.00	4	7.00	3T	1.58	4
0024	3	2	1	59.8	5	11.25	1T	10.00	1	1.91	2
0026	2	1	1	68.5	1	10.75	3	7.00	3T	1.70	3

at the Highland Rim Experiment Station.

II. GENETIC AND MATERNAL EFFECTS

Theoretical Components of Variance

The analysis of variance with the expectation of the mean squares with their theoretical genetic and environmental components are shown in Table X. Since the subclass numbers were not equal, nested (hierarchal) analysis of variance was used with the main classification of stations, and service sire, and sire of the dam nested within stations.

Based upon these expectations, it is possible to separate estimates of $\frac{1}{4}$ of the genetic variance (V_g) and $\frac{1}{4}$ of the maternal genetic variance (V_{mg}) and express these variances as portions of the total intra-station variance.

Portions of the Total Variance Due to Genetic and Maternal Effects

The results are shown in Table XI. Due to large sampling error these estimates give only an idea of the relative importance of each influence.

Birth weight. These results show that the maternal genetic factors have little influence on this trait. This may be due to the variation in age and weight of the heifers at calving. Also, first calf heifers may have a lower value than would be expected for more mature cows.

The heritability of birth weight was found to be 0.66. This

TABLE X

ANALYSIS OF VARIANCE

Source	d.f. (a-1)	Expectation of M.S.	Theoretical Components of Variance
B/A	$\sum_i (b_i-1)$	$V_{D/ABC} + k_2 V_{C/AB} + k_3 V_{B/A}$	$V_{D/ABC} = V_e + 5/8\ V_g + V_{me} + 3/4\ V_{mg}$
C/AB	$\sum_i \sum_j (c_{ij}-1)$	$V_{D/ABC} + k_1 V_{C/AB}$	$V_{C/AB} = 1/8\ V_g + 1/4\ V_{mg}$
D/ABC	$\sum_i \sum_j \sum_k (d_{ijk}-1)$	$V_{D/ABC}$	$V_{B/A} = 1/4\ V_g$

Definition of Symbols:

V_e = Uncontrolled environmental variance

V_g = Genetic variance

V_{me} = Variance due to differences in maternal environment which is environmental

V_{mg} = Variance due to differences in maternal environment which is genetic

A = Stations

B = Sire of calves

C = Maternal grand sires

D = Calves

a = Number of stations

b_i = Number of sires within i^{th} station

c_{ij} = Number of maternal grand sires within the i^{th} station and the j^{th} sire

d_{ijk} = Number of calves within the i^{th} station, j^{th} sire and k^{th} maternal grand sire

TABLE XI

PERCENTAGE OF TOTAL VARIANCE IN PRODUCTION TRAITS DUE TO GENETIC VARIANCE (h^2) AND DUE TO MATERNAL GENETIC VARIANCE (mg^2)

	Trait				
	Birth weight	Type score	Condition score	Adjusted ADG	Index
h^2	0.66	0.24	0.74	0.93	0.77
mg^2	0.00	1.00+	0.21	0.61	0.94

was approximately 25 per cent higher than the estimates reported by Koch and Clark (1955 b and 1955 c) but was not significantly different from the 0.54 estimate obtained by Shelby (1963).

Type score. In these data maternal genetic factors were a very important source of variation in type score. Perhaps this is due to the fact that only preweaning data was included in this study. This may have arisen from some sires' daughters being more outstanding in their milk production.

The heritability (0.24) of type score obtained in this analysis follows very closely with that obtained by Koch and Clark (1955 b and 1955 c), Rollins and Wagnon (1956), Lehmann et al. (1961), and Shelby et al. (1963).

Condition score. The maternal genetic factors accounted for only 21 per cent of the total variation for condition score. This is lower than might be expected and may be due to the fact that only first calf heifers were used. Under the stress of initial production, environmental factors may mask genetic differences in this trait.

Condition score appeared to be quite heritable (0.74). This may be due to the existence of a large sampling error or be indirect as a result of the high genetic correlation between AADG and this trait.

Adjusted average daily gain. These preweaning data suggest that AADG is largely dependent upon the maternal genetic effects. This is in agreement with Gifford (1953) who concluded that the dam's milk

production was more important up to preweaning than from preweaning to weaning. It appears that maternal factors of genetic origin are almost as important as direct genetic factors in the variability of this trait.

The heritability (0.93) of AADG was found to be higher in this analysis than was reported by the majority of other workers. This may be due to the fact that only preweaning data was included in this study while other workers analyzed weaning records. The bulk of the heritability estimates for AADG in the literature fall between 0.12 and 0.50. Perhaps conditions associated with the first production are more conducive to the expression of genetic difference between animals for AADG. Hence, these results might indicate that more effective improvement in this trait could be realized when first calf heifers are used.

Index. The maternal portion of genetic variation was found to be rather high for index. This was expected since index was a combination of type score and AADG and each of these components was influenced by maternal factors.

The heritability for index was 0.77 in this study. Factors which have a direct effect upon type score and AADG would have an indirect effect upon index.

Correlations

The genetic and phenotypic correlation coefficients determined from this study are given in Table XII.

TABLE XII

ESTIMATES OF GENETIC AND PHENOTYPIC CORRELATIONS[1]

	Birth weight	Type score	Condition score	Adj. ave. daily gain	Index
Birth wt.		0.03	0.10	0.07	0.19**
Type score	0.01		0.58**	0.41**	0.69**
Cond. score	-.19	0.49		0.53**	0.64**
AADG	0.27	0.28	0.53		0.95**
Index	0.24	0.53	0.62	0.95	

[1]Genetic correlations appear to the left of the diagonal and phenotypic correlations appear to the right of the diagonal.

**Significant at the 1 per cent level.

r = 0.11; P = 0.05
r = 0.15; P = 0.01

Genetic correlations. The genetic correlations were calculated by the method of Hazel (1943) where the genetic covariance component is isolated in the same manner as the genetic variance and expressed as a portion of the geometric mean of the two corresponding variances. The estimates of genetic correlations are considered to have larger sampling errors than the heritability estimates.

The genetic correlation coefficient of birth weight with AADG would indicate that selection for birth weight should give desirable improvement in this trait. This is in agreement with Shelby et al. (1963). There were no apparent correlation between birth weight and type score but birth weight and condition score were negatively correlated.

Type score was highly correlated with condition score and index and was correlated with AADG to a lesser extent. This was probably due in part to the fact that bulls which sired calves which gained faster and were fatter also sired calves which graded higher. Lehmann et al. (1961) and Shelby et al. (1963) obtained a lower correlation between type score and AADG than was found in this study.

Condition score was highly correlated genetically with AADG and index. Again, this is probably due to the fact that sire groups which gained faster were also in higher condition.

Adjusted average daily gain was very highly correlated with index. This is because the index value is derived from AADG and type score.

Phenotypic correlations. There was general agreement between the genetic and phenotypic correlations derived from this study.

Birth weight was significantly associated with index but was not significantly associated with type score, AADG, and condition score. Shelby et al. (1963) obtained greater estimates when correlating birth weight with type score and with average daily gain than was shown in this analysis.

Type score was significantly correlated with condition score, AADG, and index. This was probably due in part to the fact that calves which gained faster, were fatter and thus tended to grade higher. The estimate given for the correlation of type score with AADG was in agreement with Lehmann et al. (1961) but was greater than the estimate reported by Shelby et al. (1963).

Condition score was highly correlated with AADG and index. The high correlations of index with AADG and type score was an indirect result of index being a linear combination of these traits.

CHAPTER V

CONCLUSIONS

These results indicate that differences exist between sires as measured by the preweaning performance of the first calves of their daughters. The differences were more marked for type score and adjusted average daily gain (AADG), than for birth weight and condition score. Maternal genetic factors were also an important source of variation in the preweaning index.

The heritability estimates calculated for preweaning traits of birth weight, (0.66), type score (0.24), condition score (0.74), AADG (0.93), and index (0.77) were similar in most cases to those presented in the literature for similar traits measured at weaning time from records of dams of all ages adjusted to a mature equivalent. However, the estimate of 0.93 for the heritability of AADG is larger than many estimates of the genetic influence on this trait at weaning time as reported by most other workers and suggests that this trait is more heritable at preweaning age. One other explanation is that the environment provided by younger dams may allow for more complete expression of genetic differences between calves. However, the converse may be true for type score.

The genetic and phenotypic correlations were similar in magnitude. No serious genetic antagonisms were noted between preweaning traits although the association between birth weight and condition score was

in the negative direction. Favorable improvement in type score, birth weight, and condition score should result from selection for increased AADG.

LITERATURE CITED

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Blackwell, R. L., J. H. Knox, C. R. Shelby, and R. T. Clark. 1962. Genetic Analysis of Economic Characteristics of Young Hereford Cattle. J. Animal Sci. 21:101.

Botkin, M. P. and J. A. Whatley, Jr. 1953. Repeatability of Production in Range Beef Cows. J. Animal Sci. 12:552.

Brinks, J. S., R. T. Clark, N. M. Kieffer, and J. C. Urich. 1963. Estimates of Genetic, Environmental, and Phenotypic Parameters in Range Hereford Females. J. Animal Sci. (in press).

Brinks, J. S., R. T. Clark, F. J. Rice, and N. M. Kieffer. 1961. Adjusting Birth Weight, Weaning Weight, and Preweaning Gain for Sex of Calf in Range Hereford Cattle. J. Animal Sci. 20:363.

Carter, R. C. and C. M. Kincaid. 1959. 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. 1959. Estimates of Genetic and Phenotypic Parameters in Beef Cattle. III. Genetic and Phenotypic Correlations Among Economic Characters. J. Animal Sci. 18:331.

Christian, Lauren L. 1963. Analysis of Growth and Production Traits in Twin and Non-Twin Beef Cattle Data. PhD Thesis, University of Wisconsin.

Gifford, W. 1953. Record of Performance for Beef Cattle in Breeding Herds, Milk Production: Milk Production of Dams and Growth of Calves. Ark. Agr. Exp. Sta. Bul. 531.

Gregory, Keith E., Cecil T. Blunn, and Marvel L. Baker. 1950. A Study of Some of the Factors Influencing the Birth and Weaning Weights of Beef Calves. J. Animal Sci. 9:338.

Hazel, L. N. 1943. Genetic Basis for Selection Indexes. Genetics 28:476.

Henderson, C. R. 1953. Estimation of Variance and Covariance Components. Biometrics 9:226.

Koch, Robert M. and R. T. Clark. 1955. Influence of Sex, Season of Birth, and Age of Dam on Economic Traits in Range Beef Cattle. J. Animal Sci. 14:386.

Koch, Robert M. and R. T. Clark. 1955. Genetic and Environmental Relationships Among Economic Characters in Beef Cattle. I. Correlation Among Paternal and Maternal Half-Sibs. J. Animal Sci. 14:775.

Koch, Robert M. and R. T. Clark. 1955. Genetic and Environmental Relationships Among Economic Characters in Beef Cattle. III. Evaluating Maternal Environment. J. Animal Sci. 14:979.

Lasley, J. F., B. N. Day, and J. E. Comfort. 1961. Some Genetic Aspects of Gestation Length, and Birth and Weaning Weights in Hereford Cattle. J. Animal Sci. 20:737.

Lehmann, R. P., J. A. Gaines, R. C. Carter, K. P. Bovard, and C. M. Kincaid. 1961. Selection Indexes for Weaning Traits in Beef Calves. J. Animal Sci. 20:53.

Lindholm, Howard B. and H. H. Stonaker. 1957. Economic Importance of Traits and Selection Indexes for Beef Cattle. J. Animal Sci. 16:998.

Mahmud, Anuwar and E. H. Cobb. 1963. Factors Affecting Weaning Weights, Preweaning Gains, and Conformation Scores of Beef Calves in Hawaii. J. Animal Sci. 22:820 (abstr.).

Marlowe, Thomas J. and James A. Gaines. 1958. The Influence of Age, Sex, and Season of Birth of Calf, and Age of Dam on Preweaning Growth Rate and Type Score of Beef Calves. J. Animal Sci. 17:706.

Meyerhoeffer, D. C., R. C. Carter, and B. M. Priode. 1960. Early Selection of Beef Calves. J. Animal Sci. 19:1222 (abstr.).

Meyerhoeffer, D. C., R. C. Carter, and B. M. Priode. 1963. Sex Differences in Heritability of Traits in Beef Calves. J. Animal Sci. 22:240 (abstr.).

Miquel, Cesar and T. C. Cartwright. 1963. Comparison of Heritabilities in Crossbred and Purebred Cattle. J. Animal Sci. 22:821 (abstr.).

Neville, N. E., Jr. 1962. Influence of Dam's Milk Production and Other Factors on 120-and 240-Day Weight of Hereford Calves. J. Animal Sci. 21:315.

Pahnish, O. F., R. L. Roberson, R. L. Taylor, J. S. Brinks, R. T. Clark, and C. B. Roubicek. 1963. Genetics of Growth Traits in Range Cattle. J. Animal Sci. 22:821 (abstr.).

Pahnish, O. F., E. B. Stanley, Ralph Bogart, and C. B. Roubicek. 1961. Influence of Sex and Sire on Weaning Weights of Southwestern Range Calves. J. Animal Sci. 20:454.

Parker, J. B., N. D. Bayley, M. H. Fohrman, and R. D. Plowman. 1960. Factors Influencing Dairy Cattle Longevity. J. Dairy Sci. 43:401.

Rollins, W. C. and H. R. Guilbert. 1954. Factors Affecting the Growth of Beef Calves During the Suckling Period. J. Animal Sci. 13:517.

Rollins, W. C. and K. A. Wagnon. 1956. 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 (abstr.).

Shelby, C. E., W. R. Harvey, R. T. Clark, J. R. Quesenberry, and R. R. Woodward. 1963. Estimates of Phenotypic and Genetic Parameters in Ten Years of Miles City R. O. P. Steer Data. J. Animal Sci. 22:346.

Swiger, L. A. 1961. Genetic and Environmental Influences on Gain of Beef Cattle During Various Periods of Life. J. Animal Sci. 20:183.

Swiger, L. A., R. M. Koch, K. E. Gregory, V. H. Arthaud, W. W. Rowden, and J. E. Ingalls. 1962. Evaluating Pre-weaning Growth of Beef Calves. J. Animal Sci. 21:781.

Thornton, J. W., J. A. Gaines, and C. M. Kincaid. 1960. Estimates of Parameters of Growth in Beef Heifers. J. Animal Sci. 19:1228 (abstr.).

Van Vleck, L. D. 1962. Sire Evaluation From Five-Month Daughter Records. J. Animal Sci. 21:633.