ESTIMATED GENETIC TRENDS FOR WEIGHTS, GAINS AND TYPE SCORES IN LINES OF ANGUS, HEREFORD AND SHORTHORN FEMALES SELECTED FOR EARLY GROWTH OR TYPE

by

Larry Lee Benyshek

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APPROVED:

T. J. Marlowe, Chairman

K. P. Bovard	K. Hinkelmann
R. C. Carter	T. N. Meacham
J. A. Gaines	J. M. White

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INTRODUCTION

Selection is the basic method for changing the gene composition of a population. Natural selection, for example, is always present in a given population and it is the force, along with mutation, that allows populations to adapt to various environmental situations. Man has used selection, that is artificial selection, since before recorded history to adapt plants and animals to his needs. Selection most certainly is responsible for some of the characteristics present in today's modern breeds of livestock.

Selection is not the only method available for the genetic improvement of plants and animals. The success of hybrid corn, developed through the crossing of inbred lines, is proof of this statement. It can not be denied that heterosis exists for certain livestock traits, and it is being utilized by today's livestock industry. It can also be said that selection is basic to these systems if maximum genetic improvement is to be obtained.

Selection in the livestock industry today involves a number of traits; of which, weights and gains are probably two of the more important traits. Weights and gains are the result of a large number of physiological processes involving many genes with differing magnitudes of effect. Since at least some genes have pleiotropic effects, changes in traits, other than those under direct selection, can be expected. Some of these indirect changes are beneficial but others may be serious determents to the ultimate goals of the livestock breeder.

Thus, for selection to be most effective in livestock improvement, knowledge of such attributes as genetic variability, heritability and response to selection for criteria used in selection is essential. For maximum improvement knowledge of relationships between the selection criteria and other traits is also necessary. It is hoped that this study will add to or lend support to already existing explanations of genetic phenomena observed in beef cattle with respect to weights and gains.

REVIEW OF LITERATURE

Quantitation of genetic progress in large animal genetics experiments and in production operations has been and is now one of the most important endeavors confronting animal scientists. If it is not possible to separate genetic and environmental effects, proper evaluation of animal breeding systems is impossible. This is a particular problem in large animal selection experiments or in field situations since costs generally prohibit the maintenance of a proper genetic control. Without proper genetic controls it becomes necessary to rely more heavily on various mathematical and statistical techniques to explain phenotypic time trends in terms of genetics and environment.

Bias In Routine Least-Squares Estimation

Henderson (1949a) pointed out that least-squares methods for obtaining annual correction factors for New York dairy herds were biased due to the lack of perfect repeatability of records. It was recommended that the method of maximum likelihood, which automatically takes into account incomplete repeatability and annual culling levels, be used to obtain more precise estimates of yearly environmental effects.

Lush and Shrode (1950) gave an explanation of the biases arising in the estimation of age correction factors, which may be considered in estimation of year effects. Henderson *et al*. (1959) expanded the explanations of Lush and Shrode (1950), somewhat. If, for example, a cow's first-year record x_{i1} and her second year record y_{i2} conform to a bivariate normal distribution with an additive difference γ between the first and second year records, the following model would apply:

$$x_{i1} = \mu + c_i + e_{i1},$$

$$y_{i2} = \mu + \gamma + c_i + e_{i2}.$$

The e's are errors from differing environments among the same animal's records from year to year and from inaccuracies of measurement. C_i is common to all records of cow i. The c's and e's are random variables with variances σ_c^2 and σ_e^2, respectively and all covariances are zero. With this model the herd average for the first year (mean value of x) is μ and for the second year the average (mean value of y) is $\mu + \gamma$. X and y both have variances $\sigma_c^2 + \sigma_e^2$ with covariance σ_c^2 between them. Thus the mean value of y given x is obtained by the regression equation

$$\mu + \gamma + r\ (x - \mu)$$

where $r = \dfrac{\sigma_c^2}{\sigma_c^2 + \sigma_e^2}$, the repeatability of the trait. Culling has the effect of changing the expectation of x for cows retained in the herd, from $\mu + \gamma$ (expectation of all cows with one record) to μ^1. μ and μ^1 would not be equal unless the selection criteria was statistically independent of x. It follows that the mean of the second-year records of the cows retained would be

$$\mu + \gamma + r(\mu^1 - \mu).$$

By the method of least-squares, γ is given as the difference of the mean of the second-year records and the mean of cows with first-year records. This estimate has the expected value

$$\mu + \gamma + r(\mu^1 - \mu) - \mu^1 = \mu - (1 - r)\ (\mu^1 - \mu).$$

Under the usual type of selection μ^1 will be greater than μ thus the estimate of year difference is biased downward by the quantity

$$(1 - r)\ (\mu^1 - \mu).$$

The expectation of the comparison of the mean of all cows with first-year records and all cows with second-year records would be

$$\mu + \gamma + r(\mu^1 - \mu) - \mu.$$

In this situation, the estimate would be biased upward by the amount $r(\mu^1 - \mu)$. Both of these methods of comparison were described by Lush and Shrode (1950).

Miller *et al*. (1966) described the bias involved in routine least-squares estimation in another way with respect to estimation of age effects in dairy records. Cow effects are assumed to be completely repeatable from one observation to another; whereas in reality animals selected on early records are usually observed to show less superiority to the herd average in their later lactations. This occurs when an unusually favorable temporary environment is experienced during the first record. Later lactations, for example, would be expected to take place under less favorable conditions, since environmental influences act in a random fashion. The net result is that least-squares or paired comparison estimates of year or age group effects are biased downward, as described by Henderson *et al*. (1959).

Thus, in general, the best unbiased estimates for effects such as described above would come from maximum likelihood analyses. Harvey (1960), on the basis of work by Henderson (1949b) gives a method of obtaining maximum likelihood estimates by regressing the means from a least-squares analysis. The amount by which the least-squares mean must be regressed is a function of the corresponding diagonal inverse element,

$$\hat{\mu} + \hat{\hat{a}}_i \doteq \hat{\mu} + \frac{\hat{\sigma}_a^2}{\sigma_a^2 + A^{ii}\sigma_e^2} (\hat{a}_i).$$

where

$\mu + \hat{\hat{a}}_i$ = regressed least-squares mean, i.e., the maximum likelihood estimate

σ_a^2 = variance of random effects a_i

A^{ii} = diagonal inverse elements

σ_e^2 = error variance

$\hat{a}_i$ = least-squares estimate of random effect a_i.

It is also shown that the above reduces to

$$\hat{\mu} + \hat{\hat{a}}_i \doteq \hat{\mu} + \frac{nr}{1 + (n - 1)\ r} (\hat{a}_i)$$

where

n = number of observations in the i^{th} A class

r = repeatability.

Thus, if repeatability is known, the above equation provides a method of obtaining approximate maximum likelihood estimates by weighted least-squares.

Selection Response in Beef Cattle

One of the earliest reports with respect to selection response in beef cattle was by Alexander and Bogart (1961). The experiment included three closed lines of Hereford and one closed line of Aberdeen Angus cattle. Selection was based on an index composed of preweaning gains, postweaning gains on test, feed consumption per unit gain and score for type and conformation. These authors concluded that response to selection had offset depression of feed test criteria due to inbreeding. The depressing effect of inbreeding on suckling gains of calves indicated that selection had not been effective in increasing the frequency of genes for preweaning growth during the experimental period. The findings were somewhat different in a later report of results from the same experiment by Hoornbeck and Bogart (1966). The Hereford lines showed initial improvement after which there was a plateau followed by a decline in performance. This caused response to selection to be generally negative for growth traits, although type score responded positively. In their opinion, the Angus line responded positively to selection primarily because of a broader genetic base and more animals from which to select.

Flower et al. (1964) reported the results of selection in closed and cross lines of Hereford cattle at the Havre, Montana station. The selection procedure used was a system of sequential culling practiced on the male side with some within-line culling at the weaning period and also at the end of a 168-day feed test in the three closed lines. Each year, two high gaining yearling bulls from each of the three closed lines were progeny tested using cows from a tester herd maintained at the station. At the conclusion of the progeny tests, line bulls were selected on the basis of crossline progeny performance for weaning weight and postweaning daily gain in all progeny and carcass merit in the steers. These line bulls were used as closed line sires unless current sires were considered better. Environmental changes were estimated by using the repeat mating method, i.e., full-sibs were used to determine year effects. The environmental trends for birth and weaning weights were negative. Estimates of genetic change for the three closed lines ranged from -0.04 to 1.71 pounds per year for birthweight and 2.16 to 6.51 pounds per year for weaning weight.

Brinks, Clark and Kieffer (1965) reported the results of selection and mild inbreeding in a line of Hereford cattle that had been closed since 1934. Selection was practiced within the line on the basis of performance (weights and gains). Environmental trends were calculated from repeat mating data. Estimated genetic progress for birth weight, 180-day gain and weaning weight was 0.41, 0.87 and 1.23 pounds per year, respectively. Weaning type score increased at the rate of 0.31 percent per year. Environmental change was negative for birth weight but positive for birth to weaning gain and weaning weight.

Nelms and Stratton (1967) studied the traits birth weight, weaning weight, gain per day on feed test and final weight with respect to response to selection in a closed line of Hereford cattle. The study did not lend itself to exact computation of genetic trends but the phenotypic time trends were all positive. The magnitude of change per year for such traits as final weight, test average daily gain, 180-day weight and birth weight were 5.59, 0.03, 1.54, 0.64 pounds respectively.

The objectives of a study conducted by Chapman, Clyburn and McCormick (1969) were to determine the relative efficacy of sire selection to produce (1) differences between herds in levels of performance in traits selected for, and (2) to observe concomitant changes in traits not considered in sire selection. Sires were selected from a purebred herd of Polled Hereford cattle on a single trait basis for one of the following: weaning weight, test rate of gain or type score (selection sires). Other sires were selected on the basis of being closest to the herd average for each of the above traits (average sires). A test herd made up of randomly allotted cows was available for each of the four types of sires. Replacements for the test herds were assigned at random with reference to performance from an "extra" herd. The progenies from the test herds using selection sires were then compared with the test herd progenies in which the average sires were used. The average sire test herd represented a control herd. On the basis of these comparisons there was an indication of positive genetic trend in the traits under selection. Progeny sired by bulls selected for high rate of gain on test, weaning weight and yearling type score increased 1.23 pounds per year in birth weight ($P < .05$) over progeny from the herd in which sires were selected on an average of the traits. The rate of improvement in weaning weight was greatest by calves in the type herd. Although this rate was greater than zero ($P < .05$), it was not significantly different from increases in weaning weights of calves in the herds selected for rate of gain and weaning weight. In the case of weaning score, the differences between the weaning weight and trait average herds decreased ($P < .05$) with time, but again this change was not significantly different from the linear changes in deviations in the rate of gain and type herds.

In a more recent study Bailey et al. (1971) used a model and procedures basically the same as those used in the current study to estimate genetic and environmental trends in five closed lines of Hereford cattle. Single trait selection in their experiment was based on postweaning gain, feed efficiency or yearling conformation score. Responses to selection for gain on test in the two lines under selection for that trait were of the magnitude of 3.64 ± 2.09 and 4.77 ± 1.70 pounds per year. Genetic change per year in feed efficiency was 0.09 ± 0.07 and 0.08 ± 0.08 pounds gain per 100 pounds TDN. Type score decreased at the rate of -0.094 ± 0.110 per year. Type score was on a scale of 67 (cull) to 100 (outstanding). Traits not under direct selection in a particular line showed a positive trend except type score in line one, which was under selection for total gain on test. Inbreeding seemed to cause some reduction in performance also.

Scarsi (1971) evaluated the weaning performance of the various lines of cattle at the Front Royal, Virginia station. Repeat mating data were used to determine environmental trends. The data included both males and females. After adjusting for age of dam and sex he found positive genetic trends for weaning weight in the selection lines which ranged in magnitude from 2.9 to 4.9 pounds per year. The Hereford type selection line indicated a negative trend for weaning weight. Type score trends ranged from -0.430 to 0.073 units per year with the type lines in the Angus and Shorthorn breeds showing the most progress (scale = 3-17).

Newman, Rahnefeld and Fredeen (1973) reported the results of selection experiments utilizing Shorthorn cattle at two Canadian stations. Their experiment maintained a genetic control herd and response to selection was determined by deviations from this control herd. The herds were closed after sufficient outcrossing to broaden the genetic base for the selection program. Males in the two selection herds exhibited genetic increases of 10.6 ± 6.8 and 9.0 ± 6.6 pounds per year. The females responded to selection with positive trends of 7.3 ± 5.9 and 5.1 ± 3.3 pounds per year.

Brown et al. (1960) reported the results of selection for type in a small herd of Aberdeen Angus cattle. Type was scored on a scale of: Excellent (90-100), Very Good (80-90), Good Plus (70-80), Good (60-70), Good Minus (50-60), Fair (40-50) and Poor (30-40). Data were examined using four methods of expressing classification scores: first score, current score, average lifetime score and most probable score. All four methods of expressing score recorded an improvement in type and a decrease in the variability of the scores over the years of the experiment.

Weights, Gains and Maturity in Beef Cattle

In a recent series of papers Fitzhugh and Taylor (1971), Taylor and Fitzhugh (1971) and Brown, Brown and Butts (1972a, b, c) have discussed in some detail the relationships among weights, gains and maturity in domestic beef cattle.

Brown, Brown and Butts (1972a, b, c) used Brody's (1945) algebraic model for growth to study the weight-age curves in Hereford and Angus beef cattle. It was concluded from this study that large gains at younger ages were associated with earlier maturing females while genotypes required for continued growth at later ages were associated with late maturing females. It was also concluded that gains and weights were not regulated by identical groups of genes nor did mutual genes have an isodirectional effect on the two characters. It is apparent from their study, as is the usual case, that selection for a particular trait will result in correlated responses which may be negative or positive.

In the study by Brown, Brown and Butts (1972a, b) four growth patterns were observed in Hereford and Angus females. These growth curves are shown in figure 1, which was taken from their report. Type I indicates slow early growth without sustained later growth. Type II shows rapid early growth without sustained later growth. Type III indicates slow early growth with sustained growth. The type IV curve indicates rapid early growth with sustained later growth.

In general, a major conclusion from the studies of Fitzhugh and Taylor (1971), Taylor and Fitzhugh (1971) and Brown, Brown and Butts (1972a, b, c) was that there is sufficient genetic variation in rate of maturing and growth patterns in beef cattle to allow effective selection for desired or optimum growth patterns.

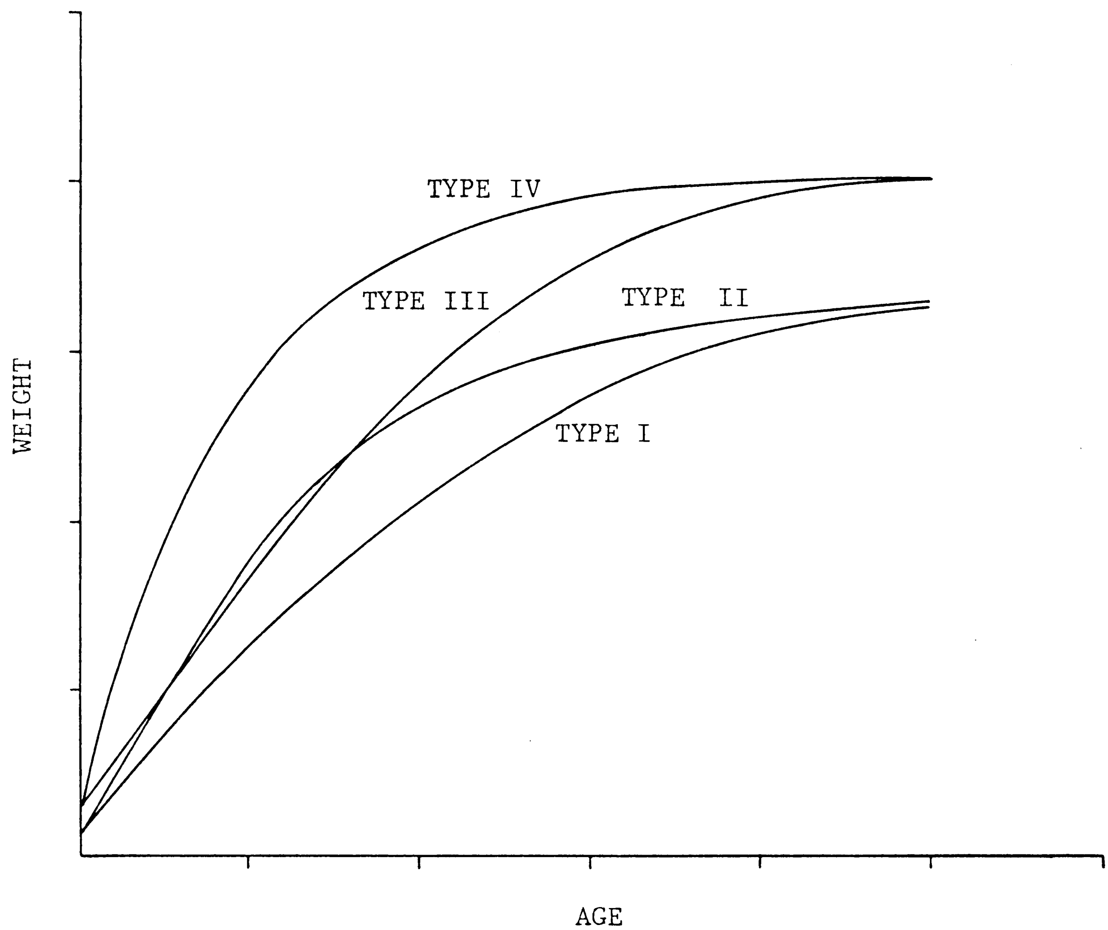

FIGURE 1. STYLIZED GROWTH CURVES

OBJECTIVES

The objectives of this study were:

(1) to determine the genetic trends for weights, gains and type scores in lines of beef cattle under selection for early growth or type;

(2) to evaluate possible growth curve changes as the result of selection for early growth or type in beef cattle; and

(3) to estimate heritabilities for and genetic correlations between the selection criteria and other measured or calculated traits.

THE DATA

The Front Royal Project

The data used in this study were collected as a part of the research effort at the Beef Cattle Research Station, Front Royal, Virginia. The Front Royal Research Station has been maintained as a cooperative project between the U.S. Department of Agriculture and the Virginia Agriculture Experiment Station since 1949.

A description of the Front Royal Project was given by Bovard and Priode (1963). The experimental herds were built from various sources since funds were not available to purchase all the cattle needed when the station was acquired from the Department of the Army in 1948. Approximately 125 head of Shorthorn cattle were transferred from Beltsville, Maryland to Front Royal by USDA in 1949. Cattle numbers, in the three breeds (Angus, Hereford and Shorthorn), were increased by transferring purebred cattle from the Blacksburg, Virginia station and also by utilizing herds owned by cooperating breeders.

The major objective of the project, as stated by Bovard and Priode (1963), was to find methods of producing genetic improvement in traits of economic importance under two different breeding systems. The traits considered most important were growth rate and conformation.

One system of breeding was concerned with inbreeding and the crossing of inbred lines. The second system, which is considered in the present study, was concerned with selection. The objectives of the selection experiment were (1) to determine direct response to selection for a trait and (2) to observe and monitor any correlated responses to selection for a particular trait.

The Shorthorn experimental herd was developed first because of a larger number of Shorthorn cows available in the early years. Angus foundation herds were completed a short time later. Development of the Hereford herds was not completed until about 1963. There were two types of selection herds (growth and type) maintained in all three breeds (Hereford, Angus and Shorthorn). A third Hereford line was developed using an index combining growth and type as the basis for selection.

The Experimental Plan

The experimental plan involved selecting four unrelated sires for each breed and mating each of them to unrelated purebred cows to produce 32 foundation daughters. The 32 females by each sire were randomly distributed to the inbred and selection lines. In each breed there were four inbred lines with 16 cows in each and two selection lines (type and growth) each containing 32 cows. In the Hereford breed a third line was established and selection practiced on the basis of an index composed of type and growth.

Bulls used in the selection lines came from any of the Front Royal lines or from outside breeders. Each year 12-18 weanling bulls of each breed were tested for postweaning performance. The fastest growing bull, on the basis of an average of pre- and postweaning average daily gains, was selected for service in the growth herd, without consideration of conformation. At the conclusion of the test the bull with the best conformation score (average of committee scores) was used in the type line without regard to growth rate.

Prior to 1958, Angus and Shorthorn selection herds were handled as single sire units, using a new sire each year. Since 1958, two sires--a yearling chosen at the conclusion of each year's performance test, and the 2-year-old used the previous year--have been used in each line of each breed.

Replacement females for the selection lines came from females born within a particular selection line. Thus, the selection lines were closed with respect to females but not males. In general, there was little culling of young females except on the basis of reproductive performance.

Description of the Data

The analysis was conducted utilizing lines 7 (type) and 8 (growth) in the Shorthorn and Angus breeds. The Hereford line 7 (type) was discarded from the study due to a confounding of dam birth year classification and the classification for year of observation. Thus, the Hereford line 6 (index) and line 8 (growth) were used in the analysis.

Complete records, birth to approximately one year of age, were available on 299 Shorthorn, 283 Aberdeen Angus and 147 Hereford females. Tables 4, 6 and 8 give the numbers of observations for weights at birth, 205 days, 19, 31 and 43 months of age in each of the lines of the three breeds. Only the Shorthorn breed provided sufficient numbers of 43-month weights for analyses. The weights at older ages were taken in the fall between September and November. In general, the data at later ages are somewhat incomplete because of failure to weigh the cattle and/or the natural turnover of females in the various lines.

Male progeny were not analyzed in this study since only a small number were maintained past the weaning period.

ANALYTICAL PROCEDURES

Nine traits considered of economic importance in the early growth of beef cattle were analyzed in this study: pre- and postweaning average daily gain (ADG, pounds per day), total daily gain (TDG, pounds per day), weights (pounds) at birth, 205 days and 12 months, 140-day test gain (pounds), weaning and yearling type scores (scale = 3-17). Fall weights (pounds) were available on a number of the females at the later ages of 19, 31 and 43 months.

The early growth traits (birth weight, preweaning ADG, 205-day weight and weaning type score) were adjusted, within breed, for age of dam using the additive correction factors constructed by Scarsi (1971). Age of dam was not considered in the model used for determining genetic trends because of a partial confounding of the classification for genetic trend and age of dam.

Weights at 205 days were calculated in the usual manner of multiplying the preweaning ADG by 205 and adding the birth weight. Weights at 12 months were calculated by multiplying the postweaning ADG by 160 and adding the weight at 205 days adjusted for age of dam.

The selection criterion in the growth lines (line 8 in each breed) was TDG. Total daily gain for this study was calculated by averaging the preweaning ADG adjusted for age of dam and the postweaning ADG.

The index used in Hereford line 6 was as follows:

$$\text{Index} = [(\text{TDG} \times 40) - 18] + 5 \times \text{Type Score}.$$

The selection criterion in the type lines, yearling type score, was not adjusted before analysis. The code used for both weaning and yearling score was 3, 4, 5 = common; 6, 7, 8 = medium; 9, 10, 11 = good; 12, 13, 14 = choice; and 15, 16, 17 = fancy.

The weights at 31 and 43 months of age were adjusted for lactation status, i.e., adjusted for whether the cow suckled a calf the summer previous to the fall weighing. The following statistical model and a Least-Squares and Maximum Likelihood General Purpose Computer Program (Harvey, 1968) were used to obtain least-squares means from which correction factors were constructed. Since there was a significant breed x lactation status interaction ($P < .01$), the least-squares means from this interaction classification were used to construct the adjustment factors for weights at 31 months.

$$Y_{ijklm} = \mu + B_i + L_{ij} + R_k + S_l + BR_{ik} + BS_{il} + RS_{kl} + b(X_{ijklm} - \overline{X}.....) + e_{ijklm}$$

where

Y_{ijklm} = 31 or 43-month weight of the ijklmth cow

μ = effect common to all observations

B_i = effect of the ith breed, i = 1, 2, 3

L_{ij} = effect of the jth line in the ith breed, j = 1, 2, 3

R_k = effect of the kth year of weighing, k = 1, ..., 10

S_l = effect of the lth lactation status, l = 1, 2

BR_{ik} = effect of the interaction of the ith breed with the kth year of weighing

BS_{il} = effect of the interaction of the ith breed with the lth lactation status

RS_{kl} = effect of the interaction of the k^{th} year of weighing with the l^{th} lactation status

b = linear partial regression coefficient of weight (Y) on age in months (X)

e_{ijklm} = random error associated with the $ijklm^{th}$ observation.

Brown, Brown and Butts (1972a, b) found a significant ($P < .05$) age of dam effect in weights of Hereford females taken through 36 months of age. On the basis of their report, it was thought necessary to conduct a preliminary analysis to check for age of dam effect in the later weights of the Front Royal females. The above model was revised by simply adding a classification for age of dam. Since the 19-month old heifers were not lactating the summer before their fall weighing, the variable for lactation status was dropped from the model for the 19-month weight analysis. Adjustment factors for age of dam were constructed by using differences between least-squares means.

Henderson *et al*. (1959) described methods of obtaining unbiased estimates of genetic and environmental trends in selection studies. The following model, which was developed by Bailey *et al*. (1971), was used in a weighted least-squares analysis to estimate the genetic and environmental trends for the various traits within each of the three breeds.

$$Y_{ijklm} = \mu + L_i + G_{ij} + C_{ijk} + R_{il} + b(X_{ijklm} - \overline{X}_{.....}) + e_{ijklm}$$

where

Y_{ijklm} = measured trait on the $ijklm^{th}$ individual

μ = effect common to all observations

L_i = effect of the i^{th} line, $i = 1, 2$

G_{ij} = effect of the j^{th} dam birth year in the i^{th} line, $j = 1, \ldots, 6$ in the Angus and Shorthorn, $j = 1, 2, 3$ in the Hereford breed

C_{ijk} = component common to the records of the k^{th} cow in the j^{th} dam birth group in the i^{th} line

R_{il} = effect of the l^{th} year of observation in the i^{th} line

b = linear partial regression coefficient of the measured trait on the age of the individual (X = days for early growth traits or months for weights at 19 and 31 months)

e_{ijklm} = random error associated with the $ijklm^{th}$ observation.

Dam birth year groups and year of observation were nested within lines to obtain estimates of genetic and environmental trends for each line.

Separate analyses were performed for each breed, using the Least-Squares and Maximum Likelihood Computer Program developed by Harvey (1968). An indirect procedure (Harvey, 1970) was employed for estimation of variance components used in the calculation of repeatabilities of two or more dam progeny records. This indirect procedure involves taking the difference in remainder sums of squares from two analyses and deriving a mean square for cows/dam birth year/line. In the first analysis the variables for cows, dam birth year and lines were absorbed and the least-squares constants were fitted for year of observation within line and the partial regression. Variance component estimates for within-cow error ($\hat{\sigma}_e^2$) were based on the residual mean square from this initial analysis. In the second analysis the variable for cows/dam birth year/lines was omitted and constants fitted for the other effects in the model. The difference between the remainder sums of squares from these two preliminary analyses was used in the derivation of a mean square for cows/dam birth year/line. Variance components for this variable ($\hat{\sigma}^2_{C/GL}$) were derived in the usual way of equating expected mean squares utilizing approximate coefficients calculated as though the model was for a completely nested design. Coefficients and degrees of freedom for cows/dam birth year/line are shown for each breed in table 1. Repeatability was calculated as follows:

$$r = \frac{\sigma^2_{C/GL}}{\sigma^2_{C/GL} + \sigma^2_e}$$

These repeatabilities were then utilized in a weighted least-squares analysis for each trait. The variable for cow/dam birth year/line was considered by absorption and constants were fitted for other components in the model. The computer program partitioned the sums of squares for dam birth year within line into single degree of freedom orthogonal polynomial effects by weighted least-squares procedures separately for each line to evaluate genetic trends. Estimates of environmental changes were based on differences between progeny year of observation means (calf crop year for early growth traits and year of weighing for weights at 19, 31 or 43 months of age).

Estimates of heritability for each trait were calculated by the regression of offspring on parent method after adjusting for year difference within each line of each breed. Correction factors were constructed by taking differences between means for progeny year of observation from the weighted least-squares analyses.

TABLE 1

DEGREES OF FREEDOM AND K-VALUES FOR COWS/DAM BIRTH YEAR/ LINE FOR THE ANGUS, HEREFORD AND SHORTHORN BREEDS[1]

	BREEDS					
	ANGUS		HEREFORD		SHORTHORN	
TRAIT	D.F.	K-VALUE	D.F.	K-VALUE	D.F.	K-VALUE
EARLY GROWTH	159	1.61	96	1.41	159	1.71
WEIGHT						
19 MONTHS	129	1.59	75	1.25	141	1.61
31 MONTHS	140	1.43	89	1.29	152	1.55
43 MONTHS	--	--	--	--	121	1.51

[1]K-values are coefficients for $\sigma^2_{C/GL}$ in the expected mean squares for the variable cows/dam birth year/line.

An attempt was made to calculate the genetic correlations, within line and breed, between the selection criteria (TDG, yearling type score) and the other traits measured or calculated in the study. This was done using the following formula from Pirchner (1969):

$$r_G = \frac{CR2}{DR_1} \cdot \sqrt{\frac{V(G_1)}{V(G_2)}}$$

where

DR_1 = direct response of trait 1

CR_2 = correlated response of trait 2

r_G = genetic correlation between traits 1 and 2

V_{G1}, V_{G2} = additive genetic variance for traits 1 and 2

The genetic variance for each trait was calculated using the following formula:

$$V_G = h^2 \cdot V_P$$

where

V_G = additive genetic variance

h^2 = heritability in the narrow sense

V_P = phenotypic variance

The phenotypic variance (V_P) was estimated by pooling the within year variances for each trait using the procedure given in Snedecor and Cochran (1967).

$$\text{pooled } \hat{s}^2 = \frac{\sum_{i=1}^{n} (\text{Corrected Sums of Squares})_i}{\sum_{i=1}^{n} (w_i - 1)}$$

where n = number of years and w = number of observations per year.

RESULTS AND DISCUSSION

Age of Dam Effect on Later Weights

A significant ($P < .05$) age of dam effect was found in the 19 months of age weight analysis (520 observations). Weight at 31 months of age was not affected by age of dam. These results seem to be in accordance with results reported by Waugh and Marlowe (1969) and Brown, Brown and Butts (1972a, b). These researchers, fitting age of dam in months as a covariable, found a significant ($P < .05$) age of dam effect on weights taken from birth through 36 months in Hereford females. In the same study the age of dam effect for Angus females declined in weights after 16 months. The breed x age of dam interaction was not significant in the current analysis but subclass numbers were small and may not have been representative of each age within each breed.

Effect of age of dam is probably not unusual in the previously described study or the current study since beef females are usually somewhat limited in feed intake. Feeding all females alike disregards preweaning environment and may prohibit compensatory gains in individuals experiencing a poor preweaning environment.

Age of dam correction factors for 19 months weight are given in appendix table 28.

Lactation Status Effect on Weights at 31 and 43 Months

The effect of lactation was estimated from a subsample of the entire data set which includes all observations for the three breeds. It was necessary to subsample the available data because in early years the replacement heifers were bred to calve as three year olds. Analysis of the entire data set would certainly have resulted in some confounding of lactation status and years for the 31-month weight. A total of 492 observations were available for analysis. All effects in the model given on page 20 were statistically significant ($P < .05$) except for breeds ($P < .10$) in the analysis of 31-month weight. Because the breed x lactation status interaction was significant, the least-squares means from the interaction classification were used in constructing correction factors for the three breeds. This procedure resulted in adjustments of 58.7, 53.2 and 125.8 pounds for the Angus, Hereford and Shorthorn breeds, respectively. The weights were adjusted to those of cows which had suckled a calf the summer previous to the cow's fall weighing.

There was a total of 407 observations available in the 43 months of age data set. This was again a sample of the total data set. The entire data set was not used in this analysis for reasons similar to the above, i.e., effort was made to obtain weights on individuals which had been treated the same. Another problem was lack of data from early corresponding years for the three breeds. The effects of breed, lines within breed, year of weighing, lactation status and breed x year of weighing were all statistically significant ($P < .025$). The least-squares means for the lactation status classification were used to construct the correction factors. This resulted in the subtraction of 130.7 pounds from the fall weight of a cow that did not suckle a calf the summer before her fall weighing. Marlowe, Freund, and Graham (1962) reported that dry Angus cows were 143 pounds heavier than cows which suckled calves. Brown and Franks (1964) reported that dry Hereford and Angus cows were 100 pounds heavier than cows which had suckled calves.

Estimated Repeatability of the Traits Analyzed

Repeatability estimates based on the records of two or more progeny of a given dam were calculated by the indirect method of Harvey (1970) described early. The repeatability estimates are shown in table 2. In general, these repeatabilities seem to be higher than most estimates found in the literature for weaning traits (Petty and Cartwright, 1966). However, the estimate for 205-day weaning weight for Angus is in close agreement with the estimate of .31 reported by Thompson and Marlowe (1971). Few estimates are given in the literature for postweaning traits but again the repeatabilities from this study are larger than those given by Koch and Clark (1955) and Bailey *et al.* (1971). The differences between repeatabilities calculated in this study and those from other studies are probably the result of estimation from populations of limited size. Some error could have resulted from the lack of a proper method for obtaining expected mean square coefficients, since a completely nested model had to be assumed in their calculation.

In all cases, repeatabilities for weights and gains in the Hereford and Shorthorn were higher than in the Angus breed. Maternal ability or at least milking ability in the Angus breed is generally considered superior to Herefords or Shorthorns. Since maternal ability must enter into this repeatability, it seems possible that maternal ability in the Angus breed may be less variable than in the other two breeds.

TABLE 2

REPEATABILITY ESTIMATES FOR ANGUS, HEREFORD AND SHORTHORN WEIGHTS, GAINS AND TYPE SCORES

	BREEDS		
TRAIT	ANGUS	HEREFORD	SHORTHORN
WEIGHT			
BIRTH	0.23	0.00	0.25
205 DAYS	0.29	0.58	0.51
12 MONTHS	0.17	0.42	0.27
19 MONTHS	0.09	0.16	0.27
31 MONTHS	0.03	0.29	0.13
43 MONTHS	--	--	0.14
TDG[1]	0.13	0.36	0.25
ADG[2]			
PREWEAN	0.33	0.60	0.55
POSTWEAN	0.22	0.16	0.27
TEST GAIN	0.11	0.19	0.19
TYPE SCORES			
WEANING	0.56	0.18	0.39
YEARLING	0.65	0.49	0.00

[1]Total daily gain (average of pre- and postweaning ADG)
[2]Average daily gain

Due to differences between breeds with respect to repeatability of the various traits it appears that a within breed analysis was justified.

Line and Age Differences Within Breed

Tables 3 through 8 show the line and overall means, with standard errors, for the three breeds. Little statistical significance could be detected from these analyses. Line differences were statistically significant for 19- and 31-month weights in the Shorthorn breed ($P < .01$ and $P < .05$, respectively).

In general, the growth lines (line 8) of the three breeds have larger means for growth traits. This follows since these lines were under selection for early growth to a year of age. The Hereford line 6 (index selection) showed slightly larger means for test gain and postweaning ADG, however, little significance can be attached to these differences. The Hereford line 6 and the type lines (line 7) in the Angus and Shorthorn breeds gave consistently larger means for type scores (weaning and yearling) which again was expected since these lines had been selected for type over the years.

Table 9 shows the mean ages of the cattle when weights were obtained. The partial regression of the various traits on age was statistically significant in some of the analyses. In the Angus breed statistical significance was found for the partial regression coefficients ($P < .05$) of weight at 205 days, 12 months, and 19 months, TDG and weaning type score on age. In Herefords, the partial regression coefficients were statistically different from zero ($P < .05$)

TABLE 3

ANGUS MEANS AND STANDARD ERRORS FOR WEIGHTS BY LINE[1]

WEIGHT	LINE 7			LINE 8			LINE 7 AND 8 COMBINED		
	NO.	MEAN	S.E.	NO.	MEAN	S.E.	NO.	MEAN	S.E.
BIRTH	129	61.5	± 1.7	154	65.9	± 1.5	283	63.7	± 1.1
205 DAYS	129	401.9	± 8.0	154	414.8	± 7.0	283	408.4	± 5.3
12 MONTHS	129	613.9	± 12.0	154	644.7	± 10.4	283	629.3	± 7.9
19 MONTHS	113	771.5	± 17.2	119	816.0	± 15.9	232	793.7	± 11.7
31 MONTHS	108	854.1	± 24.5	116	880.3	± 23.0	224	867.2	± 16.8

[1]Adjustment of data discussed on pages 19-21.

TABLE 4

HEREFORD MEANS AND STANDARD ERRORS FOR WEIGHTS BY LINE[1]

	LINE 6				LINE 8				LINE 6 AND 8 COMBINED			
WEIGHT	NO.	MEAN		S.E.	NO.	MEAN		S.E.	NO.	MEAN		S.E.
BIRTH	68	64.8	±	2.8	79	70.8	±	2.5	147	67.8	±	1.9
205 DAYS	68	381.9	±	12.4	79	410.9	±	10.9	147	396.4	±	8.3
12 MONTHS	68	585.6	±	16.9	79	613.5	±	14.7	147	599.6	±	11.3
19 MONTHS	51	732.0	±	29.9	58	775.3	±	33.9	109	753.7	±	22.6
31 MONTHS	59	905.8	±	34.3	65	930.3	±	30.0	124	918.1	±	22.8

[1]Adjustment of data discussed on pages 19-21.

TABLE 5

SHORTHORN MEANS AND STANDARD ERRORS FOR WEIGHTS BY LINE

WEIGHT[1]	LINE 7			LINE 8			LINE 7 AND 8		
	NO.	MEAN	S.E.	NO.	MEAN	S.E.	NO.	MEAN	S.E.
BIRTH	129	68.2 ±	1.8	170	71.9 ±	1.3	299	70.1 ±	1.1
205 DAYS	129	388.3 ±	8.5	170	394.7 ±	6.3	299	391.5 ±	5.3
12 MONTHS	129	622.3 ±	14.3	170	637.9 ±	10.1	299	630.1 ±	8.7
19 MONTHS	108	755.7 ±	18.3	145	833.0 ±	13.7	253	794.3 ±	11.4
31 MONTHS	112	807.0 ±	19.1	146	865.9 ±	18.1	258	836.1 ±	13.2
43 MONTHS	91	917.9 ±	25.3	110	966.6 ±	24.5	201	942.2 ±	17.6

[1]Adjustment of data discussed on pages 19-21.

TABLE 6

ANGUS MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY LINE[1]

	LINE 7			LINE 8			LINE 7 AND 8 COMBINED		
TRAIT	MEAN		S.E.	MEAN		S.E.	MEAN		S.E.
TDG[2]	1.50	±	0.03	1.57	±	0.03	1.53	±	0.02
ADG[3]									
PREWEAN	1.68	±	0.04	1.71	±	0.03	1.69	±	0.02
POSTWEAN	1.31	±	0.05	1.43	±	0.05	1.38	±	0.03
TEST GAIN	181.80	±	7.17	196.63	±	6.18	189.21	±	4.73
TYPESCORE									
WEANING	12.51	±	0.25	11.84	±	0.22	12.18	±	0.17
YEARLING	12.16	±	0.44	11.49	±	0.40	11.82	±	0.30
OBSERVATIONS		129			154			283	

[1]Adjustment of data discussed on pages 19-21.
[2]Total daily gain (average of preweaning and postweaning ADG)
[3]Average daily gain

TABLE 7

HEREFORD MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY LINE[1]

TRAIT	LINE 6 MEAN		LINE 6 S.E.	LINE 8 MEAN		LINE 8 S.E.	LINE 6 AND 8 COMBINED MEAN		LINE 6 AND 8 COMBINED S.E.
TDG[2]	1.41	±	0.05	1.46	±	0.04	1.43	±	0.03
ADG[3]									
PREWEAN	1.55	±	0.06	1.66	±	0.05	1.61	±	0.04
POSTWEAN	1.27	±	0.08	1.26	±	0.07	1.27	±	0.06
TEST GAIN	179.83	±	12.36	176.72	±	10.76	178.28	±	8.20
TYPESCORE									
WEANING	12.16	±	0.35	11.90	±	0.30	12.03	±	0.23
YEARLING	12.04	±	0.41	11.50	±	0.36	11.77	±	0.27
OBSERVATIONS	68			79			147		

[1]Adjustment of data discussed on pages 19-21.
[2]Total daily gain (average of preweaning and postweaning ADG)
[3]Average daily gain

TABLE 8

SHORTHORN MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY LINE

TRAIT[1]	LINE 7 MEAN	LINE 7 S.E.	LINE 8 MEAN	LINE 8 S.E.	LINE 7 AND 8 MEAN	LINE 7 AND 8 S.E.
TDG[2]	1.51 ±	0.04	1.55 ±	0.03	1.53 ±	0.02
ADG[3]						
PREWEAN	1.57 ±	0.04	1.57 ±	0.03	1.57 ±	0.02
POSTWEAN	1.46 ±	0.07	1.51 ±	0.05	1.49 ±	0.05
TEST GAIN	198.95 ±	8.58	207.77 ±	5.59	203.36 ±	5.23
TYPESCORE						
WEANING	12.57 ±	0.39	11.35 ±	0.29	11.96 ±	0.24
YEARLING	12.35 ±	0.91	11.32 ±	0.67	11.83 ±	0.57
OBSERVATIONS	129		170		299	

[1]Adjustment of data discussed on pages 19-21.
[2]Total daily gain (average pre- and postweaning ADG)
[3]Average daily gain

TABLE 9

MEAN AGES FOR THE THREE BREEDS

TRAIT	ANGUS	HEREFORD	SHORTHORN
Weaning Age (Days)	239.3 ± 34.9	221.7 ± 34.8	245.4 ± 37.6
WEIGHT			
19 MONTHS	19.5 ± 1.1	19.4 ± 1.0	19.3 ± 1.4
31 MONTHS	31.5 ± 1.2	31.5 ± 1.7	31.3 ± 1.6
43 MONTHS	--	--	43.5 ± 0.9

for yearling type score and weight at 19 months of age. In Shorthorns, the partial regression coefficients for weight at 205 days, 19 months and 31 months, preweaning average daily gain and weaning type score on age were statistically different from zero ($P < .05$).

Age was not considered in the final model if preliminary analysis indicated that the partial regression coefficient was not statistically different from zero.

Genetic Trends in Gains and Type Scores

Statistical significance for the dam birth year classification or for the polynomial regression coefficients was not found in any of the lines evaluated for the various traits. Therefore, it cannot be said with certainty that any genetic change has actually occurred in these lines, even though the estimated trends in many cases are of considerable magnitude. However, in light of the selection practiced and on the basis of reports in the literature which indicate that some of these trends might be expected, some discussion of these trends seems to be in order.

Total Daily Gain (TDG). Total daily gain was the direct selection criterion in the growth lines (line 8) of all three breeds and was considered one of the early growth traits. TDG was part of the index used in Hereford line 6 selection, also. TDG was calculated as the average of the pre- and postweaning average daily gain (ADG). Preweaning ADG was adjusted for age of dam before calculation of TDG in this study but not in the data used in selection of the breeding cattle.

Numbers of observations for the dam birth year classification are shown in tables 10, 11 and 12 for each line of the three breeds. The genetic trend was positive for all lines of the three breeds as indicated by the positive linear polynomial regression coefficients for TDG on dam birth year, which are shown in tables 13, 14 and 15. As would be expected the trends in the line 8 Angus and Shorthorn females were of greater magnitude than the type lines. The type lines probably did not change genetically with respect to TDG which may be of significance since no conscientious selection for growth was practiced in these lines. Bailey et al. (1971) found a positive genetic trend for feedlot gain in a line of Hereford cattle selected for type score but the genetic trend for type score in that line was slightly negative. The scale for type in his study differed from the scale used in the current study.

It appears that both lines of Herefords contained individuals with considerable early growth potential. Since selection had not been practiced as long in the Hereford lines as in the other breeds perhaps it was too early for differences between the lines to develop. The differences seen between lines 7 and 8 in the Angus and Shorthorn breeds would not be expected between Hereford lines 6 and 8 since the index used in Hereford line 6 considered both TDG and type. Also, it is possible that present type is more indicative of growth than in past years. Type score criteria have certainly changed over the years, although at least some researchers scoring cattle at Front Royal tried to maintain the original criteria. If changes in scoring criteria had

TABLE 10

NUMBER OF OBSERVATIONS FOR THE ANGUS BREED BY LINE AND DAM BIRTH YEAR

DAM BIRTH YEAR	EARLY[1] GROWTH		19 MONTHS WEIGHT		31 MONTHS WEIGHT	
	LINE 7	LINE 8	LINE 7	LINE 8	LINE 7	LINE 8
1954[2]	58	62	45	40	56	52
1955-56	18	18	18	17	15	14
1957-58	11	26	10	24	7	20
1959-60	17	8	17	5	11	4
1961-62	7	23	7	19	5	16
1963-64	18	17	16	14	14	10
TOTAL	129	154	113	119	108	116

[1]Traits include pre- and postweaning average daily gain, weights at birth, 205 days, 12 months, gain on test, weaning and yearling type scores and total daily gain (average of pre- and postweaning).
[2]Includes 1954 or earlier

TABLE 11

NUMBER OF OBSERVATIONS FOR THE HEREFORD BREED BY LINE AND DAM BIRTH YEAR

DAM BIRTH YEAR	EARLY GROWTH[2]		19 MONTHS WEIGHT		31 MONTHS WEIGHT	
	LINE 6	LINE 8	LINE 6	LINE 8	LINE 6	LINE 8
1959[1]	45	47	15	41	42	43
1960-61	8	12	6	9	7	10
1962-63	15	20	6	8	10	12
TOTAL	68	79	51	58	59	65

[1]1959 or earlier
[2]Traits include pre- and postweaning average daily gain, weights at birth, 205 days and 12 months, gain on test, weaning and yearling type scores and total daily gain (average of pre- and post-weaning).

TABLE 12

NUMBER OF OBSERVATIONS FOR THE SHORTHORN BREED BY LINE AND DAM BIRTH YEAR

DAM BIRTH YEAR	EARLY[2] GROWTH		19 MONTHS WEIGHT		31 MONTHS WEIGHT		43 MONTHS WEIGHT	
	LINE 7	LINE 8	LINE 7	LINE 8	LINE 7	LINE 8	LINE 7	LINE 8
1954[1]	56	75	39	57	54	73	47	60
1955-56	14	24	14	22	12	19	12	17
1957-58	12	22	11	20	11	17	9	12
1959-60	17	16	16	15	12	13	11	8
1961--62	17	22	16	21	15	16	12	13
1963-64	13	11	12	10	8	8	--	--
TOTAL	129	170	108	145	112	146	91	110

[1]1954 or earlier

[2]Traits include pre- and postweaning average daily gain, weights at birth, 205 days and 12 months, gain on test, weaning and yearling type scores and total daily gain (average of pre- and post-weaning).

[3]Final classification combined with the 1961-62 classification.

TABLE 13

GENETIC TRENDS IN THE ANGUS BREED
FOR WEIGHTS, GAINS AND TYPE SCORES

TRAIT	LINEAR POLYNOMIAL[1] REGRESSION COEFFICIENTS LINE 7	LINE 8
WEIGHT		
BIRTH	0.199 ± 1.033	- 0.532 ± 1.044
205 DAYS	0.746 ± 4.836	2.161 ± 4.848
12 MONTHS	1.153 ± 7.300	7.440 ± 7.469
19 MONTHS	- 5.121 ± 10.393	- 3.541 ± 11.341
31 MONTHS	-10.758 ± 14.757	- 2.714 ± 17.442
TDG[2]	0.006 ± 0.020	0.024 ± 0.020
ADG[3]		
PREWEAN	0.008 ± 0.022	0.017 ± 0.022
POSTWEAN	0.001 ± 0.033	0.037 ± 0.033
TEST GAIN	1.155 ± 4.328	5.073 ± 4.483
TYPE SCORES		
WEANING	0.003 ± 0.148	- 0.037 ± 0.143
YEARLING	0.118 ± 0.254	0.012 ± 0.244

[1]Values represent the approximate total genetic change per year
[2]Total daily gain (average of pre- and postweaning ADG)
[3]Average daily gain

TABLE 14

GENETIC TRENDS IN THE HEREFORD BREED
FOR WEIGHTS, GAINS AND TYPE SCORES

TRAIT	LINEAR POLYNOMIAL[1] REGRESSION COEFFICIENTS	
	LINE 6	LINE 8
WEIGHT		
BIRTH	- 2.491 ± 3.094	1.554 ± 3.090
205 DAYS	9.998 ± 13.506	18.988 ± 13.331
12 MONTHS	21.589 ± 18.592	25.759 ± 18.783
19 MONTHS	4.520 ± 52.144	5.122 ± 42.844
31 MONTHS	-13.631 ± 38.865	-27.948 ± 44.269
TDG[2]	0.064 ± 0.051	0.063 ± 0.052
ADG[3]		
PREWEAN	0.062 ± 0.062	0.085 ± 0.061
POSTWEAN	0.051 ± 0.093	0.038 ± 0.097
TEST GAIN	7.445 ± 13.582	5.557 ± 14.108
TYPE SCORES		
WEANING	0.282 ± 0.381	0.285 ± 0.396
YEARLING	0.054 ± 0.453	- 0.405 ± 0.452

[1]Values represent the approximate total genetic change per year
[2]Total daily gain (average of pre- and postweaning ADG)
[3]Average daily gain

TABLE 15

GENETIC TRENDS IN THE SHORTHORN BREED
FOR WEIGHTS, GAINS AND TYPE SCORES

TRAIT	LINEAR POLYNOMIAL[1] REGRESSION COEFFICIENTS	
	LINE 7	LINE 8
WEIGHT		
BIRTH	- 3.034 ± 1.272	- 0.918 ± 1.042
205 DAYS	5.744 ± 5.793	3.779 ± 4.952
12 MONTHS	0.392 ± 9.835	6.647 ± 8.392
19 MONTHS	-23.889 ± 14.260	17.351 ± 12.007
31 MONTHS	-33.094 ± 18.951	- 0.037 ± 16.445
43 MONTHS	-28.753 ± 28.483	-13.942 ± 25.696
TDG[2]	0.006 ± 0.027	0.022 ± 0.023
ADG[3]		
PREWEAN	0.044 ± 0.026	0.021 ± 0.022
POSTWEAN	- 0.016 ± 0.051	0.035 ± 0.043
TEST GAIN	- 2.511 ± 5.929	4.844 ± 5.034
TYPE SCORES		
WEANING	0.330 ± 0.270	- 0.156 ± 0.231
YEARLING	0.163 ± 0.618	- 0.209 ± 0.529

[1]Values represent the approximate total genetic change per year
[2]Total daily gain (average of pre- and postweaning ADG)
[3]Average daily gain

an effect on the genetic trends of the cattle at Front Royal then the Hereford line 6 would be most affected since most of the selection practiced was in later years. All of the regression coefficients had large standard errors which make it difficult to attach a great deal of significance to the differences, but it is significant that the trends are those which might be expected under the specific selection practiced.

Means and standard errors from the weighted least-squares analyses are shown in tables 16-21 by classification of dam birth year. In general, the means for TDG indicate the same trends as the polynomial regression coefficients. It may be well to note, however, that certain years, such as 1959-60 in the Angus and Shorthorns, seem somewhat out of line for a linear response to selection. The Angus mean is too small while the Shorthorn mean seems too large; although, considering the large standard errors neither mean may be out of order. Reasons for these discrepancies were not obvious from the analyses. It is possible that the response to selection may not have been exactly linear since the lines were not closed on the male side. Sampling error is certainly a problem when only limited numbers of observations are available. Even if the trends are not exactly linear they are for the most part positive. Thus, it appears that the assumption of linear response would probably be justified in the evaluation of the selection lines of cattle at Front Royal.

Yearling Type Score. Yearling type score was the selection criterion for the line 7 Angus and Shorthorn breeds and made up part of

TABLE 16

ANGUS LINE EIGHT MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY DAM BIRTH YEAR[1,2]

DAM BIRTH YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST	TYPE SCORE	
		PREWEAN	POSTWEAN	GAIN	WEANING	YEARLING
1954	1.48 ± 0.08	1.62 ± 0.10	1.35 ± 0.14	184.9 ± 18.2	12.17 ± 0.66	11.75 ± 1.16
1955-56	1.44 ± 0.09	1.56 ± 0.10	1.35 ± 0.15	182.5 ± 18.9	11.39 ± 0.73	11.32 ± 1.30
1957-58	1.53 ± 0.08	1.70 ± 0.09	1.38 ± 0.14	189.2 ± 17.5	12.45 ± 0.70	12.26 ± 1.25
1959-60	1.38 ± 0.10	1.55 ± 0.12	1.25 ± 0.17	169.6 ± 22.6	11.14 ± 0.86	11.29 ± 1.53
1961-62	1.57 ± 0.09	1.69 ± 0.10	1.46 ± 0.14	201.1 ± 18.8	11.79 ± 0.71	11.74 ± 1.25
1963-64	1.64 ± 0.10	1.71 ± 0.11	1.61 ± 0.16	219.6 ± 21.6	12.14 ± 0.76	11.87 ± 1.31

[1]Number of observations per subclass given in table 10.
[2]Adjustment of data discussed on pages 19-21.

TABLE 17

HEREFORD LINE EIGHT MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY DAM BIRTH YEAR[1,2]

DAM BIRTH YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORE	
		PREWEAN	POSTWEAN		WEANING	YEARLING
1959	1.33 ± 0.10	1.37 ± 0.12	1.26 ± 0.20	175.6 ± 29.4	11.63 ± 0.83	11.85 ± 0.90
1960-61	1.37 ± 0.12	1.46 ± 0.14	1.24 ± 0.23	173.3 ± 32.6	11.52 ± 0.91	11.65 ± 1.04
1962-63	1.46 ± 0.11	1.54 ± 0.13	1.34 ± 0.22	187.0 ± 31.7	12.21 ± 0.89	11.77 ± 0.97

[1]Number of observations per subclass given in table 11.
[2]Adjustment of data discussed on pages 19-21.

TABLE 18

SHORTHORN LINE EIGHT MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY DAM BIRTH YEAR[1,2]

DAM BIRTH YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORE	
		PREWEAN.	POSTWEAN.		WEANING	YEARLING
1954	1.48 ± 0.10	1.48 ± 0.10	1.42 ± 0.18	194.6 ± 20.8	12.43 ± 0.99	11.67 ± 2.31
1955-56	1.51 ± 0.09	1.59 ± 0.10	1.43 ± 0.18	196.2 ± 19.9	11.33 ± 0.98	11.56 ± 2.35
1957-58	1.50 ± 0.09	1.53 ± 0.10	1.43 ± 0.17	194.9 ± 19.8	11.65 ± 0.97	11.63 ± 2.33
1959-60	1.60 ± 0.10	1.52 ± 0.11	1.65 ± 0.18	225.2 ± 20.9	10.45 ± 1.03	11.16 ± 2.46
1961-62	1.56 ± 0.10	1.63 ± 0.10	1.51 ± 0.18	206.3 ± 20.9	11.85 ± 1.00	11.18 ± 2.35
1963-64	1.55 ± 0.12	1.60 ± 0.12	1.51 ± 0.22	206.4 ± 24.9	11.70 ± 1.17	10.36 ± 2.74

[1]Number of observations per subclass given in table 12.
[2]Adjustment of data discussed on pages 19-21.

TABLE 19

ANGUS LINE SEVEN MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY DAM BIRTH YEAR[1,2]

DAM BIRTH YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORE	
		PREWEAN	POSTWEAN		WEANING	YEARLING
1954	1.49 ± 0.05	1.69 ± 0.06	1.30 ± 0.08	175.7 ± 10.3	12.93 ± 0.40	11.82 ± 0.70
1955-56	1.47 ± 0.07	1.62 ± 0.08	1.34 ± 0.11	183.7 ± 14.4	12.18 ± 0.55	12.04 ± 0.98
1957-58	1.51 ± 0.08	1.63 ± 0.13	1.38 ± 0.13	190.7 ± 17.1	11.52 ± 0.64	11.78 ± 1.14
1959-60	1.48 ± 0.07	1.73 ± 0.09	1.26 ± 0.12	172.8 ± 15.4	12.66 ± 0.62	12.31 ± 1.12
1961-62	1.50 ± 0.10	1.69 ± 0.11	1.29 ± 0.17	181.0 ± 22.1	13.18 ± 0.79	12.70 ± 1.40
1963-64	1.52 ± 0.08	1.69 ± 0.09	1.34 ± 0.13	186.9 ± 18.0	12.60 ± 0.59	12.32 ± 1.02

[1]Number of observations per subclass given in table 10.
[2]Adjustment of data discussed on pages 19-21.

TABLE 20

HEREFORD LINE SIX MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY DAM BIRTH YEAR[1,2]

DAM BIRTH YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST	TYPE SCORE	
		PREWEAN	POSTWEAN	GAIN	WEANING	YEARLING
1959	1.44 ± 0.07	1.60 ± 0.08	1.27 ± 0.13	188.8 ± 18.3	11.36 ± 0.51	10.23 ± 0.59
1960-61	1.53 ± 0.13	1.53 ± 0.16	1.51 ± 0.25	222.3 ± 36.7	11.21 ± 1.03	10.37 ± 1.16
1962-63	1.56 ± 0.11	1.73 ± 0.14	1.37 ± 0.21	202.9 ± 30.3	11.94 ± 0.85	10.34 ± 1.01

[1]Number of observations per subclass given in table 11.
[2]Adjustment of data discussed on pages 19-21.

TABLE 21

SHORTHORN LINE SEVEN MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY DAM BIRTH YEAR[1,2]

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORE	
		PREWEAN.	POSTWEAN.		WEANING	YEARLING
1954	1.49 ± 0.10	1.47 ± 0.09	1.46 ± 0.19	201.0 ± 22.4	12.18 ± 0.98	12.47 ± 2.18
1955-56	1.51 ± 0.08	1.55 ± 0.09	1.46 ± 0.15	199.5 ± 17.9	12.18 ± 0.86	11.77 ± 2.02
1957-58	1.51 ± 0.09	1.46 ± 0.09	1.57 ± 0.16	213.9 ± 18.7	11.73 ± 0.89	11.93 ± 2.08
1959-60	1.50 ± 0.09	1.57 ± 0.09	1.44 ± 0.16	196.0 ± 18.7	12.88 ± 0.90	12.71 ± 2.13
1961-62	1.50 ± 0.09	1.65 ± 0.09	1.37 ± 0.17	186.5 ± 19.9	13.11 ± 0.90	12.70 ± 2.05
1963-64	1.55 ± 0.10	1.69 ± 0.10	1.45 ± 0.19	196.9 ± 22.1	13.37 ± 1.00	12.51 ± 2.29

[1]Number of observations per subclass given in table 12.
[2]Adjustment of data discussed on pages 19-21.

the index in Hereford line 6. Estimates of genetic change for each line of the three breeds are shown in tables 13-15.

Means and standard errors from the analyses are given in tables 16-21. The most progress was made in type selection lines (line 7) of the Angus and Shorthorn breeds. Hereford line 6 showed a slightly positive trend as did the Angus line 8, but the Hereford and Shorthorn growth lines (line 8) gave negative trends.

Exactly what is to be expected with respect to type selection or genetic trends in type for lines under selection for growth, on the basis of reports in the literature, is not at all clear. Bailey et al. (1971) concluded that selection response for type score (scale of 60 to 100) was essentially zero, the polynomial linear regression coefficient was small, but negative. Type scores are usually considered to be low to moderate in heritability and should respond to selection (Petty and Cartwright, 1966).

Genetic correlations between measurements of growth, such as feedlot gain, and type score have been, in general, positive, although negative correlations have been reported in a summary of genetic and environmental statistics by Petty and Cartwright (1966). Thus, reports in the literature do not indicate exactly what the genetic trends in type might be in lines selected for growth.

The ideal type in beef cattle has changed in recent years and the relationship between the subjective measurement of type and the objective measurement of growth has undoubtedly changed. Thus, the major problem with type selection is that criteria for type may change with time in the view of one individual and not in the view of another. Type score is probably of limited usefulness in the efficient production of beef cattle because it is a composite of several criteria, measured subjectively, which may change in value to the cattle industry. That is not to say, however, that the individual criteria are not of importance at a particular time.

Pre- and Postweaning Average Daily Gain and Total Gain on Test. These three traits are discussed together because of the close relationship between test gain and postweaning ADG. Preweaning ADG seemed to fit the general pattern of response, thus, it is also discussed in this section.

All lines, except the Shorthorn line 7, exhibited positive trends for these three traits. The trends are given in tables 13-15. Trends in the Angus breed were of greater magnitude in line 8 for all three traits. It appears that there was little genetic change for growth rate in the Angus type line.

In the Hereford breed, growth selection (line 8) seemed to favor preweaning ADG; whereas, index selection gave a similar response for both pre- and postweaning gain. Hereford line 6 showed a greater response for postweaning ADG and test gain. This difference may be meaningless if the large standard errors are considered. Yet, some discussion of how this difference could come about, other than sampling error, seems to be in order. It seems possible that the index might favor growth more than type. As was stated earlier, type in the later years of the experiment may have been more indicative of growth, perhaps postweaning growth. If this were true, the index would favor both pre- and postweaning growth; whereas, single trait selection in line 8 Hereford females, based on TDG, may have placed more emphasis on preweaning ADG. This is possible since the magnitude of the value for preweaning ADG going into the calculation of TDG was greater than the value for postweaning ADG in the females. In general, the results from the Hereford analyses were greater than expected and in some cases seemed unreasonable without considering standard errors.

Type selection in the Shorthorn breed seemed to favor preweaning ADG as indicated by the greater magnitude of genetic change by line 7. Petty and Cartwright (1966) give correlations of 0.86 and 1.29 for gain from birth to weaning and feedlot score. It may be that selection for type favored preweaning ADG in the Shorthorns. One question that is raised is, why was the same relationship not found in the Angus breed? It seems possible that this difference, if real, could be the result of differences in initial growth curves and changes in growth curves as a result of selection for type in these two breeds. Further discussion of this reasoning will be delayed until a later section.

The trends for test gain in the growth lines were considerably larger than those reported by Bailey et al. (1971) for closed lines of Herefords.

Weaning Type Score. The same problems involved with yearling type score selection are inherent in weaning type score. Genetic trends for this trait are shown in tables 13-15. It appears little can be said about these trends except that as preweaning ADG increased weaning type score increased in the Hereford and Shorthorn breeds. This was not true in the Angus line 8 where the trend for weaning type score was slightly negative, probably zero, but the genetic trend for preweaning ADG was positive.

These trends are not in complete agreement with weaning type score trends calculated by Scarsi (1971) using both males and females from the Front Royal station. In general, the magnitudes found for type score genetic trends in the present study are greater and signs differ in some cases. One reason for these differences could be the fact that Scarsi (1971) used data from both males and females after adjusting for sex and age of dam.

Genetic Trends in Weights and Growth Curve Changes

The genetic trends for the various weights (birth, 205 day, 12 months, 19 months, 31 months and 43 months) are shown in tables 13-15 for the three breeds. The genetic trends for these weights will be discussed in this section since they fit together in a particular pattern of growth. An attempt will be made to explain the genetic trends in these weights as well as some explanation of the possible changes in the growth curves these weights form.

The means and standard errors for these weights by classification of dam birth year are given in tables 22-27 and the number of observations per subclass are given in tables 10-12 for each line of the three breeds. Number of observations tend to decline for the later weights. Only the Shorthorn breed provided enough observations of 43 months of age weight to allow analysis. Since there was little intentional

TABLE 22

ANGUS LINE EIGHT MEANS AND STANDARD ERRORS FOR WEIGHT BY DAM BIRTH YEAR[1]

DAM BIRTH YEAR	WEIGHTS[2]				
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1954	63.5 ± 4.4	396.3 ± 20.8	611.9 ± 31.0	821.3 ± 45.5	906.2 ± 64.6
1955-56	67.1 ± 4.6	384.9 ± 21.9	597.1 ± 32.2	823.8 ± 44.7	864.4 ± 66.8
1957-58	61.7 ± 4.3	408.8 ± 20.7	628.3 ± 30.0	801.0 ± 41.3	927.8 ± 59.8
1959-60	58.1 ± 5.5	372.3 ± 25.9	569.1 ± 38.3	759.8 ± 62.0	788.3 ± 92.4
1961-62	65.8 ± 4.6	410.4 ± 21.6	642.4 ± 32.0	806.1 ± 45.7	913.6 ± 66.9
1963-64	60.5 ± 5.1	408.7 ± 24.1	661.7 ± 36.3	812.7 ± 53.0	892.5 ± 83.3

[1]Number of observations per subclass given in table 10.
[2]Adjustment of data discussed on pages 19-21.

TABLE 23

HEREFORD LINE EIGHT MEANS AND STANDARD ERRORS FOR WEIGHT BY DAM BIRTH YEAR[1]

DAM BIRTH YEAR	WEIGHTS[2]				
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1959	59.5 ± 6.1	340.5 ± 25.7	550.3 ± 37.6	754.5 ± 77.4	942.4 ± 80.8
1960-61	63.9 ± 7.1	363.0 ± 30.3	570.9 ± 43.0	757.5 ± 86.8	937.5 ± 87.2
1962-63	62.6 ± 6.5	378.4 ± 27.6	601.9 ± 40.2	765.4 ± 93.7	886.2 ± 88.5

[1]Number of observations per subclass given in table 11.
[2]Adjustment of data discussed on pages 19-21.

TABLE 24

SHORTHORN LINE EIGHT MEANS AND STANDARD ERRORS FOR WEIGHT BY DAM BIRTH YEAR[1]

DAM BIRTH YEAR	WEIGHTS[2]					
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS	43 MONTHS
1954	73.0 ± 4.3	374.0 ± 21.9	614.1 ± 35.0	764.3 ± 49.7	872.3 ± 63.2	962.0 ± 77.8
1955-56	76.0 ± 4.2	399.3 ± 22.1	631.4 ± 34.1	794.1 ± 46.3	901.5 ± 57.3	1000.9 ± 71.5
1957-58	71.7 ± 4.2	386.3 ± 21.8	621.6 ± 33.9	825.3 ± 46.2	875.5 ± 56.8	947.7 ± 74.2
1959-60	74.7 ± 4.4	386.3 ± 23.1	658.2 ± 35.6	845.2 ± 49.0	918.1 ± 60.7	966.3 ± 84.7
1961-62	69.4 ± 4.4	403.4 ± 22.0	642.1 ± 35.3	841.1 ± 48.3	893.0 ± 63.3	905.6 ± 90.7
1963-64	68.7 ± 5.2	397.0 ± 25.7	635.9 ± 41.9	842.7 ± 57.3	847.3 ± 75.8	

[1]Number of observations per subclass given in table 12.
[2]Adjustment of data discussed on pages 19-21.

TABLE 25

ANGUS LINE SEVEN MEANS AND STANDARD ERRORS FOR WEIGHTS BY DAM BIRTH YEAR[1]

DAM BIRTH YEAR	WEIGHTS[2]				
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1954	62.5 ± 2.6	409.0 ± 12.3	617.8 ± 17.8	776.3 ± 27.8	888.0 ± 36.1
1955-56	60.5 ± 3.5	390.5 ± 16.8	603.0 ± 24.7	781.9 ± 33.2	869.1 ± 47.3
1957-58	60.0 ± 4.1	393.0 ± 19.5	618.0 ± 29.0	778.6 ± 41.6	839.1 ± 65.9
1959-60	60.2 ± 3.8	410.3 ± 18.3	610.0 ± 26.5	763.4 ± 36.2	859.9 ± 56.2
1961-62	62.1 ± 5.3	403.3 ± 24.7	612.6 ± 37.2	781.1 ± 52.3	832.7 ± 81.3
1963-64	63.9 ± 4.2	405.8 ± 19.6	621.9 ± 30.0	747.8 ± 43.7	836.2 ± 67.1

[1]Number of observations per subclass given in table 10.
[2]Adjustment of data discussed on pages 19-21.

TABLE 26

HEREFORD LINE SIX MEANS AND STANDARD ERRORS FOR WEIGHTS BY DAM BIRTH YEAR[1]

DAM BIRTH YEAR	WEIGHTS[2]				
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1959	71.7 ± 3.9	400.0 ± 17.0	604.0 ± 24.0	725.5 ± 65.1	917.6 ± 40.1
1960-61	68.7 ± 8.0	381.5 ± 34.5	629.7 ± 48.3	737.5 ± 70.9	909.8 ± 78.3
1962-63	66.7 ± 6.8	420.8 ± 29.5	647.0 ± 40.9	733.0 ± 79.8	889.9 ± 68.0

[1]Number of observations per subclass given in table 11.
[2]Adjustment of data discussed on pages 19-21.

TABLE 27

SHORTHORN LINE SEVEN MEANS AND STANDARD ERRORS FOR WEIGHTS BY DAM BIRTH YEAR[1]

DAM BIRTH YEAR	WEIGHTS[2]					
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS	43 MONTHS
1954	76.3 ± 4.6	379.1 ± 20.5	623.4 ± 36.7	863.7 ± 56.7	924.8 ± 69.9	997.2 ± 89.4
1955-56	70.4 ± 3.7	387.9 ± 19.0	626.1 ± 30.2	780.1 ± 39.1	854.3 ± 47.5	932.7 ± 60.8
1957-58	71.8 ± 3.9	369.1 ± 19.5	619.0 ± 31.4	760.8 ± 42.9	796.3 ± 48.7	919.9 ± 68.6
1959-60	68.3 ± 3.9	389.2 ± 20.0	618.3 ± 31.7	723.0 ± 42.1	782.4 ± 51.3	879.7 ± 67.0
1961-62	63.2 ± 4.1	400.9 ± 19.1	616.9 ± 32.9	692.4 ± 44.5	741.7 ± 54.9	859.9 ± 76.0
1963-64	59.3 ± 4.5	403.8 ± 21.3	629.9 ± 36.5	714.1 ± 50.4	742.5 ± 70.0	

[1]Number of observations per subclass given in table 12.
[2]Adjustments of data discussed on pages 19-21.

culling of females on the basis of progeny performance at these later ages, it was assumed that these weights provided a sample of the weights of the cattle in the various lines. However, there probably was some natural selection of females over the years because of such phenomena as infertility. It is not possible to determine the extent to which this selection might have affected weight.

Figures 2-7 show the graphs of the means, from the weighted least-squares analyses, given in tables 21-27. These graphs provide some indication of the growth curves for the various dam birth years; although, certainly some inaccuracies are involved and will be pointed out in the discussion.

Observation of the genetic trends in tables 13-15 indicates that some increase in growth occurred in all lines to a particular age, except perhaps the Angus line 7. The particular time at which growth seems to diminish is different in the several selection lines. Changes in the growth curves of these cattle, if indeed there have been any changes, are dependent on the original types of curves in the population as well as the selection practiced.

Brown, Brown and Butts (1972a, b, c) reported a number of genetic and phenotypic correlations between weights, gains and rate of maturing. Maturity in their study was defined in terms of weight or, more specifically, proportion of mature weight at a given age. They were able to show distinct breed differences with respect to these relationships indicating that selection on the basis of performance traits such as gains to the same fixed period of time may result in

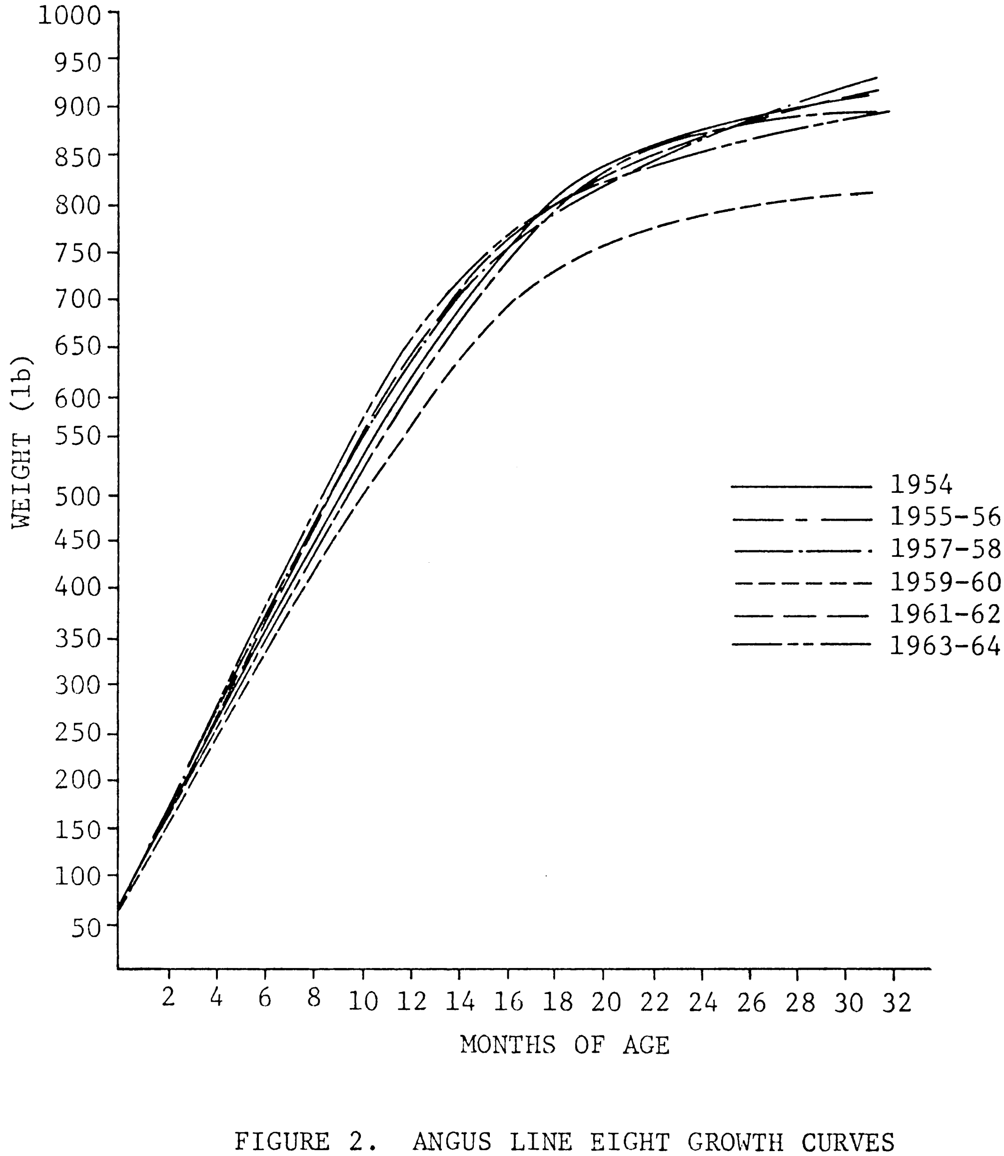

FIGURE 2. ANGUS LINE EIGHT GROWTH CURVES BY DAM BIRTH YEARS

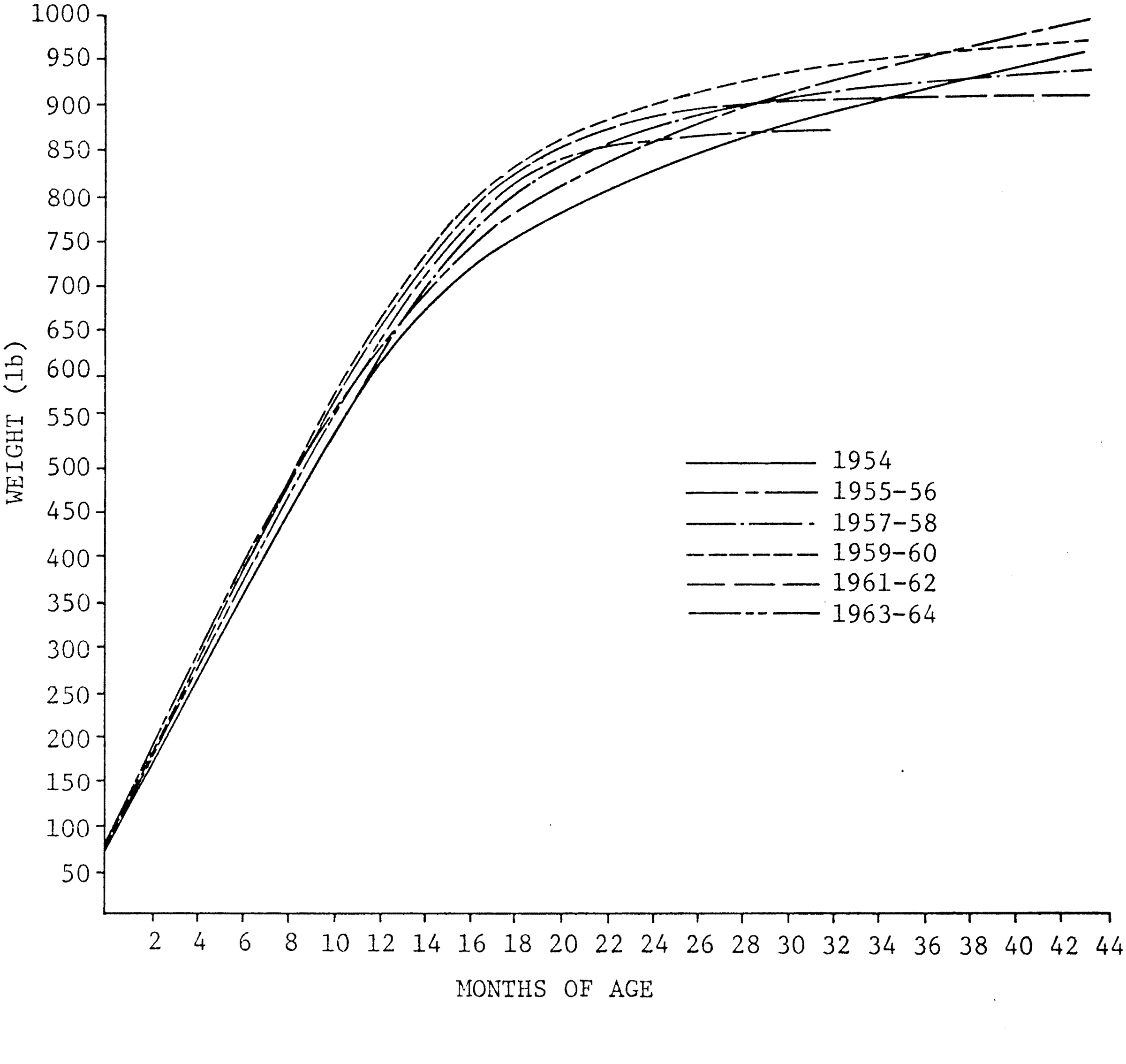

FIGURE 3. SHORTHORN LINE EIGHT GROWTH CURVES BY DAM BIRTH YEARS

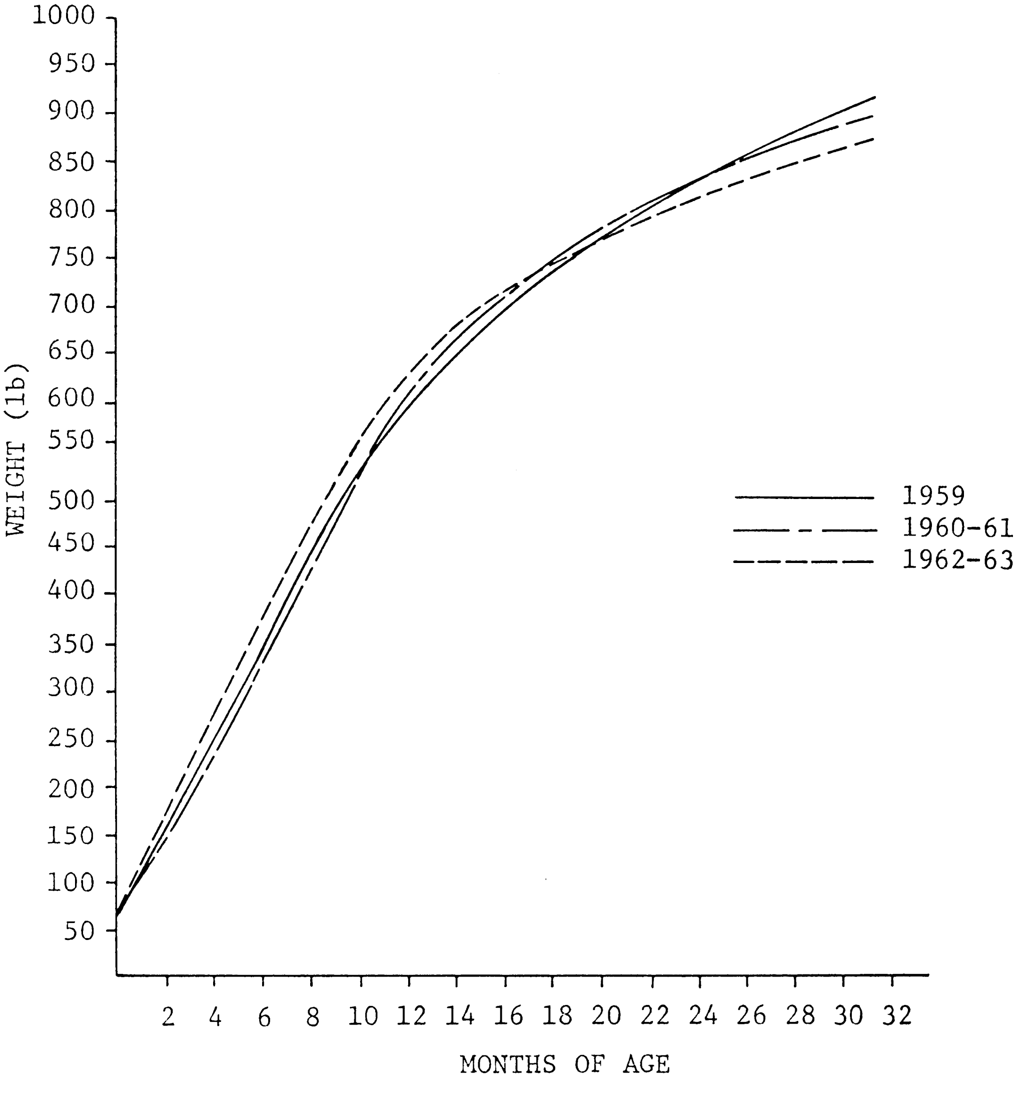

FIGURE 4. HEREFORD LINE SIX GROWTH CURVES
BY DAM BIRTH YEARS

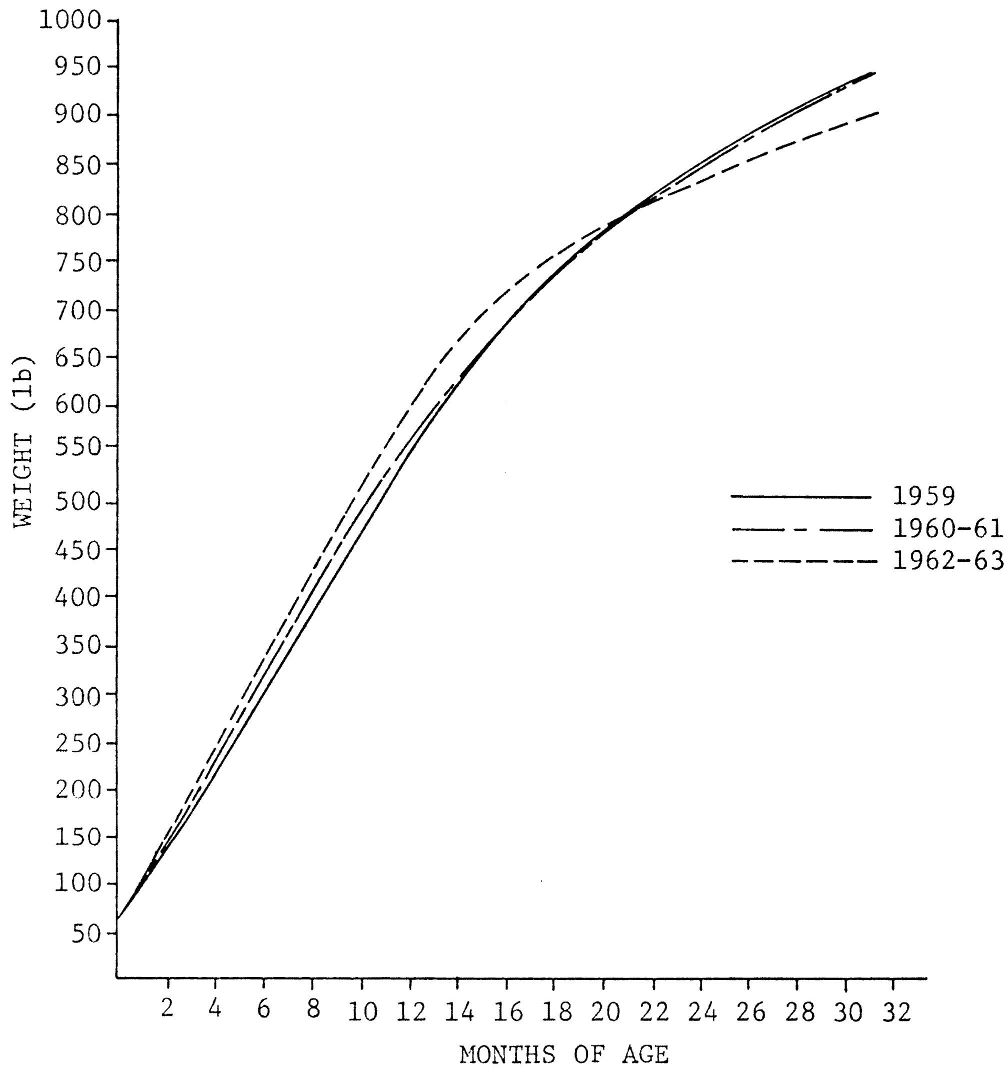

FIGURE 5. HEREFORD LINE EIGHT GROWTH CURVES BY DAM BIRTH YEARS

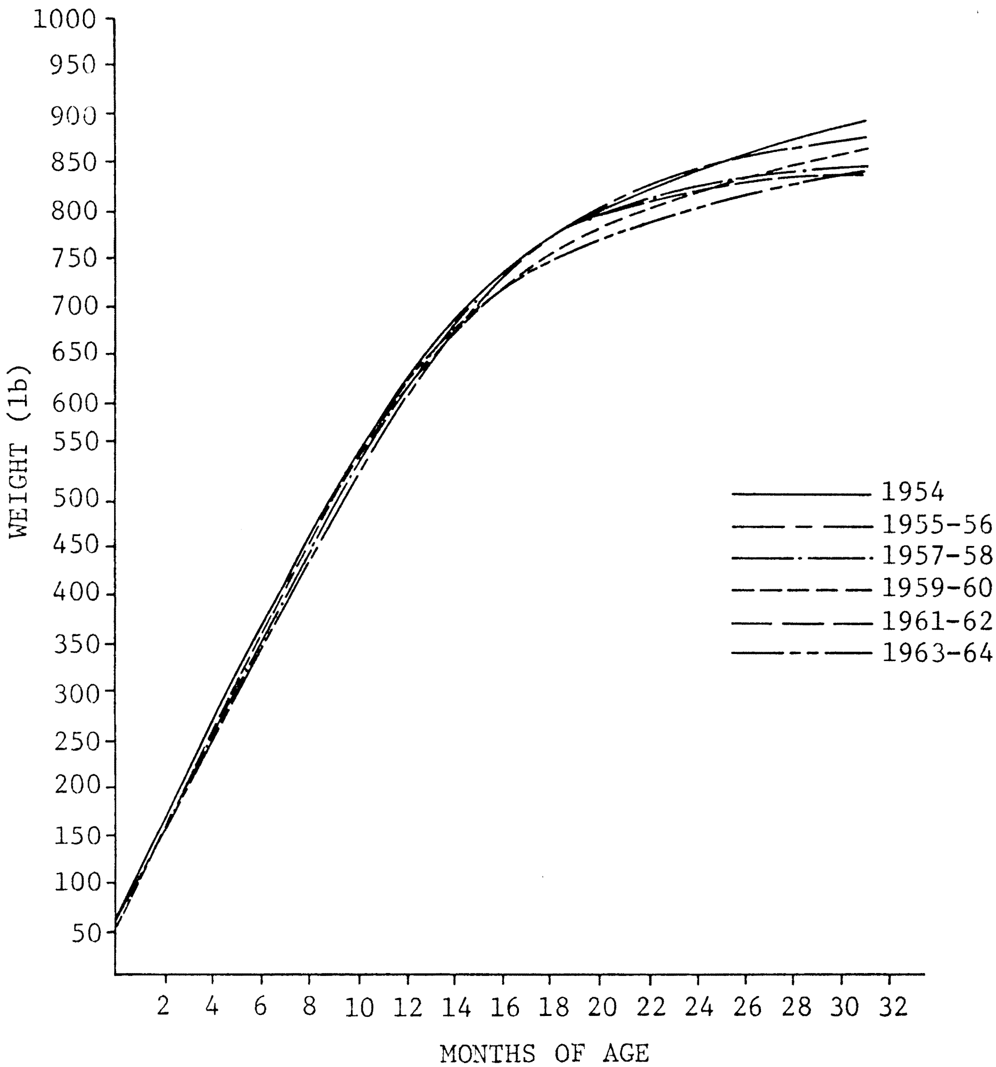

FIGURE 6. ANGUS LINE SEVEN GROWTH CURVES BY DAM BIRTH YEARS

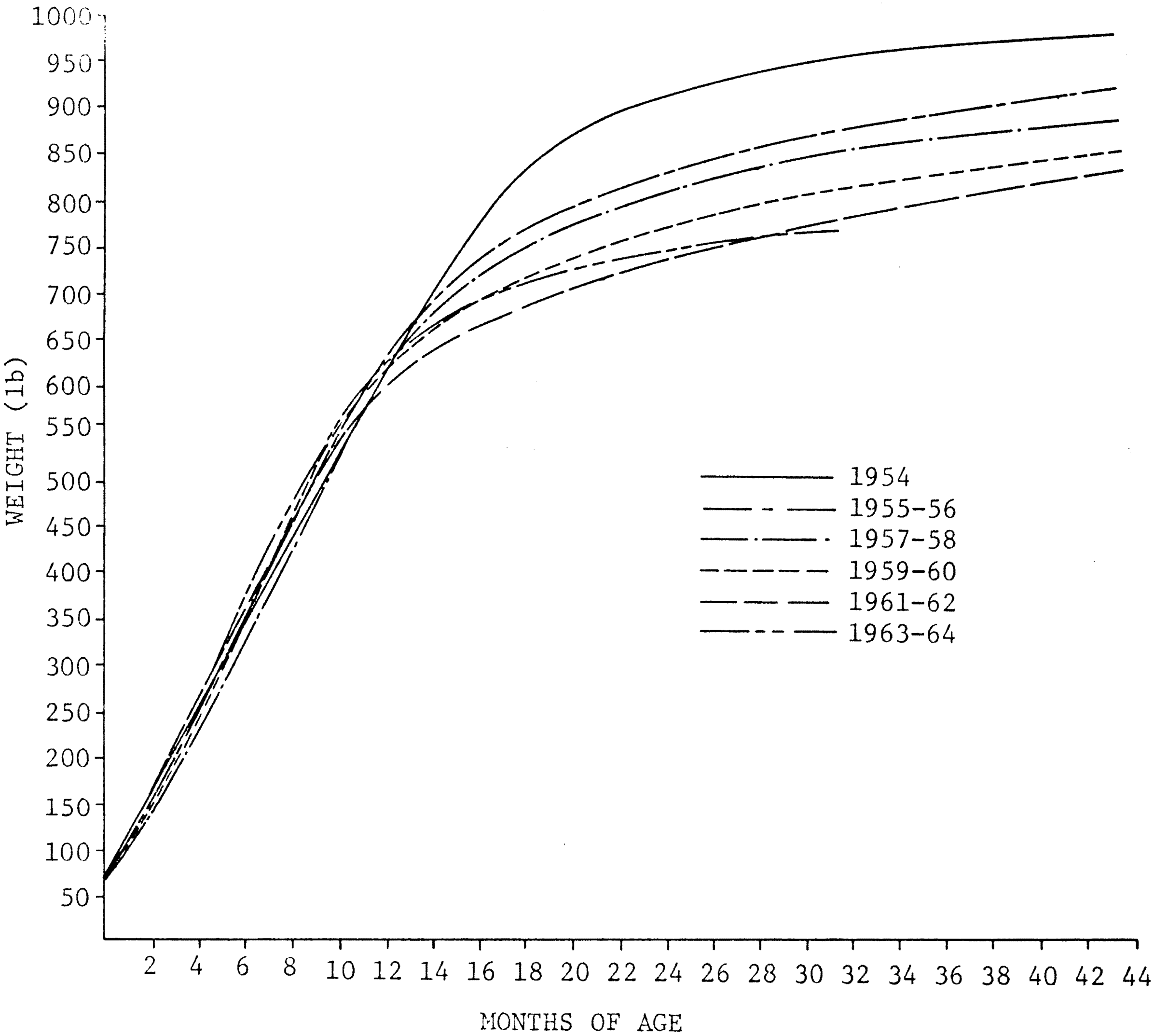

FIGURE 7. SHORTHORN LINE SEVEN GROWTH CURVES BY DAM BIRTH YEARS

different responses after that time in Angus and Hereford females. It was also noted that genes influencing gains may not be entirely the same genes influencing weight.

Brown, Brown and Butts (1972a, c) reported negative genetic correlations between early gains up to 12 months and mature weight for the Hereford breed. The Angus breed showed little genetic relationship between early gains and mature weight. Both breeds exhibited positive genetic relationships between early gains and weights taken at 8 to 36 months of age. At the same time, there was a positive genetic relationship of considerable magnitude between early gains and rate of maturing. Rate of maturing was shown to have a negative genetic relationship with early weights (8-36 months) in Hereford cattle but a positive relationship in Angus cattle. Angus cattle seemed to exhibit growth curves of types II and III, shown in figure 1, while Hereford cattle seemed to show differences in growth curves but without a large number of intersections between curves. The question raised in the minds of these researchers was, "Do genes which promote large early gains cause early maturing by increasing the rate of approach to a comparatively inflexible mature weight, or do the genes influencing maturity dictate the gain potential of an animal?" In their opinion, since there were slow and fast gaining animals in each of the large and small mature weight categories, it appeared that the genotype for gain and genetic limits on mature weight combine to establish the general rate of maturing and development pattern of the animal.

In light of the above, what is to be expected in the Front Royal growth lines with respect to growth curves or growth curve changes is not exactly clear. The following discussion is further complicated by only partial data, i.e., lack of enough weights to fit growth curves for each individual. Negative changes in later weights of Angus females would not be expected as a result of selection for TDG based on the work of Brown, Brown and Butts (1972a, b, c). This conclusion results from the positive genetic relationship between rate of maturing and weights and the positive relationship between early gains and immature weights. Observation of figure 2 and the genetic trends in table 12 for Angus line 8 would indicate that perhaps there has not been much change with respect to 19- and 31-month weights. This could be an indication that the females in Angus line 8 are somewhat inflexible in mature weight, genetically. If this were true and degree of maturity was measured as a proportion of mature weight at a given age, then perhaps rate of maturing was increasing in Angus line 8. Figure 2 shows that the curves for the various dam birth years are quite similar, but differences are most prominent between 7 and 19 months of age. Of course, these comments involve some extrapolation since there was not an analysis of mature weights in any of the lines studied.

Another reason that changes may not have taken place in the Angus line 8 curves is that the male side of the line was open which could allow selection of a sire from any one of the four types of curves shown in figure 1. It seems that this would lessen the tendency toward a particular type of curve.

Some of the same comments made for figure 2 can probably be made for figure 3 which represents the growth curves for Shorthorn line 8. These cattle seemed to maintain the genetic potential for growth for a longer period of time than the Angus. It would also be of interest to know the mature weights of the cattle in Shorthorn line 8. It appears that these curves might eventually come together at a particular point. The large standard errors for mean weights at 43 months would indicate little difference in those weights over the various dam birth years.

One question that is raised by figure 3 and the genetic trends in table 15 is, "Which breed described by Brown, Brown and Butts (1972c), Angus or Hereford, is representative of the Shorthorn breed?" The graph and genetic trends indicate that these cattle are increasing in genetic potential for growth through at least 31 months. The graph in figure 3 could be considered similar to the Angus graph in figure 2 except that the genetic limits on mature weight may be greater and reached at a later time. That is to say, the Shorthorns are later maturing than the Angus, but the relationship between early gains, maturity and later weights may be the same. It is not possible to say that rate of maturing is increasing in Shorthorn line 8 without a mature weight analysis. Two curves are above the 1954 base line and three are below it at the 43 months of age area of the graph, suggesting there was much variation in mature weight.

Figures 4 and 5 show the growth curves for the Hereford lines 6 and 8. These curves would tend to substantiate the view of Brown, Brown and Butts (1972a, b) that Hereford cattle tended to sustain growth for a longer period of time than Angus cattle. These curves are steeper at later ages than either the Shorthorn or Angus curves. It is also of interest to note that in both lines genetic potential for early growth is increasing to a point somewhere between 12 and 19 months of age and then declining. This could mean that rate of maturing was being positively altered by early growth selection in the lines which would tend to decrease later weights because of the negative genetic correlation between the traits. This argument can not be completely substantiated without weights at even later ages. It is obvious these curves are still going up and may all eventually reach approximately the same points on the graph.

Figures 6 and 7 show the growth curves for type line 7 Angus and Shorthorn cattle. These curves also seem to substantiate, at least in part, the work of Brown, Brown and Butts (1972a, b, c). If type was indirectly measuring maturity over the years of selection at Front Royal then perhaps some alteration in rate of maturity may have taken place over the years at the Front Royal station. In the earlier years at least, scoring favored the shorter, deeper bodied individuals which were probably earlier maturing. Type selection seemed to have a drastic effect on the Shorthorn line 7. Early growth up to 205 days responded positively (as shown in table 14) but then genetic growth potential declined rapidly. This might be expected if the Shorthorn breed was similar genetically to the Hereford breed described by Brown, Brown and Butts (1972a, b, c). It appears that, in this case, a rapid increase in genes for rate of maturing could be dictating the growth potential of the line. It also appears that these cattle may have been in a transition from a growth curve of type III to that of type II shown in figure 1.

The Angus line 7 seemed to show the same type of phenomenon as the Shorthorn line 7 but the magnitude of differences was small--but weights were available only up to 31 months of age in the Angus breed.

These differences are probably not significant; thus, these results would tend to agree with the work of Brown, Brown and Butts (1972a, b, c) for Angus cattle. That is; genes for rate of maturing do not have a negative effect on later and mature weights.

The literature contains few reports which can be compared directly with the genetic trends found in this study. A recent report by Newman, Rahnefeld and Fredeen (1973) indicated that selection for yearling weight resulted in responses of 7.3 ± 5.4 and 5.1 ± 3.3 pounds per year in the females of two herds of Shorthorn cattle. These herds were closed and response to selection calculated on the basis of deviations from a genetic control herd. Their findings suggest that the trends in the Front Royal Angus and Shorthorn growth lines for 12-month weight may be very reasonable since they were not completely closed.

Scarsi (1971) determined the genetic trends for 205-day weaning weight in the selection lines at Front Royal. The data were adjusted for sex of calf and age of dam. The Shorthorn lines seemed to make the most genetic progress with line 7 increasing at the rate of 4.5 and line 8 at 4.3 pounds per year. The current study also shows that the Shorthorn line 7 cattle have made greater genetic progress than line 8 through weaning. Line 8 Herefords exhibited greater genetic progress than line 6 in both studies, but magnitudes of change were considerably greater in the current study. The Hereford line 7 was not analyzed in the current study. The Angus trends from the two studies are somewhat in agreement, i.e., magnitude of differences between trends from the two studies is less than those in the other two breeds.

Year of Observation Effect

Number of observations by years within line are given in appendix tables 1-3 for each breed. Year of observation refers to calf crop year in early growth traits and actual year of weighing in later weights. Some combining of years was necessary since limited numbers of observations caused determinants of the correlation matrix to go to zero.

Means and standard errors for the various traits from the weighted least-squares analyses for year of observation within line and breed are shown in appendix tables 4-15. Statistical significance for this effect was detected in a small number of the analyses. These means indicate a considerable within-line fluctuation in the various traits of Angus, Hereford and Shorthorn females. Within-line differences in the various traits can be attributed to changes in environmental factors and to sire effects.

Estimates of Heritability

Heritability estimates for the various traits were calculated by doubling the regression coefficient of offspring on parent. The data were adjusted for year differences by using correction factors constructed from the means for year of observation obtained from the weighted least-squares analyses. The adjustment factors are shown in appendix tables 16-27 and the estimates are shown in tables 28-33. The data were also adjusted for age at time of observation, if necessary.

TABLE 28

ESTIMATES OF HERITABILITY FOR WEIGHTS, GAINS AND TYPE SCORES IN THE LINE EIGHT ANGUS BREED[1]

TRAIT	REGRESSION COEFFICIENT	HERITABILITY ESTIMATE
WEIGHT		
BIRTH	0.20 ± 0.09	0.40
205 DAYS	-0.03 ± 0.09	--
12 MONTHS	0.20 ± 0.11	0.40
19 MONTHS	0.17 ± 0.12	0.35
31 MONTHS	-0.14 ± 0.12	--
TDG[2]	0.24 ± 0.11	0.48
ADG[3]		
PREWEAN	-0.01 ± 0.09	--
POSTWEAN	0.17 ± 0.08	0.34
TEST GAIN	0.21 ± 0.09	0.42
TYPE SCORES		
WEANING	0.17 ± 0.07	0.34
YEARLING	0.08 ± 0.07	0.16

[1]Heritability calculated by regression of offspring on parent method
[2]Total daily gain (average pre- and postweaning ADG)
[3]Average daily gain

TABLE 29

ESTIMATES OF HERITABILITY FOR WEIGHTS, GAINS AND TYPE SCORES IN LINE EIGHT HEREFORD BREED[1]

TRAIT	REGRESSION COEFFICIENT	HERITABILITY ESTIMATE
WEIGHT		
BIRTH	0.01 ± 0.18	0.02
205 DAYS	0.12 ± 0.11	0.23
12 MONTHS	0.12 ± 0.13	0.24
19 MONTHS	0.11 ± 0.10	0.23
31 MONTHS	-0.09 ± 0.14	--
TDG[2]	0.13 ± 0.15	0.26
ADG[3]		
PREWEAN	0.09 ± 0.10	0.18
POSTWEAN	0.33 ± 0.19	0.66
TEST GAIN	0.36 ± 0.21	0.71
TYPE SCORES		
WEANING	-0.02 ± 0.15	--
YEARLING	-0.05 ± 0.15	--

[1]Heritabilities calculated by regression of offspring on parent method
[2]Total daily gain (average of pre- and postweaning ADG)
[3]Average daily gain

TABLE 30

ESTIMATES OF HERITABILITY FOR WEIGHTS, GAINS AND TYPE SCORES IN LINE EIGHT SHORTHORN BREED[1]

TRAIT	REGRESSION COEFFICIENT	HERITABILITY ESTIMATE
WEIGHT		
BIRTH	0.32 ± 0.09	0.64
205 DAYS	0.34 ± 0.17	0.68
12 MONTHS	0.29 ± 0.09	0.57
19 MONTHS	0.45 ± 0.11	0.90
31 MONTHS	0.08 ± 0.10	0.15
43 MONTHS	0.24 ± 0.11	0.48
TDG[2]	0.26 ± 0.09	0.52
ADG[3]		
PREWEAN	0.33 ± 0.12	0.66
POSTWEAN	0.27 ± 0.09	0.54
TEST GAIN	0.32 ± 0.11	0.64
TYPE SCORES		
WEANING	0.25 ± 0.08	0.50
YEARLING	0.10 ± 0.07	0.20

[1]Heritabilities calculated by regression of offspring on parent method
[2]Total daily gain (average pre- and postweaning ADG)
[3]Average daily gain

TABLE 31

ESTIMATES OF HERITABILITY FOR WEIGHTS, GAINS AND TYPE SCORES IN LINE SEVEN ANGUS BREED[1]

TRAIT	REGRESSION COEFFICIENT	HERITABILITY ESTIMATE
WEIGHT		
BIRTH	0.12 ± 0.08	0.24
205 DAYS	0.05 ± 0.24	0.10
12 MONTHS	0.38 ± 0.09	0.76
19 MONTHS	0.32 ± 0.12	0.64
31 MONTHS	0.30 ± 0.10	0.60
TDG[2]	0.35 ± 0.10	0.70
ADG[3]		
PREWEAN	0.03 ± 0.09	0.06
POSTWEAN	0.07 ± 0.09	0.14
TEST GAIN	0.14 ± 0.12	0.28
TYPE SCORES		
WEANING	0.10 ± 0.09	0.20
YEARLING	0.29 ± 0.06	0.58

[1]Heritabilities calculated by regression of offspring on parent method
[2]Total daily gain (average of pre- and postweaning ADG)
[3]Average daily gain

TABLE 32

ESTIMATES OF HERITABILITY FOR WEIGHTS, GAINS AND TYPE SCORES IN LINE SIX HEREFORD BREED[1]

TRAIT	REGRESSION COEFFICIENT	HERITABILITY ESTIMATE
WEIGHT		
BIRTH	0.07 ± 0.16	0.14
205 DAYS	0.23 ± 0.21	0.46
12 MONTHS	0.43 ± 0.17	0.85
19 MONTHS	0.57 ± 0.17	1.13
31 MONTHS	0.40 ± 0.20	0.80
TDG[2]	0.43 ± 0.17	0.86
ADG[3]		
PREWEAN	0.27 ± 0.21	0.54
POSTWEAN	0.31 ± 0.18	0.62
TEST GAIN	0.24 ± 0.16	0.47
TYPE SCORES		
WEANING	0.02 ± 0.16	0.04
YEARLING	0.23 ± 0.15	0.46

[1]Heritabilities calculated by regression of offspring on parent method
[2]Total daily gain (average of pre- and postweaning ADG)
[3]Average daily gain

TABLE 33

ESTIMATES OF HERITABILITY FOR WEIGHTS, GAINS AND TYPE SCORES IN LINE SEVEN SHORTHORN BREED[1]

TRAIT	REGRESSION COEFFICIENT	HERITABILITY ESTIMATE
WEIGHT		
BIRTH	0.61 ± 0.11	1.22
205 DAYS	0.08 ± 0.10	0.16
12 MONTHS	0.09 ± 0.09	0.18
19 MONTHS	0.57 ± 0.10	1.14
31 MONTHS	0.53 ± 0.11	1.06
43 MONTHS	0.51 ± 0.11	1.03
TDG[2]	0.07 ± 0.09	0.13
ADG[3]		
PREWEAN	0.12 ± 0.11	0.24
POSTWEAN	0.13 ± 0.08	0.26
TEST GAIN	0.31 ± 0.14	0.62
TYPE SCORES		
WEANING	0.26 ± 0.11	0.52
YEARLING	0.12 ± 0.07	0.24

[1]Heritabilities calculated by regression of offspring on parent method
[2]Total daily gain (average of pre- and postweaning ADG)
[3]Average daily gain

Some of these estimates are in the range of those reported by Petty and Cartwright (1966), but others show distinct discrepancies. Differences between these estimates and others found in the literature are probably the result of estimation in small populations and inadequate adjustment for year effects.

Little discussion of these estimates seems justified since more reliable estimates are available in the literature. However, one consideration may be in line. It has been suggested, although not completely proven, that preweaning environment may have an effect on the later productivity of beef heifers (McDaniel, Carter and Butts, 1969; Mangus and Brinks, 1969; Koch, 1969; Marlowe and Thompson, 1969; and Marlowe and Zabel, 1969). That is, exceptionally good milking dams tend to produce heifers which do not milk well. If this phenomenon, which appears to be environmental rather than genetic, is true then it would tend to bias downward the covariance between daughter-dam pairs and lower the estimate of heritability. It is not suggested that this is the entire cause for the negative regression coefficients for 205-day weight and preweaning ADG in Angus line 8 cattle; but it is interesting that these negative regressions were exhibited in the Angus which are considered a better milking breed. Lower than expected heritabilities were calculated for the other breeds except the Hereford line 6 and Shorthorn line 8. The Shorthorn breed was probably one of the poorer milking breeds when originally transferred to Front Royal. Of course, the Hereford breed has been somewhat noted for its poor milking ability. It is also possible that this bias may have carried into the 31 months of age estimates. If the heifer progeny of a high producing dam tended to lose milking ability due to preweaning environment, it would probably mean they would be heavier than their dams during first lactation. This, coupled with the effect of first calving and lactation, might lower the covariance between daughter-dam pairs for weights at 31 months.

Estimates of Genetic Correlation

The estimates of genetic correlation between direct selection criteria (TDG, yearling type score) and the other measured or calculated traits are shown in tables 34 and 35.

These correlations add little to the explanation of results from this study since their magnitudes are in general too large and the signs are determined by the ratio of genetic trends for the traits. Reliability of the estimates can be judged on the basis of the standard errors of the genetic trends (tables 13-15) used in the calculation procedure.

TABLE 34

ESTIMATES OF GENETIC CORRELATION BETWEEN TOTAL DAILY GAIN[1] AND OTHER TRAITS IN LINE EIGHT ANGUS, HEREFORD AND SHORTHORN BREEDS

TRAITS	BREEDS		
	ANGUS	HEREFORD	SHORTHORN
WEIGHT			
BIRTH	-0.47	0.11	-0.82
205 DAYS	--	1.15	0.65
12 MONTHS	0.91	1.15	0.81
19 MONTHS	-0.36	0.21	1.30
31 MONTHS	--	--	-0.01
43 MONTHS	--	--	-1.06
ADG[2]			
PREWEAN	--	1.30	0.81
POSTWEAN	1.00	0.22	0.85
TEST GAIN	1.01	0.21	0.89
TYPE SCORES			
WEANING	-0.21	--	-0.89
YEARLING	0.11	--	-1.84

[1]Average of the pre- and postweaning ADG
[2]Average daily gain

TABLE 35

ESTIMATES OF GENETIC CORRELATION BETWEEN YEARLING TYPE SCORE AND OTHER TRAITS IN LINE SEVEN ANGUS AND SHORTHORN BREEDS

	BREEDS	
TRAITS	ANGUS	SHORTHORN
WEIGHT		
BIRTH	0.34	-1.61
205 DAYS	0.44	1.63
12 MONTHS	0.16	0.07
19 MONTHS	-0.61	-1.24
31 MONTHS	-1.32	-1.59
43 MONTHS	--	-1.14
TDG[1]	0.33	0.45
ADG[2]		
PREWEAN	1.15	2.20
POSTWEAN	0.08	-0.45
TEST GAIN	0.51	-0.44
TYPE SCORES		
WEANING	0.03	0.15

[1]Total daily gain (average of pre- and postweaning ADG)
[2]Average daily gain

SUMMARY

Data used in this study were collected at the Beef Cattle Research Station, Front Royal, Virginia. The analysis utilized weights, gains and type scores of females from lines 7 (type selection) and 8 (growth selection) in the Shorthorn and Angus breeds. In the Hereford breed line 6 (index selection) and line 8 (growth selection) females were available for analysis. Complete records, birth to approximately one year of age, were available on 299 Shorthorn, 283 Aberdeen Angus and 147 Hereford females. A lesser number of fall weights at ages of 19, 31 and 43 months was available on the same females.

Early growth traits considered were: pre- and postweaning average daily gain (pounds per day); total daily gain (pounds per day); weights (pounds) at birth, 205 days and 12 months; and 140-day test gain (pounds). Also considered were weaning and yearling type score (scale = 3-17). Weights (pounds) at ages of 19, 31 and 43 months were considered indicators of later growth. Weaning traits were adjusted for age of dam prior to analysis as were the weights at birth and 19 months of age. The calculation procedure adjusted for age of dam effect in total daily gain and 12 months weight. Weights at 31 and 43 months were adjusted for lactation status.

A model basically the same as the one developed by Bailey *et al*. (1971) was used in a weighted least-squares analysis to estimate the genetic and environmental trends for the various traits within each of the three breeds.

Approximate growth curves were constructed for each genetic classification by plotting the adjusted means from the weighted least-squares analysis for weights at birth, 205 days, 12, 19, 31 and 43 (Shorthorn only) months of age.

In general, little statistical significance was detected in the analyses. Positive genetic trends were found for the traits under direct selection, total daily gain and yearling type score. Selection for growth resulted in positive trends for weights and gains through 19 months in the Hereford and Shorthorn growth lines but only through 12 months in the Angus growth line. Selection for type may have resulted in a slight genetic improvement for early growth in the type selection lines. Genetic change for 205-day weight in the Shorthorn breed was actually greater in the type line than in the growth line. Type line Angus improved little, if any, for early growth potential but they did not show the magnitude of negative genetic change for later growth exhibited by the type line Shorthorns. Type score, weaning or yearling, showed little and in some cases negative genetic change in lines selected for growth.

Growth curves for the various lines of cattle indicated much the same type of results as the genetic trends, as would be expected. If degree of maturity is defined as proportion of mature weight at a given age, then there appeared to be some indirect selection for rate of maturing in the Shorthorn line seven. This seems possible, at least in early years, since type selection involved the selection of short, deeper-bodied types of cattle which would be considered early maturing.

The Angus type line did not respond the same as the Shorthorn line. This could be an indication of a breed difference with respect to the relationship between maturity and later growth. The Angus line 8 growth curves and genetic trends indicate that these cattle probably increased in early growth potential but their later growth did not change considerably, which could mean they also increased in rate of maturing. Interpretation of the Shorthorn curve is difficult since some of the curves at the 43 months of age area of the graph are below and some are above the initial selection year curve. It does not seem possible to say whether or not Shorthorn line 8 cattle are increasing in rate of maturing. The Hereford curves show that they are probably the latest maturing of the three breeds studied.

Heritabilities and genetic correlations did not seem to be very reliable, due to inaccurate adjustment for year of observation and sampling error.

The lack of statistical significance throughout the various analyses and the large standard errors for means and regression coefficients indicate some weaknesses in the study. But, in general, results of the study are those which might be expected on the basis of the selection applied and results from other investigations.

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APPENDIX

TABLE 1

NUMBER OF OBSERVATIONS FOR THE ANGUS BREED BY LINE AND YEAR OF OBSERVATION

	EARLY[1,2] GROWTH		19 MONTHS WEIGHT		31 MONTHS WEIGHT		43 MONTHS WEIGHT	
YEAR[3]	LINE 7	LINE 8	LINE 7	LINE 8	LINE 7	LINE 8	LINE 7	LINE 8
1955	17	17						
1956	10	16						
1957	10	10	16	16				
1958	5	6	8	7	27	29		
1959	5	10	5	6	8	7		
1960	11	17	5	9	5	6		
1961	--	--	9	7	5	8		
1962	8	13	2	8	9	5		
1963	14	17	8	12	2	7		
1964	9	9	13	13	7	12		
1965	14	10	9	9	12	12		
1966	13	16	14	10	4	8		
1967	13	13	12	12	14	9		
1968			12	10	8	3		
1969					7	10		
TOTAL	129	154	113	119	108	116		

[1]Traits include pre- and postweaning average daily gain, weights at birth, 205 days, 12 months, gain on test, weaning and yearling type scores and total daily gain (average of pre- and postweaning).

[2]1960 and 1961 combined

[3]Initial year includes that year or earlier

TABLE 2

NUMBER OF OBSERVATIONS FOR THE HEREFORD BREED BY LINE AND YEAR OF OBSERVATION

	EARLY[2] GROWTH		19 MONTHS WEIGHT		31 MONTHS WEIGHT	
YEAR[1]	LINE 6	LINE 8	LINE 6	LINE 8[3]	LINE 6	LINE 8
1960	15	17				
1961	5	4				
1962	8	10	20	18		
1963	5	9	8	10	20	20
1964	3	8	5	8	8	10
1965	10	11	3	8	5	8
1966	13	10	9	14	3	8
1967	19	10	6		10	10
1968					13	9
TOTAL	68	79	51	58	59	65

[1]Initial year includes that year or earlier

[2]Traits include pre- and postweaning average daily gain, weights at birth, 205 days and 12 months, gain on test, weaning and yearling type scores and total daily gain (average of pre- and post-weaning).

[3]1966 and 1967 combined

TABLE 3

NUMBER OF OBSERVATIONS FOR THE SHORTHORN BREED BY LINE AND YEAR OF OBSERVATION

YEAR[1]	EARLY[2,3] GROWTH		19 MONTHS WEIGHT		31 MONTHS WEIGHT		43 MONTHS WEIGHT	
	LINE 7	LINE 8	LINE 7	LINE 8	LINE[4] 7	LINE 8	LINE[5] 7	LINE 8
1955	26	37						
1956	14	13						
1957	11	8	23	33				
1958	2	7	11	7	39	50		
1959	9	15	2	7	11	7	33	40
1960	6	13	9	13	9	7	10	5
1961	--	--	1	4	--	13	9	7
1962	12	20	5	7	--	4	--	13
1963	9	12	12	20	5	6	--	3
1964	8	10	9	10	12	16	4	5
1965	4	11	7	10	9	8	11	12
1966	15	11	4	11	7	7	9	6
1967	13	13	15	11	4	8	4	4
1968			10	12	16	8	3	7
1969					--	12	8	8
TOTAL	129	170	108	145	112	146	91	110

[1]Initial year includes that year or earlier.
[2]Traits include pre- and postweaning average daily gain, weights at birth,205 days and 12 months, gain on test, weaning and yearling type scores and total daily gain (average of pre- and post-weaning.
[3]1960 and 1961 combined
[4]1960 and 1961 combined, 1962 and 1969 missing
[5]1961 and 1962 combined, 1963 missing

TABLE 4

ANGUS LINE SEVEN MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY YEAR OF OBSERVATION[1,2]

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST	TYPE SCORE	
		PREWEAN	POSTWEAN	GAIN	WEANING	YEARLING
1955	1.57 ± 0.09	1.56 ± 0.11	1.56 ± 0.15	183.4 ± 20.4	11.97 ± 0.69	10.39 ± 1.16
1956	1.60 ± 0.10	1.79 ± 0.12	1.37 ± 0.17	175.8 ± 22.7	11.75 ± 0.80	11.60 ± 1.36
1957	1.54 ± 0.10	1.69 ± 0.11	1.35 ± 0.16	171.9 ± 22.2	11.75 ± 0.69	11.88 ± 1.13
1958	1.44 ± 0.12	1.67 ± 0.12	1.17 ± 0.19	163.3 ± 26.3	12.52 ± 0.74	12.39 ± 1.21
1959	1.46 ± 0.12	1.47 ± 0.13	1.39 ± 0.19	234.3 ± 25.6	11.73 ± 0.82	11.52 ± 1.37
1960	1.54 ± 0.09	1.79 ± 0.11	1.27 ± 0.14	176.5 ± 19.8	12.27 ± 0.59	11.40 ± 0.99
1961						
1962	1.48 ± 0.10	1.58 ± 0.11	1.33 ± 0.16	185.1 ± 21.8	12.11 ± 0.65	11.61 ± 1.07
1963	1.48 ± 0.08	1.68 ± 0.09	1.27 ± 0.13	178.1 ± 18.3	12.90 ± 0.56	12.67 ± 0.93
1964	1.40 ± 0.10	1.56 ± 0.10	1.28 ± 0.15	179.5 ± 20.7	12.79 ± 0.65	12.13 ± 1.04
1965	1.50 ± 0.08	1.77 ± 0.09	1.28 ± 0.13	175.8 ± 18.1	13.40 ± 0.57	12.23 ± 0.93
1966	1.55 ± 0.09	1.81 ± 0.09	1.33 ± 0.14	185.4 ± 19.2	13.58 ± 0.59	12.50 ± 0.97
1967	1.53 ± 0.10	1.75 ± 0.11	1.36 ± 0.16	187.0 ± 21.5	13.28 ± 0.66	12.09 ± 1.08

[1]Number of observations per subclass given in table 1.
[2]Adjustment of data discussed on pages 19-21.

TABLE 5

ANGUS LINE EIGHT MEANS AND STANDARD ERROR FOR GAINS AND TYPE SCORES BY YEAR OF OBSERVATION[1,2]

YEAR	TOTAL DAILY GAIN	GAIN AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORE	
		PREWEAN	POSTWEAN		WEANING	YEARLING
1955	1.56 ± 0.10	1.54 ± 0.11	1.60 ± 0.16	174.5 ± 21.1	11.78 ± 0.77	9.84 ± 1.34
1956	1.42 ± 0.10	1.63 ± 0.11	1.24 ± 0.16	152.7 ± 21.2	11.40 ± 0.73	11.25 ± 1.25
1957	1.47 ± 0.11	1.56 ± 0.12	1.35 ± 0.17	167.8 ± 22.8	10.36 ± 0.77	11.21 ± 1.27
1958	1.38 ± 0.11	1.65 ± 0.12	1.14 ± 0.17	159.5 ± 23.9	11.35 ± 0.75	11.00 ± 1.27
1959	1.38 ± 0.08	1.49 ± 0.09	1.23 ± 0.13	212.6 ± 17.9	11.43 ± 0.62	10.31 ± 1.06
1960	1.54 ± 0.07	1.77 ± 0.08	1.31 ± 0.12	182.3 ± 15.8	11.96 ± 0.58	12.11 ± 1.01
1961						
1962	1.51 ± 0.08	1.60 ± 0.09	1.39 ± 0.13	193.6 ± 18.2	11.31 ± 0.61	11.51 ± 1.06
1963	1.55 ± 0.08	1.65 ± 0.09	1.46 ± 0.13	201.8 ± 17.9	11.75 ± 0.62	11.59 ± 1.08
1964	1.44 ± 0.11	1.62 ± 0.12	1.31 ± 0.17	181.6 ± 23.5	12.78 ± 0.75	13.03 ± 1.27
1965	1.43 ± 0.11	1.65 ± 0.12	1.25 ± 0.17	174.7 ± 23.8	12.27 ± 0.75	11.74 ± 1.27
1966	1.47 ± 0.10	1.64 ± 0.11	1.35 ± 0.17	188.9 ± 22.7	12.37 ± 0.73	11.73 ± 1.23
1967	1.40 ± 0.11	1.60 ± 0.12	1.27 ± 0.18	176.5 ± 24.4	11.93 ± 0.79	11.92 ± 1.32

[1]Number of observations per subclass given in table 1.
[2]Adjustment of data discussed on pages 19-21.

TABLE 6

HEREFORD LINE SIX MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY YEAR OF OBSERVATION[1,2]

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST	TYPE SCORE	
		PREWEAN	POSTWEAN	GAIN	WEANING	YEARLING
1960	1.51 ± 0.08	1.62 ± 0.10	1.38 ± 0.15	204.7 ± 22.4	11.50 ± 0.63	10.31 ± 0.72
1961	1.52 ± 0.15	1.77 ± 0.17	1.23 ± 0.27	181.4 ± 39.7	11.88 ± 1.11	9.95 ± 1.28
1962	1.46 ± 0.13	1.47 ± 0.14	1.39 ± 0.25	205.0 ± 35.6	11.26 ± 1.00	10.30 ± 1.11
1963	1.58 ± 0.12	1.61 ± 0.13	1.55 ± 0.24	226.1 ± 34.8	12.11 ± 0.98	10.87 ± 1.07
1964	1.47 ± 0.13	1.78 ± 0.13	1.20 ± 0.27	177.1 ± 39.0	12.06 ± 1.10	11.13 ± 1.08
1965	1.41 ± 0.10	1.55 ± 0.11	1.26 ± 0.20	185.5 ± 28.5	11.71 ± 0.80	10.70 ± 0.82
1966	1.54 ± 0.09	1.67 ± 0.10	1.39 ± 0.19	203.5 ± 26.7	11.44 ± 0.75	10.48 ± 0.79
1967	1.43 ± 0.08	1.45 ± 0.09	1.44 ± 0.16	200.7 ± 23.0	11.11 ± 0.65	11.68 ± 0.69

[1]Number of observations per subclass given in table 2.
[2]Adjustment of data discussed on pages 19-21.

TABLE 7

HEREFORD LINE EIGHT MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY YEAR OF OBSERVATION[1,2]

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORE	
		PREWEAN	POSTWEAN		WEANING	YEARLING
1960	1.38 ± 0.12	1.48 ± 0.13	1.23 ± 0.23	172.2 ± 33.2	11.87 ± 0.93	10.42 ± 1.05
1961	1.38 ± 0.15	1.44 ± 0.17	1.30 ± 0.30	181.5 ± 43.2	11.50 ± 1.21	12.04 ± 1.33
1962	1.35 ± 0.12	1.32 ± 0.13	1.35 ± 0.24	187.7 ± 34.0	11.69 ± 0.95	11.45 ± 1.01
1963	1.44 ± 0.12	1.44 ± 0.13	1.39 ± 0.24	194.9 ± 34.5	12.92 ± 0.97	11.99 ± 1.05
1964	1.33 ± 0.12	1.39 ± 0.13	1.24 ± 0.24	173.7 ± 34.2	11.43 ± 0.96	11.91 ± 0.99
1965	1.34 ± 0.11	1.42 ± 0.12	1.22 ± 0.23	170.5 ± 32.8	11.39 ± 0.92	11.90 ± 0.95
1966	1.43 ± 0.12	1.52 ± 0.13	1.29 ± 0.24	180.9 ± 34.0	11.77 ± 0.96	11.91 ± 0.99
1967	1.45 ± 0.12	1.66 ± 0.13	1.20 ± 0.24	167.6 ± 34.2	11.71 ± 0.96	12.42 ± 0.99

[1]Number of observations per subclass given in table 2.
[2]Adjustment of data discussed on pages 19-21.

TABLE 8

SHORTHORN LINE SEVEN MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY YEAR OF OBSERVATION[1,2]

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORE	
		PREWEAN.	POSTWEAN.		WEANING	YEARLING
1955	1.54 ± 0.14	1.39 ± 0.13	1.79 ± 0.25	193.1 ± 30.0	12.01 ± 1.33	9.03 ± 2.96
1956	1.37 ± 0.14	1.58 ± 0.12	1.22 ± 0.26	150.7 ± 30.6	12.56 ± 1.33	11.89 ± 2.95
1957	1.39 ± 0.14	1.53 ± 0.12	1.29 ± 0.26	158.9 ± 31.1	11.63 ± 1.35	10.94 ± 2.98
1958	1.54 ± 0.19	1.62 ± 0.18	1.45 ± 0.36	199.9 ± 42.7	12.17 ± 1.90	11.65 ± 4.28
1959	1.39 ± 0.10	1.34 ± 0.09	1.41 ± 0.18	239.4 ± 21.4	12.57 ± 0.95	11.55 ± 2.13
1960	1.46 ± 0.11	1.53 ± 0.10	1.36 ± 0.21	190.9 ± 24.3	12.52 ± 1.07	12.64 ± 2.38
1961						
1962	1.46 ± 0.09	1.50 ± 0.09	1.40 ± 0.18	197.7 ± 20.9	13.26 ± 0.92	12.56 ± 2.06
1963	1.55 ± 0.10	1.51 ± 0.09	1.53 ± 0.19	214.3 ± 21.9	13.57 ± 0.96	13.65 ± 2.15
1964	1.38 ± 0.11	1.43 ± 0.10	1.23 ± 0.21	173.9 ± 24.1	13.63 ± 1.07	13.67 ± 2.42
1965	1.57 ± 0.14	1.50 ± 0.13	1.54 ± 0.25	215.0 ± 29.8	13.85 ± 1.32	13.40 ± 2.95
1966	1.52 ± 0.10	1.54 ± 0.09	1.37 ± 0.18	194.0 ± 21.4	13.55 ± 0.96	13.44 ± 2.17
1967	1.49 ± 0.10	1.43 ± 0.10	1.42 ± 0.19	200.4 ± 22.3	12.53 ± 0.99	12.47 ± 2.22

[1]Number of observations per subclass given in table 3.
[2]Adjustment of data discussed on pages 19-21.

TABLE 9

SHORTHORN LINE EIGHT MEANS AND STANDARD ERRORS FOR GAINS AND TYPE SCORES BY YEAR OF OBSERVATION[1,2]

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORE	
		PREWEAN.	POSTWEAN.		WEANING	YEARLING
1955	1.61 ± 0.09	1.47 ± 0.10	1.85 ± 0.17	201.9 ± 19.3	11.04 ± 0.94	10.03 ± 2.23
1956	1.42 ± 0.10	1.70 ± 0.10	1.24 ± 0.18	153.9 ± 21.0	11.59 ± 0.98	12.19 ± 2.27
1957	1.35 ± 0.11	1.60 ± 0.11	1.19 ± 0.20	147.5 ± 23.2	10.75 ± 1.07	10.84 ± 2.48
1958	1.54 ± 0.11	1.58 ± 0.09	1.51 ± 0.18	208.2 ± 20.9	9.56 ± 0.95	12.13 ± 2.19
1959	1.60 ± 0.07	1.54 ± 0.07	1.68 ± 0.14	284.0 ± 15.8	11.27 ± 0.75	11.44 ± 1.75
1960	1.53 ± 0.07	1.69 ± 0.07	1.43 ± 0.14	201.1 ± 15.9	12.39 ± 0.75	11.92 ± 1.76
1961						
1962	1.48 ± 0.07	1.54 ± 0.07	1.47 ± 0.13	206.3 ± 14.9	12.84 ± 0.71	12.89 ± 1.69
1963	1.47 ± 0.09	1.57 ± 0.09	1.41 ± 0.16	198.6 ± 18.5	12.74 ± 0.86	12.29 ± 2.00
1964	1.50 ± 0.09	1.62 ± 0.09	1.32 ± 0.18	184.5 ± 20.5	12.10 ± 0.94	12.78 ± 2.16
1965	1.53 ± 0.10	1.77 ± 0.10	1.21 ± 0.19	170.0 ± 21.9	12.45 ± 1.00	13.07 ± 2.28
1966	1.50 ± 0.11	1.51 ± 0.11	1.42 ± 0.21	199.5 ± 24.5	12.49 ± 1.11	12.93 ± 2.52
1967	1.52 ± 0.12	1.59 ± 0.11	1.37 ± 0.21	192.1 ± 25.1	11.47 ± 1.15	13.09 ± 2.62

[1]Number of observations per subclass given in table 3.
[2]Adjustment of data discussed on pages 19-21.

TABLE 10

ANGUS LINE SEVEN MEANS AND STANDARD ERRORS FOR WEIGHTS BY YEAR OF OBSERVATION[1]

YEAR	WEIGHTS[2] BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1955	64.6 ± 4.9	383.5 ± 23.1	635.1 ± 34.5		
1956	65.3 ± 5.4	432.6 ± 25.8	657.5 ± 38.6		
1957	69.8 ± 5.1	416.8 ± 24.2	638.0 ± 37.2	792.8 ± 52.8	
1958	62.5 ± 5.9	406.7 ± 27.3	600.0 ± 43.3	849.0 ± 59.7	892.2 ± 66.7
1959	63.0 ± 5.9	361.3 ± 27.9	598.7 ± 42.6	794.7 ± 65.3	911.6 ± 80.0
1960	63.9 ± 4.5	430.3 ± 20.9	636.5 ± 32.7	758.7 ± 62.9	896.1 ± 90.0
1961				844.2 ± 53.1	865.5 ± 86.8
1962	60.5 ± 5.0	386.0 ± 23.1	608.1 ± 36.4	849.0 ± 88.4	887.7 ± 73.1
1963	64.2 ± 4.2	407.5 ± 19.5	613.9 ± 30.3	793.4 ± 54.4	896.7 ± 122.6
1964	70.1 ± 4.8	387.9 ± 22.8	586.3 ± 35.3	801.9 ± 47.3	844.3 ± 79.8
1965	64.2 ± 4.2	426.2 ± 19.8	625.1 ± 30.6	814.1 ± 51.9	875.9 ± 66.9
1966	63.0 ± 4.4	431.8 ± 20.9	640.4 ± 32.4	780.0 ± 45.9	875.7 ± 92.9
1967	61.9 ± 4.9	422.5 ± 23.1	633.8 ± 36.0	835.7 ± 48.7	903.8 ± 64.0
1968				816.8 ± 53.9	944.9 ± 79.6
1969					901.1 ± 92.0

[1]Number of observations per subclass given in table 1.
[2]Adjustment of data discussed on pages 19-21.

TABLE 11

ANGUS LINE EIGHT MEANS AND STANDARD ERRORS FOR WEIGHTS BY YEAR OF OBSERVATION[1]

YEAR	WEIGHTS[2]				
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1955	62.5 ± 5.1	374.6 ± 24.4	626.6 ± 35.9		
1956	68.9 ± 5.0	399.7 ± 23.7	596.5 ± 35.6		
1957	69.3 ± 5.3	388.6 ± 25.7	610.8 ± 39.1	735.0 ± 53.5	
1958	66.3 ± 5.5	398.7 ± 25.6	577.1 ± 39.7	792.9 ± 63.3	843.9 ± 69.2
1959	60.1 ± 4.2	359.0 ± 20.1	567.8 ± 29.3	759.2 ± 58.7	818.9 ± 85.7
1960	72.1 ± 3.8	431.3 ± 17.9	642.3 ± 26.7	761.8 ± 46.3	873.8 ± 81.9
1961				836.5 ± 52.2	820.3 ± 65.7
1962	69.5 ± 4.3	396.9 ± 20.0	626.4 ± 30.8	856.2 ± 46.1	846.8 ± 82.4
1963	65.4 ± 4.2	403.0 ± 19.8	638.5 ± 30.1	865.2 ± 45.7	883.5 ± 64.6
1964	72.2 ± 5.4	402.1 ± 25.4	607.1 ± 39.2	822.6 ± 47.4	903.9 ± 65.0
1965	69.9 ± 5.5	404.4 ± 25.8	598.6 ± 40.0	850.5 ± 57.5	875.9 ± 71.5
1966	71.2 ± 5.3	404.1 ± 24.8	613.9 ± 38.2	814.0 ± 57.9	780.6 ± 86.3
1967	69.3 ± 5.7	394.6 ± 26.8	589.3 ± 41.2	851.4 ± 58.2	884.4 ± 87.5
1968				816.1 ± 61.0	804.3 ± 126.4
1969					857.5 ± 97.5

[1]Number of observations per subclass given in table 1.
[2]Adjustment of data discussed on pages 19-21.

TABLE 12

HEREFORD LINE SIX MEANS AND STANDARD ERRORS FOR WEIGHTS BY YEAR OF OBSERVATION[1]

	WEIGHTS[2]				
YEAR	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1960	69.1 ± 4.9	400.7 ± 20.9	626.9 ± 21.5		
1961	65.6 ± 8.7	428.5 ± 37.8	634.1 ± 53.0		
1962	63.3 ± 7.3	365.0 ± 31.0	601.7 ± 45.4	786.9 ± 81.7	
1963	68.4 ± 6.9	397.5 ± 29.1	645.7 ± 43.3	747.0 ± 61.1	927.9 ± 91.5
1964	68.8 ± 7.3	432.1 ± 29.9	620.9 ± 46.1	724.9 ± 92.0	941.0 ± 66.9
1965	70.2 ± 5.6	389.3 ± 23.4	593.7 ± 35.0	743.3 ± 105.0	993.0 ± 90.7
1966	69.7 ± 5.4	412.4 ± 22.6	638.4 ± 33.3	735.0 ± 77.3	842.4 ± 95.4
1967	74.8 ± 4.5	371.6 ± 18.9	599.2 ± 28.3	758.2 ± 75.7	975.1 ± 78.4
1968					920.7 ± 49.5

[1]Number of observations per subclass given in table 2.
[2]Adjustment of data discussed on pages 19-21.

TABLE 13

HEREFORD LINE EIGHT MEANS AND STANDARD ERRORS FOR WEIGHTS BY YEAR OF OBSERVATION[1]

YEAR	WEIGHTS[2]				
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1960	63.0 ± 6.9	366.7 ± 29.2	575.1 ± 42.5		
1961	66.6 ± 9.0	360.8 ± 38.3	573.9 ± 55.4		
1962	60.0 ± 6.6	330.9 ± 27.6	552.7 ± 41.6	749.8 ± 90.9	
1963	61.1 ± 6.9	356.5 ± 28.6	591.3 ± 42.8	706.9 ± 93.9	966.8 ± 90.6
1964	62.9 ± 6.7	347.1 ± 27.9	554.2 ± 42.1	729.6 ± 103.4	956.4 ± 90.6
1965	66.3 ± 6.5	356.6 ± 27.0	562.1 ± 40.6	743.9 ± 93.1	928.5 ± 94.9
1966	56.8 ± 6.8	367.7 ± 28.4	585.7 ± 42.3	727.6 ± 86.8	886.0 ± 89.7
1967	59.3 ± 6.7	398.7 ± 28.0	599.7 ± 42.2		1068.8 ± 88.2
1968					1013.8 ± 95.4

[1]Number of observations per subclass given in table 2.
[2]Adjustment of data discussed on pages 19-21.

TABLE 14

SHORTHORN LINE SEVEN MEANS AND STANDARD ERRORS FOR WEIGHTS BY YEAR OF OBSERVATION[1]

YEAR	WEIGHTS[2]					
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS	43 MONTHS
1955	64.3 ± 6.1	345.3 ± 27.9	616.8 ± 49.3			
1956	63.2 ± 6.2	385.2 ± 27.7	570.3 ± 49.9			
1957	65.0 ± 6.3	376.7 ± 27.9	577.9 ± 50.6	644.6 ± 72.2		
1958	68.8 ± 8.7	397.0 ± 40.0	638.2 ± 70.2	662.2 ± 73.9	717.8 ± 88.0	
1959	65.2 ± 4.4	337.2 ± 20.0	572.6 ± 35.2	674.9 ± 98.8	718.0 ± 92.8	938.7 ± 104.7
1960	73.4 ± 5.0	385.9 ± 22.2	609.1 ± 39.8	684.3 ± 50.6	756.3 ± 68.7	1049.9 ± 111.5
1961				710.9 ±108.6		931.5 ± 79.3
1962	73.3 ± 4.3	379.7 ± 19.3	608.6 ± 34.2	760.0 ± 58.8		
1963	70.3 ± 4.5	377.8 ± 20.3	634.3 ± 35.9	805.0 ± 48.2	813.2 ± 76.6	
1964	75.1 ± 4.9	366.2 ± 23.1	584.3 ± 39.7	735.4 ± 50.3	895.3 ± 63.1	1027.4 ± 97.6
1965	72.2 ± 6.1	379.3 ± 28.3	646.1 ± 49.0	780.1 ± 59.0	867.6 ± 65.9	1035.6 ± 73.7
1966	76.6 ± 4.4	389.7 ± 21.2	636.0 ± 35.3	789.1 ± 68.9	845.8 ± 74.8	944.0 ± 76.5
1967	82.2 ± 4.6	374.1 ± 21.7	629.0 ± 36.7	835.6 ± 50.6	899.1 ± 91.3	1018.6 ± 106.8
1968				795.9 ± 55.6	911.5 ± 67.0	952.2 ± 125.5
1969						1003.2 ± 85.1

[1]Number of observations per subclass given in table 3.
[2]Adjustment of data discussed on pages 19-21.

TABLE 15

SHORTHORN LINE EIGHT MEANS AND STANDARD ERRORS FOR WEIGHTS BY YEAR OF OBSERVATION[1]

	WEIGHTS[2]					
YEAR	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS	43 MONTHS
1955	71.1 ± 4.1	372.6 ± 21.4	648.0 ± 32.8			
1956	71.4 ± 4.4	421.1 ± 21.7	601.5 ± 35.2			
1957	73.5 ± 4.8	402.6 ± 23.9	574.4 ± 38.7	759.6 ± 47.2		
1958	69.5 ± 4.3	393.8 ± 20.4	635.1 ± 34.6	775.0 ± 59.3	851.9 ± 56.1	
1959	70.9 ± 3.3	385.1 ± 16.4	654.5 ± 26.6	764.7 ± 48.3	789.7 ± 71.5	921.6 ± 85.5
1960	74.2 ± 3.3	418.7 ± 16.5	637.8 ± 26.7	877.2 ± 39.5	889.0 ± 60.7	965.5 ± 107.3
1961				800.6 ± 55.1	933.4 ± 49.3	971.9 ± 92.4
1962	72.5 ± 3.1	385.3 ± 15.8	615.3 ± 25.2	789.6 ± 47.3	842.2 ± 68.0	993.7 ± 76.8
1963	71.4 ± 3.8	389.0 ± 18.7	612.2 ± 30.9	794.9 ± 35.1	833.4 ± 60.6	927.7 ± 103.2
1964	80.7 ± 4.2	409.2 ± 20.8	635.6 ± 34.1	765.2 ± 45.0	884.7 ± 48.9	910.5 ± 82.2
1965	77.7 ± 4.5	439.0 ± 22.1	650.2 ± 36.4	734.3 ± 48.1	841.9 ± 60.7	955.0 ± 64.4
1966	75.8 ± 5.1	382.2 ± 23.9	626.5 ± 40.6	693.6 ± 51.3	785.6 ± 64.0	819.1 ± 83.5
1967	76.6 ± 5.2	399.7 ± 25.0	639.5 ± 41.7	781.5 ± 57.5	959.9 ± 71.5	903.5 ± 93.6
1968				699.3 ± 58.6	800.8 ± 79.8	963.0 ± 92.7
1969					837.6 ± 78.5	929.3 ± 101.0

[1]Number of observations per subclass given in table 3.
[2]Adjustment of data discussed on pages 19-21.

TABLE 16

ANGUS LINE SEVEN GAIN AND TYPE SCORE ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST	TYPE SCORES	
		PREWEAN	POSTWEAN	GAIN	WEANING	YEARLING
1955	-0.04	0.19	-0.21	3.6	1.31	1.70
1956	-0.07	-0.04	-0.01	11.2	1.53	0.49
1957	-0.01	0.06	0.01	15.1	1.53	0.21
1958	0.09	0.08	0.19	23.7	0.76	-0.30
1959	0.07	0.28	-0.03	-47.3	1.55	0.57
1960	-0.01	-0.04	0.09	10.6	1.01	0.69
1961	-0.01	-0.04	0.09	10.6	1.01	0.69
1962	0.05	0.17	0.03	1.9	1.17	0.48
1963	0.05	0.07	0.09	8.9	0.38	-0.58
1964	0.13	0.19	0.08	7.6	0.49	-0.04
1965	0.03	-0.02	0.08	11.2	-0.12	-0.14
1966	-0.02	-0.06	0.03	1.7	-0.30	-0.41
1967	0.00	0.00	0.00	0.0	0.00	0.00

TABLE 17

ANGUS LINE EIGHT GAIN AND TYPE SCORE ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORES	
		PREWEAN	POSTWEAN		WEANING	YEARLING
1955	-0.16	0.06	-0.33	2.0	0.15	2.08
1956	-0.02	-0.03	0.03	23.7	0.53	0.67
1957	-0.07	0.04	-0.08	8.6	1.57	0.61
1958	0.02	-0.05	0.13	16.9	0.58	0.92
1959	0.02	0.11	0.04	-36.1	0.50	1.61
1960	-0.14	-0.17	-0.04	- 5.9	-0.03	-0.19
1961	-0.14	-0.17	-0.04	- 5.9	-0.03	-0.19
1962	-0.11	0.00	-0.12	-17.1	0.62	0.41
1963	-0.15	-0.05	-0.19	-25.3	0.18	0.33
1964	-0.04	-0.02	-0.04	- 5.1	-0.85	-1.11
1965	-0.03	-0.05	0.02	1.8	-0.34	0.18
1966	-0.07	-0.04	-0.08	-12.4	-0.44	0.19
1967	0.00	0.00	0.00	0.0	0.00	0.00

TABLE 18

HEREFORD LINE SIX GAIN AND TYPE SCORE ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST	TYPE SCORES	
		PREWEAN	POSTWEAN	GAIN	WEANING	YEARLING
1960	-0.08	-0.17	0.06	- 3.9	-0.39	1.37
1961	-0.09	-0.32	0.21	18.9	-0.77	1.73
1962	-0.03	-0.02	0.05	- 4.3	-0.15	1.38
1963	-0.15	-0.16	-0.11	-25.3	-1.00	0.81
1964	-0.04	-0.33	0.24	23.6	-0.95	0.55
1965	0.02	-0.10	0.18	15.2	-0.60	0.98
1966	-0.11	-0.22	0.05	- 2.8	-0.33	1.19
1967	0.00	0.00	0.00	0.0	0.00	0.00

TABLE 19

HEREFORD LINE EIGHT GAIN AND TYPE SCORE ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORES	
		PREWEAN	POSTWEAN		WEANING	YEARLING
1960	0.07	0.18	-0.03	- 4.6	-0.16	2.00
1961	0.07	0.22	-0.10	-13.9	0.21	0.38
1962	0.10	0.34	-0.15	-20.1	0.02	0.97
1963	0.01	0.22	-0.19	-27.2	-1.21	0.43
1964	0.12	0.27	-0.04	- 6.1	0.28	0.51
1965	0.11	0.24	-0.02	- 2.9	0.32	0.52
1966	0.02	0.14	-0.09	-13.3	-0.08	0.51
1967	0.00	0.00	0.00	0.0	0.00	0.00

TABLE 20

SHORTHORN LINE SEVEN GAIN AND TYPE SCORE ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST	TYPE SCORES	
		PREWEAN	POSTWEAN	GAIN	WEANING	YEARLING
1955	-0.05	0.04	-0.37	7.3	1.5	3.4
1956	0.12	-0.17	0.20	49.7	0.9	0.6
1957	0.10	-0.10	0.13	41.5	1.7	1.5
1958	-0.05	-0.19	-0.03	0.5	0.7	0.8
1959	0.10	0.09	0.01	-40.0	0.3	0.9
1960	-0.03	-0.10	0.06	9.5	0.5	-0.2
1961	-0.03	-0.10	0.06	9.5	0.5	-0.2
1962	-0.03	-0.07	0.02	2.6	-0.2	-0.1
1963	-0.06	-0.08	-0.11	-13.9	-0.7	-1.2
1964	0.11	0.00	0.19	26.5	-1.0	-1.2
1965	-0.08	-0.07	-0.12	-14.6	-1.3	-0.9
1966	-0.03	-0.11	0.05	6.4	-1.0	-1.0
1967	0.00	0.00	0.00	0.0	0.0	0.0

TABLE 21

SHORTHORN LINE EIGHT GAIN AND TYPE SCORE ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

YEAR	TOTAL DAILY GAIN	AVERAGE DAILY GAIN		TEST GAIN	TYPE SCORES	
		PREWEAN	POSTWEAN		WEANING	YEARLING
1955	-0.09	0.12	-0.48	- 9.8	1.41	3.06
1956	0.10	-0.11	0.13	38.2	0.78	0.90
1957	0.17	-0.01	0.18	44.6	1.76	2.25
1958	-0.02	0.01	-0.14	-16.1	2.48	0.96
1959	-0.08	0.05	-0.31	-91.9	0.65	1.65
1960	-0.01	-0.10	-0.06	- 9.0	-0.29	1.17
1961	-0.01	-0.10	-0.06	- 9.0	-0.29	1.17
1962	0.04	0.05	-0.10	-14.3	-0.76	0.20
1963	0.05	0.02	-0.04	- 6.5	-0.88	0.80
1964	0.02	-0.03	0.05	7.6	-0.60	0.31
1965	-0.01	-0.18	0.16	22.1	-0.99	0.02
1966	0.02	0.08	-0.05	- 7.4	-0.94	0.16
1967	0.00	0.00	0.00	0.0	0.00	0.00

TABLE 22

ANGUS LINE SEVEN WEIGHT ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

	WEIGHTS				
YEAR	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1955	-2.8	39.1	- 1.3		
1956	-3.5	-10.1	-23.7		
1957	-7.9	5.7	- 4.2	24.0	
1958	-3.6	15.8	33.9	-32.2	8.9
1959	-1.2	61.2	35.1	22.1	-10.5
1960	-2.1	- 7.8	- 2.6	58.1	5.0
1961	-2.1	- 7.8	- 2.6	-27.4	35.7
1962	1.3	36.6	25.7	-32.2	13.4
1963	-2.3	15.1	19.9	23.4	4.4
1964	-8.3	34.7	47.6	14.9	56.8
1965	-2.4	- 3.7	8.7	2.7	25.2
1966	-1.2	- 9.3	- 6.5	36.8	25.4
1967	0.0	0.0	0.0	-18.9	- 2.7
1968				0.0	-34.7
1969					0.0

TABLE 23

ANGUS LINE EIGHT ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

	WEIGHTS				
YEAR	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1955	6.8	20.1	-37.3		
1956	0.4	- 5.1	- 7.2		
1957	0.0	6.0	-21.4	81.0	
1958	3.1	- 4.1	12.2	23.2	13.6
1959	9.3	35.7	21.5	56.9	38.5
1960	-2.7	-36.6	-53.0	54.3	-16.3
1961	-2.7	-36.6	-53.0	-20.4	37.2
1962	-0.1	- 2.2	-37.0	-40.1	10.7
1963	3.9	- 8.3	-49.2	-49.1	-26.0
1964	-2.9	- 7.5	-17.7	- 6.5	-46.4
1965	-0.6	- 9.7	- 9.3	-34.4	-18.5
1966	-1.9	- 9.5	-24.6	2.1	76.9
1967	0.0	0.0	0.0	-35.3	-26.9
1968				0.0	53.2
1969					0.0

TABLE 24

HEREFORD LINE SIX WEIGHT ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

YEAR	WEIGHTS				
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1960	5.7	-29.1	-27.7		
1961	9.1	-56.9	-35.0		
1962	11.5	6.6	- 2.5	-28.7	
1963	6.4	-25.9	-46.5	11.2	0.0
1964	5.9	-60.5	-21.7	33.3	-13.1
1965	4.6	-17.7	5.5	14.9	-65.1
1966	5.1	-40.8	-39.2	23.2	85.5
1967	0.0	0.0	0.0	0.0	-47.1
1968					7.2

TABLE 25

HEREFORD LINE EIGHT WEIGHT ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

YEAR	WEIGHTS				
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS
1960	-3.7	31.7	24.6		
1961	-7.3	37.9	25.8		
1962	-0.7	67.8	47.0	-22.2	
1963	-1.8	42.1	8.5	20.7	0.0
1964	-3.6	51.5	45.5	- 2.0	10.4
1965	-7.0	42.1	37.6	-16.3	38.3
1966	2.5	31.0	14.0	0.0	80.8
1967	0.0	0.0	0.0	0.0	-101.9
1968					- 47.0

TABLE 26

SHORTHORN LINE SEVEN WEIGHT ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

	WEIGHTS					
YEAR	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS	43 MONTHS
1955	17.9	28.8	12.3			
1956	19.0	-11.0	58.7			
1957	17.2	- 2.5	51.1	151.3		
1958	13.4	-22.8	- 9.2	133.7	0.0	
1959	17.0	37.0	56.4	121.0	- 0.1	64.5
1960	8.8	-11.8	20.0	111.6	- 38.4	-46.7
1961	8.8	-11.8	20.0	85.0	- 38.4	71.7
1962	8.9	- 5.5	20.4	36.2		71.7
1963	11.9	- 3.7	- 5.3	- 9.7	- 95.4	
1964	7.1	8.0	44.7	60.5	-177.5	-24.2
1965	10.0	- 5.1	-17.1	15.8	-149.7	-32.4
1966	5.6	-15.6	- 7.0	6.8	-128.0	59.2
1967	0.0	0.0	0.0	- 39.7	-181.3	-15.4
1968				0.0	-193.6	51.0
1969					-193.6	0.0

TABLE 27

SHORTHORN LINE EIGHT WEIGHT ADJUSTMENT FACTORS FOR YEAR OF OBSERVATION

YEAR	WEIGHTS					
	BIRTH	205 DAYS	12 MONTHS	19 MONTHS	31 MONTHS	43 MONTHS
1955	5.4	27.1	- 8.5			
1956	5.1	-21.4	38.0			
1957	3.1	- 2.9	65.1	- 60.3		
1958	7.0	5.9	4.4	- 75.7	0.0	
1959	5.6	14.6	-15.0	- 65.4	62.2	7.7
1960	2.4	-19.0	1.7	-177.9	- 31.1	- 36.1
1961	2.4	-19.0	1.7	-101.3	- 81.5	- 42.5
1962	4.1	14.4	21.1	- 90.3	9.7	- 64.3
1963	5.2	10.7	27.3	- 95.6	18.5	1.6
1964	-4.1	- 9.5	3.9	- 65.9	- 32.8	18.8
1965	-1.5	-39.3	-10.7	- 35.0	10.0	- 25.7
1966	0.8	17.5	12.9	5.7	66.3	110.2
1967	0.0	0.0	0.0	- 82.2	-108.0	25.8
1968				0.0	51.1	- 33.6
1969					14.3	0.0

TABLE 28

AGE OF DAM CORRECTION FACTORS FOR WEIGHTS AT 19 MONTHS OF AGE

AGE[1] OF DAM	ADJUSTMENTS
2	33.6
3	32.6
4	6.9
5	- 1.1
6	6.2
7	0.0
8	14.8
9[2]	11.6

[1]Age in years
[2]Includes 9 years and older

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ESTIMATED GENETIC TRENDS FOR WEIGHTS, GAINS AND TYPE SCORES IN LINES OF ANGUS, HEREFORD AND SHORTHORN FEMALES SELECTED FOR EARLY GROWTH OR TYPE

by

Larry Lee Benyshek

(ABSTRACT)

The purpose of the study was to evaluate the genetic trends in lines of Angus, Hereford and Shorthorn females which had been selected for early growth or type. One line of the Hereford breed was selected on the basis of an index combining both type and growth. All cattle were maintained at the Beef Cattle Research Station, Front Royal, Virginia. Complete records, birth to approximately one year of age, were available on 299 Shorthorn, 283 Aberdeen Angus and 147 Hereford females. A lesser number of weights at the ages of 19, 31 and 43 months of age were also available. Little statistical significance was detected from the various analyses performed because of insufficient numbers of observations. Results were not conclusive as to whether there had been genetic change for the several traits in the various lines because of the lack of statistical significance. The magnitudes of estimates from the data were large indicating the possibility of genetic change but standard errors for these values were also large. It was suggested but not proven that selection for early growth had not changed the weights of females at later ages over the years of selection. Yearling type selection seems to have decreased the later weights of the Shorthorn females, but again results were not conclusive. The analyses

did not indicate statistical significance, but there was a positive genetic trend for the direct selection criterion in the lines under selection for type or growth. The Hereford index line also indicated a positive, but nonsignificant trend for type and growth. It would appear that a sample size larger than the one available for this study is necessary to accurately determine genetic trends in beef cattle without a genetic control line.