EVALUATION OF PHENOTYPIC AND GENETIC TRENDS IN WEANING WEIGHT IN ANGUS AND HEREFORD POPULATIONS IN VIRGINIA

by

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INTRODUCTION

The goal of animal breeding programs is to enhance genetic merit for economically important traits by improving the average genetic constitution of a population of animals. Thus, evaluation of genetic progress for economic traits becomes an essential part of successful planning of future breeding schemes, as well as providing documentation of progress from past selection.

The genetic merit of an individual is the reflection of the average effect of the genes it carries, but the average level of performance at any point in the individual's life is a function of both genetic merit and environment. Therefore, any change in performance of a population over time should be the outcome of change in one or both of these components. More precisely, genetic trend is the change in performance per unit of time due to change in additive genetic merit, or mean breeding value, of successive progeny groups. The change in production per unit of time due to change in environment denotes the environmental trend. Phenotypic trend is the sum of the above two measurements or the total change in performance per unit of time. The rate of genetic change in a population depends largely on the heritabilities of the traits considered in selection, the intensity of selection applied and the generation interval.

Problems Encountered in Estimation of Trends

The basic problem confronting animal scientists is the accurate estimation of the genetic and environmental portions of the total phenotypic trend. If either portion could be estimated, then separating that portion from the total phenotypic trend would not be difficult. However, obtaining unbiased estimates for either genetic or environmental trend is extremely difficult because of the confounding of changes in the environment with changes in genotype and the complex manner in which individuals express their performance in a particular environment. If the environmental trend or magnitude of the environmental fluctuations are known, then confounding of environmental and genetic changes may be reduced by proper adjustments. On the other hand, if the environment is constant over time, the genetic change is simply the phenotypic change in the absence of any genotype-environment interaction. Obviously, it would be extremely difficult to maintain a constant environment in a field situation and different genotypes may respond differently under a range of controlled environments.

Early literature on estimation of genetic trends clearly indicates the difficulty in obtaining unbiased estimates of genetic and environmental components, particularly from field data. However, with the current understanding of the concepts involved and the advent of high speed computers, much more efficient estimates can be obtained with less bias. Presently, the available procedures for appraising or evaluating genetic and environmental trends in selection experiments vary depending on the experimental situations (i.e., controlled laboratory experiments vs field experiments). In all of these approaches, whether implicitly or explicitly stated, a regression procedure assumes a central role.

Reasons for Estimating Trends in Beef Cattle

Historically, one finds that the research in estimation of genetic trends in beef cattle research has been minimal compared to that in dairy cattle. The widespread use of artificial insemination, which produces large half-sib groups among dairy herds across the nation, has generated an increasing interest among dairy scientists in evaluation of genetic progress at different time intervals. For example, estimation of genetic trends for dairy cattle performance traits reported by Van Vleck and Henderson (1961), Arave et al. (1964), Everett et al. (1967), Harville and Henderson (1967), Powell and Freeman (1974), Tomar and Singh (1981) and Schaeffer et al. (1982) cover the literature on most trend evaluation studies in dairy cattle. In comparison, the few available early studies in beef cattle have been confined to small, closed herd populations (Brinks et al., 1961,1965; Armstrong et al., 1965; Nelms and Stratton, 1967; Baily et al., 1971; Schalles and Marlowe, 1971). However, in recent years, as in dairy cattle breeding, major emphasis has been given to performance and progeny testing and extensive use of AI sires in North American beef cattle herds. Thus, many beef herds have adopted some kind of selective breeding policy. Consequently, increasing interest among beef cattle geneticists in estimation of genetic progress from herds involved in regional and national programs are evident from recent research publications (Kennedy and Henderson, 1977; Schaeffer et al., 1981; Crow and Howell, 1983; Zollinger and Nielsen, 1984). Therefore, the need for more investigations of genetic progress in beef cattle populations is apparent.

Scope and Objectives of Study

A state program for beef cattle improvement (Beef Cattle Improvement Association, BCIA) has been in operation in Virginia since 1954 to assist beef breeders in the genetic improvement of their herds. Therefore, it is assumed that every herd participating in this program has been following some kind of selective breeding policy since enrolling in the program. Records on weights of all calves at weaning are available through the Virginia BCIA. The genetic composition of these calves at any time is a sample of the gene pool of their parents. Thus, the change in the genetic composition of calves in the population for economic traits should provide an estimate of net genetic change resulting from these breeding programs.

In order to investigate this change, this study was undertaken with the following objectives.

1. To study the phenotypic change over time in performance of successive progeny groups in each herd, as well as in all herds combined, using records of 13 Angus and 11 Hereford herds throughout Virginia.
2. To estimate the genetic and environmental trends in preweaning growth traits in the above herds from the corresponding phenotypic trends.
3. To attempt to partition the overall genetic trend into direct additive and maternal additive components.

REVIEW OF LITERATURE

Approaches to Estimation of Phenotypic and Genetic Trends

The estimation of phenotypic trend for performance is straightforwardly the regression of the actual records of performance on time. However, the important question is whether the improvement came through selection for superior genes or simply through improvement of the environment or both. If the environment could be held constant, then the estimation of genetic trend could be obtained by simply measuring the phenotypic trend. However, under farm condition this is not possible. Hence, several techniques have been developed and tried for obtaining estimates of genetic and environmental trends in selection experiments.

Maintenance of a random-bred unselected control population along with the selection lines has been used extensively in selection experiments with laboratory animals (Broy et al., 1962; Orozco and Bell, 1974) to measure environmental change over time. In such situations, environmental change was computed as differences in performance for control stocks in consecutive years. Unlike carefully planned laboratory experiments, maintenance of control populations along with selection lines in selection experiments involving large animals is extremely difficult and would be very expensive. For these reasons, only a few studies have been conducted in large animal breeding experiments using control populations. In order to overcome this problem to some extent, Smith (1977) suggested the use of stored frozen semen and embryos to reproduce a genetic base.

Hill (1972) discussed the use of a control population to estimate genetic change and gave suggestions to effectively maintain control lines. Also, in his review paper, Hill (1972) discussed the bias in genetic trend estimates because of nonrandom mating, sampling error, random genetic drift and small effective number. Hill emphasized that even without environmental trends and with only random fluctuations between generations, precision of estimates of selection response could be substantially improved by using deviations from control performance. However, if genetic change in the selected line yields genotypes which give new responses to environmental change (genotype x environment interaction), then the random mating, unselected, control population will not be helpful in separating genetic and environmental trends.

An alternate method to estimate the rate of genetic change in single trait selection experiments is to utilize information from the actual selection practiced with truncation selection. Such an approach has been tried in dairy cattle (Rendel and Robertson, 1950, Acharya and Lush, 1968) and in sheep (Peters et al., 1961). The phenotypic selection differential for a particular trait from such truncation selection experiments can be computed and multiplied by the heritability estimate of the trait to obtain the apparent genotypic selection differential. The rate of improvement will depend on the mean generation length of the species. Further, in the absence of a control population, a much more refined selection procedure to assess progress would be to use divergent selection, where individuals are selected for high and low merit for a particular trait. In such divergent selection experiments (Hill, 1972), environmental effects would not be confounded with net genetic change and no additional expense is involved in maintaining a control population. However, one has to be very careful when using this estimate of genetic change because, often, multiple traits of economical importance are considered in selection goals. Examples of multiple-trait selection criteria would include milk and butterfat in dairy cattle and growth rate and feed efficiency in beef cattle. In such situations, if negative pleiotropic effects exist among the traits considered for selection (as they may in the dairy cattle example) then the selection differential will be underestimated. Furthermore, in order to quantify genetic progress from selection differentials, one has to estimate the heritability values from data appropriate for that particular population. Often, such estimates will have large standard errors.

Another approach to estimating genetic and environmental change would be to use an experimental design similar to the one proposed by Goodwin et al. (1960). In their model, progenies are replicated at different generations from the same parents or grandparents. The mean performance of progenies of such repeated matings in successive years should have the same genetic expectations, and differences in performance are assumed to account for environmental changes. Such repeat-mating techniques have been used by Giesbrecht and Kempthorne (1965) in poultry and Burnside and Legates (1967) in dairy cattle to estimate environmental and genetic trends. A similar approach could be used in beef cattle. However, the performance of two progenies of the same parents in successive years will vary not only due to the changes in feeding and management practices but also due to increase in age of the dam. Therefore, in such an approach, all records must be adjusted to a standard age of dam before obtaining any estimates (Powell and Freeman, 1974). Rendel and Robertson (1950) gave an excellent account of the bias which can arise from attempting to correct for environmental factors. They concluded that the magnitude of the bias due to age of dam adjustment factors was much larger than with other effects. In their view, even a small error in age of dam adjustment factors could introduce a substantial cumulative bias in the estimation of genetic and environmental change.

A method proposed by Smith (1962) to estimate genetic trend from field records compares the performance of the progeny of individual sires with the mean of the population for each year. In his method, the within-sire (S) changes in performance (P) over time (T) is assumed to be composed of environmental change plus one-half the genetic change associated with selection of sires. Thus, deviating the individual's record from the contemporary average is believed to eliminate the environmental component. Therefore, the estimate of genetic trend due to sire selection is obtained from the pooled intrasire regression of sire progeny on time, where the records are deviated from the contemporary average as shown in the formula:

$$2[\hat{\beta}(\bar{P}_S - \bar{P})\cdot Y/\text{sire}]$$

where $(P_S - \bar{P})$ is the deviated sire progeny value from the contemporary average and $\hat{\beta}$ is the regression on years (Y) estimated within sires, (Y/sire). The expectation of the above estimate would be a negative one-half of the genetic trend. In this approach, one can see how the sires of the cows in the population improve over time relative to known sires whose genotypes are assumed to be constant. Smith acknowledged the fact that genetic change estimated by this method may be biased by the selection of sires based on the performance of first progeny or by the systematic relationship of the length of time a sire remained in service and age or production of the sire's mates. However, in spite of all these limitations, Smith's (1962) method laid the foundation for the development of an extremely important basic model for the understanding of the several aspects of measuring genetic change in farm animals. Regardless of the nature of the bias involved by failure to satisfy the above-mentioned assumptions, Smith's (1962) method has been extensively used with slight or no modifications to estimate genetic trends in dairy cattle (Arave et al., 1964; Acharya and Lush, 1968; Powell and Freeman, 1974; Tomar and Singh, 1981; Cicogna et al., 1982; Gurnani and Nagarcenkar, 1982), swine (Standal, 1979), beef cattle (Zabel, 1973; Zollinger and Nielsen, 1984) and dairy goats (Singh and Acharya, 1982).

Following the work of Harville and Henderson (1967) and Everett et al. (1967), Powell and Freeman (1974) in Iowa and Cicogna et al. (1982) in Italy used a modification of the procedure of Smith (1962) to obtain more efficient estimates of genetic trend from first lactation records in dairy cattle. Their modified procedure is assumed to eliminate the bias in genetic trends associated with assortative mating (top proven bulls being bred to best cows in herd) and female culling practices. It might be possible also, to apply such an approch to obtain efficient estimates of genetic trends in beef cattle performance data.

For intraherd estimation of genetic trend in dairy cattle, Cicogna et al. (1982) used the following formula:

$$\hat{G} = \frac{-2[b(P - \bar{P})\cdot T/H,S - \frac{\Delta D}{2}}{1 + \Delta A}$$

where, $b(P - \bar{P})\bullet T/H,S$ is the regression coefficient of the deviated first lactation record of an individual (P) from the herd mean ($\bar{P}$) on time (T) within herd (H) and sires (S). ΔD is an adjustment to account for the dam's merit resulting from assortative mating. It is estimated as $\Delta D = h^2 b(DP - \overline{DP})\bullet T/H,S$, which is the product of the heritability (h^2) of the trait of interest with the within-sire and herd regression of dam's deviated first lactation production on time. ΔA is an estimate used to adjust for culling of females and is estimated by:

$$\Delta A = bDA\bullet T/H,S - bDA\bullet T/H$$

where, $bDA\bullet T/HS$ and $bDA\bullet T/H$ are the regression coefficients of dam's age (DA) on time of birth (T), within-herd and sires, and within herd, respectively.

Researchers at Cornell and Iowa State Universities (Henderson et al., 1959) also became interested in developing new procedures for predicting unbiased estimates of genetic merit of individuals from progeny test records of dairy cattle. Perhaps the most fruitful procedure for evaluating genetic and environmental changes has emerged from the work of these two groups. Van Vleck and Henderson (1961) proposed a more refined least-squares procedure to estimate genetic and environmental trends simultaneously for dairy cattle performance data. By utilizing the basic least-squares procedures in linear models, this group has developed more formal and complex theoretical approaches using such analytical techniques as the best linear unbiased prediction (BLUP) and maximum likelihood estimation from mixed models to obtain unbiased estimates of genetic and environmental trends. Subsequently, Henderson (1973) presented his classic paper on mixed-model techniques for maximum likelihood estimation at the symposium held in honor of Dr. J. L. Lush in 1972. Since then, his procedure has enjoyed considerable success in predicting unbiased estimates of genetic change. Following that symposium, several studies for measurement of genetic change have been carried out utilizing maximum likelihood estimation procedures in mixed-model techniques (Schaeffer and Wilton, 1975; Kennedy and Henderson, 1977; Hintz et al., 1978; Eriksson et al., 1979; Danell and Eriksson, 1982; Crow and Howell, 1983).

The BLUP procedure is often used in dairy sire evaluation to estimate breeding values of sires and dams and to describe genetic change in the population. Slanger (1979) described the application of Henderson's mixed-model (BLUP) methodology more specifically to beef cattle with an example based on performance test data. Later, in a fairly complex formulation, Quass and Pollak (1980) and Pollak and Quass (1984) outlined the genetic evaluation procedure of BLUP methodology which would also accommodate multitrait selection in beef cattle. However, in order to estimate breeding values, all these procedures require the knowledge of the genetic variances and covariances of the direct and maternal influences on the traits in question.

Such a procedure can be briefly described in the following manner. A simple "animal model" for a weaning weight record on the jth calf in beef cattle can be written as (Slanger, 1979):

$$Y_{ijk} = h_{ijk} + d_j + m_k + e_{ijk} \qquad (1)$$

where,

Y_{ijk} is the observed weaning weight on the jth animal.

h_i is the fixed effect of herd-year subclass i on the jth animal's weaning weight.

d_j is the direct additive genetic value of individual j (which is the direct additive genetic effect for growth contributed by a sample of genes from its parents).

m_k is the maternal additive genetic value of the individual k influencing her offspring j's weaning weight.

e_{ijk} is the random residual (environmental effect) associated with the individual j's weaning weight.

The above described mixed model (1) can be represented in a matrix notation as:

$$Y = Xb + Zu + e \qquad (2)$$

where,

Y is the vector of observations (weaning weight of the individual j).

b is an unknown vector of fixed effects (herd-year means) for which estimable functions are to be estimated.

u is an unknown vector of direct and maternal additive genetic values reflected on the weaning weight of j.

e is an unknown vector of the random residual effects related to the weaning weight of the individual j.

X is a known design matrix representing the fixed effects affecting the individual j's weaning weight, and

Z is a known design matrix representing the random direct and maternal effects related to the weaning weight record of the particular individual j.

Thus, if we translate the above described properties to the animal model (1) for weaning weight, then the expectations, variances and covariances of the model are (Slanger, 1979):

$$E(d_j) = E(m_k) = E(e_{ijk}) = 0 \text{ and } E(h_i) = b_t$$

and

$$Var \begin{bmatrix} u_d \\ u_m \\ e \end{bmatrix} = \begin{bmatrix} \sigma_d^2 & d_{dm} & 0 \\ & \sigma_m^2 & 0 \\ \text{symmetric} & & \sigma_e^2 \end{bmatrix}$$

where, σ_d^2 is the additive genetic variance for direct, σ_m^2 is the additive genetic variance for maternal and σ_{dm} is the additive genetic covariance for direct and maternal and σ_d^2 is the environmental variance. The mixed model equations for such model would be (Pollack and Quass, 1984) as follows:

$$\begin{bmatrix} X'X & X'Z_d & X'Z_m \\ & Z'_dZ_d + A^{-1}_{\alpha_1} & Z'_dZ_m + A^{-1}_{\alpha_2} \\ & & Z'_mZ_m + A^{-1}_{\alpha_3} \end{bmatrix}$$

where A^{-1} is the inverse of the numerator relationship matrix and $\alpha 1=\sigma_e^2/\sigma_d^2$, $\alpha 2= \sigma_e^2/\sigma_{dm}$, and $\alpha 3 = \sigma_e^2/\sigma_m^2$.

Solutions to these equations yield evaluations of additive genetic effect for direct and maternal ability for all animals. The most important aspect of this procedure is that the accuracy of prediction of $u_d$and u_m. This is due to their adjustment for nonrandom mating effects with respect to each other (Pollak and Quass, 1984), i.e. the sires direct additive genetic merit is adjusted for his mate's maternal influences. Furthermore, the estimate of [u_m + $1/2u_d$] would represent the dam's total genetic contribution to her progeny's performance.

Schaeffer and Wilton (1975) stressed that for the estimation of breeding values through BLUP to be unbiased the assumption of homogeneity of sire and error components of variances is often important. The maximum likelihood estimation (although computationally complicated) could be used to analyze large volumes of data very quickly with the present advanced high speed computers by making use of least-squares and maximum likelihood mixed model computer program (W.R. Harvey, LSML82, 1982).

Estimation of Phenotypic, Genetic and Environmental Trends in Beef Cattle. The initial recorded interest in genetic gain estimates in dairy cattle was made more than 40 years ago (Nelson, 1943); whereas, such interest in beef cattle has emerged as late as early sixties (Brinks et al., 1961, 1965; Flower et al., 1964 and Armstrong et al., 1965).

In a study involving 25 yr of weaning records (1934 through 1959) on 2,027 calves in a closed herd of Herefords at the U.S. Range Livestock Experiment Station, Miles City, Montana, Brinks et al., (1961, 1965) obtained estimates of realized genetic response of 4.4 kg for birth weight, 9.4 kg for 180 d wt, 13.4 kg for weaning weight and 7.5% for weaning scores over the 25 yr period. The estimate of genetic change obtained from their study for birth weight, 180 d wt and weaning weight were .19, .39 and .56 kg/yr, respectively. They reported negative environmental trends for birth weight but positive environmental trends for gain from birth to weaning and weaning weight. They also reported a genetic increase of .38 σ for final weight off test for bulls and .40 σ for 18 mo weight of heifers.

Flower et al. (1964) estimated phenotypic trends within sex, utilizing weaning records of four inbred lines of Herefords and three line crosses. Their estimates showed a negative time trend in birth weight, weaning weight and postweaning average daily gain in heifers but a positive time trend in postweaning average daily gain of steers and bulls. The environmental trends for birth and weaning weights in their study obtained from repeat matings indicated a negative time trend. Estimates of genetic progress accomplished per year were found to be positive for birth weight (.44 kg/yr) and weaning weight (2.07 kg/yr). Nelms and Stratton (1967) reported a positive phenotypic change of 10.9 kg for yearling weight over a period of 12 yr in a small herd of Hereford cattle at Wyoming, but did not make any attempt to estimate environmental trend.

Armstrong et al. (1965) studied the effectiveness of selection for weaning traits using 17 yr of weaning data (785 inbred and 77 control calves) from an experimental herd comprising 14 inbred and a single random mating control line of Hereford cattle at the San Juan Agricultural Experiment Station, Colorado. In their study, the environmental trends were estimated from both repeat matings and control line information and indicated a strong positive trend over years. The average phenotypic trends, calculated as the regression of annual means of the traits on year and pooled over all lines showed a positive trend for weaning weight (b = .2 kg/yr), weaning score (b = .02 units/yr), and final grade (b = .05 units/yr) and a negative trend for feed efficiency. However, the estimates of genetic trend pooled over all lines, calculated by subtracting the environmental trend from the phenotypic trends, were negative for all traits studied except for feed efficiency.

Scarsi (1971) evaluated the weaning performance of selection lines in three breeds of cattle (Angus, Hereford and Shorthorn) at Front Royal, Virginia. In each of the three breeds there was one line in which the selection was based on type (conformation) and another line selected for growth rate. The repeat matings information was used to estimate environmental trend in his study. The estimate of genetic progress in these selection lines ranged from 1.3 to 1.6, -1.2 to 1.3 and 1.95 to 2.05 kg of weaning weight/yr for Angus, Hereford and Shorthorns, respectively.

Encouraging results were obtained in a Nevada selection experiment involving five closed lines of Herefords (Baily et al., 1971) in which single-trait selection was practiced over a period of 13 yr for postweaning gain, feed efficiency or yearling conformation score. Two lines that were selected for gain on a 140-d test showed an annual mean selection differential of 1.2 and 2.6 kg/yr and the two lines selected for high feed efficiency showed an annual mean selection differential of .30 and .39 kg gain/100 kg TDN. The estimates of one half of the annual genetic changes obtained by the maximum likelihood procedure in their study were .75 ± .48 and 1.08 ± .39 kg /yr for lines selected for gain and .09 ± .06 and .08 ± .08 kg gain/100 kg TDN/yr for feed efficiency, respectively.

Similarly, Koch et al. (1974) studied the selection response in three lines of Herefords selected for weaning weight (WWL), yearling weight (YWL) and index of yearling weight and muscling score (IXL) over a 10 yr period at the Fort Robinson Beef Cattle Research Station, Nebraska. They used five different measures of offspring regression on selection in parents to appraise the selection response. They found that the weaning gain and weaning weight responses were greater in the WWL than in the YWL or IXL but the responses for postweaning gain and yearling weight were found to be greater in the YWL than either WWL or IXL. Their estimates showed an increase in weaning weight of 1.1 kg/yr in bulls and 1.0 kg/yr in heifers in WWL. The corresponding increase in yearling weight were 3.3 kg/yr in bulls and 2.8 kg/yr in heifers in the YWL.

Newman et al. (1973) studied the response to selection in Shorthorn cattle selected for yearling weight over a 10-yr period at two Canadian stations involving two replicated herds and an unselected control herd. Response to selection was determined by the deviation from the unselected control. They reported genetic changes of 4.8 ± 3.1 and 4.1 ± 3.0 kg/yr in males and 3.3 ± 2.7 and 2.3 ± 1.5 kg/yr in females, respectively, in those herds. About 60 to 65% of the total realized annual phenotypic increase in yearling weight was accounted for by environmental changes at both stations.

Zabel (1973) used Smith's method to estimate phenotypic and genetic trends for 205-d weight and weaning grade from 16-yr of weaning performance data involving 20 herds of Angus cattle in Virginia. In his study the phenotypic change was estimated by regression of total change on time and the genetic change was determined by regression of deviations between sire progeny means and population means on time. The difference between the two estimates was assumed to be the environmental change. He reported a significant positive trend ranging from -1.5 to 2.7 kg/yr for 205-d weight.

Phenotypic, environmental and genetic trends of weaning weight were re-evaluated by Nwakalor et al. (1976) for the previously discussed 14 inbred Hereford population at the San Juan Research Center (Armstrong et al., 1965) along with another 14 corresponding line crosses using additional 9 yr of weaning weight data. Authors reported phenotypic regression of adjusted weaning weight on years of -.346, .355, and .575 kg/yr for inbred, inbred adjusted for inbreeding of calf and dam and line cross groups, respectively. The environmental trend for weaning weight estimated from repeat-matings information was -1.52 kg/yr. The estimate of genetic trends in their study obtained from subtracting the environmental regression from the phenotypic regressions were 1.17, 1.87 and 2.09 kg/yr for the same three groups.

Kennedy and Henderson (1977) utilized mixed-model procedures to estimate annual genetic and phenotypic trends from a total of 61,688 Hereford and 22,333 Angus calf growth records obtained through the Canadian performance testing program. In their study, the average sire and dam merits of different birth year groups were considered to evaluate genetic trends in dams and sires. They obtained the regressions of both dam and sire year of birth constants on year with a maximum likelihood absorption of the random sire effects using the mixed model procedure and calculated the annual genetic trend. They estimated the phenotypic trend from the regression of year constants on year. Their estimated average annual genetic trends of dams were .27, .0012, .64 and .0044 kg for weaning weight, preweaning average daily gain, yearling weight and postweaning average daily gain, respectively. The corresponding genetic trends in average sire merit were 1.74 kg for weaning weight, .0084 kg for preweaning average daily gain, 2.60 kg for yearling weight and .0065 kg for postweaning average daily gain.

Eriksson et al. (1979) used data on the average daily gain on test from 805 Hereford and 272 Charolais bulls in the Swedish performance test program and calculated genetic trend in growth rate from the estimate of breeding values obtained from the BLUP procedure. The annual genetic trends among bulls tested in their study were observed as 3.6 ± 0.2 g/day for Hereford and 6.1 ± 1.1 g/day for Charolais.

Schaeffer et al. (1981) estimated phenotypic and genetic trends utilizing the weaning performance records of 281,744 calves gathered through the Canadian beef cattle performance test program. The calves were out of seven breeds and born over a period of 9 yr (1971 to 1978). They took a different approach in their evaluation procedure, where the genetic trends were computed using the changes in weighted average sire transmitting abilities over time. These authors reported a noticeable positive annual trend for Angus, Hereford and Shorthorn breeds and a negative trend for Charolais, Limousin, Maine-Anjou and Simmental breeds. In another Canadian study (Crow and Howell, 1983), the best linear unbiased prediction (BLUP) method with a mixed model was used to estimate genetic trends in beef sires for maternal genetic effects utilizing 5 yr progeny records. They noticed only a slight trend in maternal genetic effects in that study. But, in a study of estimation of genetic trend from an Ohio purebred Angus herd, Wilkes (1983) reported that the maternal additive trend to account for more than 90% of the total genetic trend for weaning weight. The total genetic trend estimated for weaning weight over a period of 11 yr from that study was 1.84 kg /yr.

In a more recent effort to quantify genetic trends in estimated breeding values for weaning weight ratio Zollinger and Nielsen (1984) used 53,989 field records of weaning weight data from 15 Angus herds participating in the U.S. Angus Herd Improvement Records production testing program. Estimates of genetic trends were obtained by Smith's procedure (Smith, 1962). Sire genetic trend was estimated as the pooled within sire regression of weaning weight ratio on year of calf birth and dam's genetic progress as the pooled within dam regression of offspring weaning weight ratio, deviated from the mean contemporary paternal half sib group ratio on years of birth. They reported an average annual trend of .51 ratio units/yr as the sire contribution and .34 ratio units/yr as the dam's contribution, respectively. The annual genetic gain in weaning weight in this study was observed to be 1.8 kg/yr.

Though the studies devoted to evaluation of genetic trends in beef cattle are not numerous, it is evident from the estimates of genetic trends available in the literature (summary in table 1) that genetic changes for growth are definitely occuring in beef cattle populations.

TABLE 1. SUMMARY OF STUDIES REPORTING ESTIMATES OF GENETIC TRENDS FOR PREWEANING GROWTH IN BEEF CATTLE

Type of study	Design of experiment	Genetic trend	Source
Single trait selection			
Selection lines for WW and average performance.	Sires were repeatedly selected from a base herd and used in separate herds for a 7-year period.	Mean differences between herds were: BW, 1.8 kg WW, 12.7 kg	Chapman et al. (1969)
Selection lines for WW, yearling weight, and an index of yearling weight and muscling score (10 yr period).	Intra-year regression of offspring deviations (from the mean) on mid-parent selection differentials.	In the WW line: BW, 0.18 kg/year WW, 1.04 kg/year ADGW, 0.004 kg/year	Koch et al. (1974)
Selection for WW.	Comparison of calves from selected sires with calves from foundation sires following seven years of selection.	Total gains (%) BW, 5.6 WW, 5.9	Stanforth and Frahm (1975)
Continuation of the selection study of Koch et al. (1974) for additional 5-year period.	Cumulative selection differentials method was used to calculate response to selection.	Cumulative selection differentials in the WW line: BW, 2.1 kg WW, 3.5 kg ADGW, 3.3 kg	Buchanan et al. (1982)
Selection lines for WW and postweaning gain.	Genetic trends were estimated by separating environmental trend using random bred control line for 11 years of selection.	In the WW line: WW, 1.07 kg/yr in bulls and .62 kg/yr in heifers	Irgang et al. (1985)

Table 1 (Cont'd)

Type of study	Design of experiment	Genetic trend	Source
Multitrait selection			
Based on progeny test for WW, postweaning gain and carcass merit.	Repeat matings were used to determine environmental trends over 6 years in three inbred lines.	BW, 0.44 kg/year WW, 2.07 kg/year	Flower et al. (1964)
Primarily WW, wenaing score and postweaning gain.	Repeat matings were used to determine environmental trends over 26 years in a single inbred line.	BW, 0.18 kg/year ADGW, 0.002 kg/year WW, 0.56 kg/year	Brinks et al. (1965)
Primarily WW, postweaning efficiency and gain, and yearling grade.	Environmental trends were estimated from repeat matings in 14 inbred and 14 linecross groups over 26 years.	WW, 1.58 to 1.87 kg/year in inbred lines and 1.87 to 2.09 kg/year in linecrosses	Nwakalor et al. (1976)
Using the progeny record of performance data			
61,688 Hereford and 22,333 Angus in Canada.	Weighted average annual genetic trends of dams and sires were estimated from regressions of dam's birth year and sire birth year constants (obtained from a mixed model maximum likelihood procedure) on year.	Average genetic trends for WW: in dams, .27 kg/yr in sires, 1.74 kg/yr	Kennedy and Henderson (1977)

Table 1 (Cont'd)

Type of study	Design of experiment	Genetic trend	Source
Weaning performance records of 281,744 calves out of seven breeds born over 8-year period (1971 through 1978).	Genetic trends were computed using the changes in weighted average sire transmitting abilities over time.	Weighted average of sire proofs for WW for all breeds: .84 ± .13 kg in 1972 and 1.62 ± .09 kg in 1978	Schaeffer et al. (1981)
Weaning weight records (53,989) from 15 Angus herds.	Estimates of sire genetic trend (pooled within sire regression of WW ratio on year of calf birth) and dam's genetic trend (pooled within dam regression of WW ratio, deviated from the mean contemporary paternal half-sib group) were obtained.	Average annual trend in WW: sire contribution, .51 ratio units/year dam contribution, .34 ratio units/year	Zollinger and Nielsen (1984)
Sire summaries			
National sire evaluation in Angus breed.	Genetic trend estimated from average sire Expected Progeny Differences (EPDs) of bulls born from 1964 to 1981.	WW: .58 kg/yr and total genetic change 10.5 kg	American Angus Association Sire Summary, 1984
National sire evaluation in Hereford breed.	Same as in Angus but out of bulls born from 1966 to 1982.	WW: 1.0 kg/yr	American Polled Hereford Association Sire Summary, 1985

MATERIALS AND METHODS

Source and Description of the Data

The data used in this study were from the weaning weight records of calves recorded by the Virginia Beef Cattle Improvement Association (BCIA) except for a small portion of the data which were obtained from the American Angus Association and the American Polled Hereford Association for the same BCIA herds. Thirteen herds of Angus and 11 herds of Hereford cattle were selected from across the state of Virginia. The herds had been in the program continuously for 20 yr or more during the period 1953 through 1983 and had weaned a substantial number of calves in each year. The distribution of the herds across the state is shown in figure 1. The edited data used for the preliminary analyses of phenotypic trend consisted of actual weaning weight of 29,832 Angus and 15,765 Hereford calves (table 2). The mean number of calves weaned per year in each herd ranged from 26 to 285 in Angus and from 23 to 97 in Herefords. The herd by year distribution of weaning records of calves of the Angus and Hereford breeds are shown in appendix tables 1a and 1b, respectively.

All herds had a primary breeding season (weaning during late summer to early fall) in each year, but in some years a

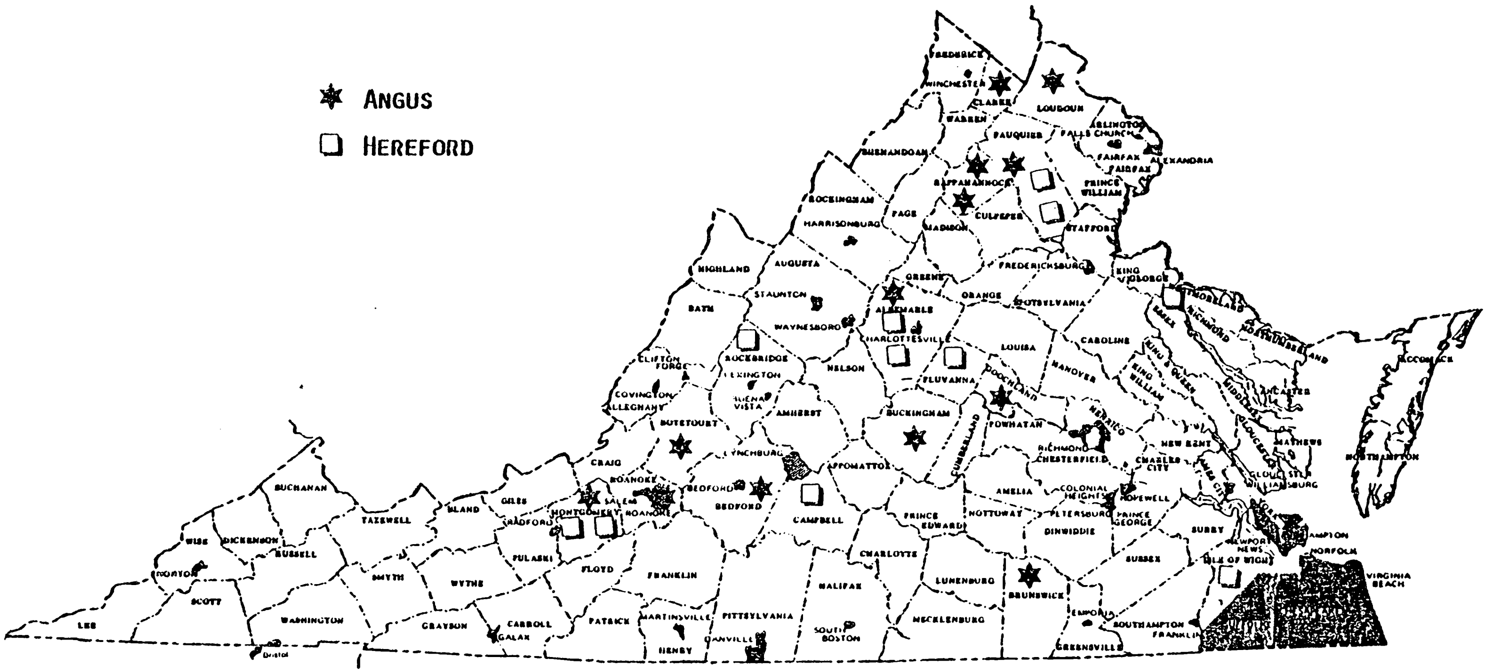

FIGURE 1. SAMPLING OF HERDS IN VIRGINIA

TABLE 2. HERD SIZE, NUMBER OF WEANING WEIGHT RECORDS IN EACH HERD AND NUMBER OF YEARS FOR RECORDS AVAILABLE FOR THE TWO BREEDS OF CATTLE

Angus			Hereford		
Herd no.	Herd size[a]	No. records	Herd no.	Herd size[a]	No. records
a	26	799 (31)[b]	n	66	1,984 (30)
b	66	1,991 (30)	o	76	2,281 (29)
c	122	3,543 (29)	p	23	656 (28)
d	34	996 (29)	q	33	864 (25)
e	285	8,275 (29)	r	76	2,053 (21)
f	78	2,171 (28)	s	73	1,542 (21)
g	40	1,042 (26)	t	53	1,227 (23)
h	49	1,339 (27)	u	32	642 (20)
i	73	1,899 (26)	v	51	1,019 (20)
j	97	2,530 (26)	w	78	1,559 (20)
k	73	1,744 (24)	x	97	1,938 (20)
l	74	1,634 (22)			
m	75	1,419 (20)			
TOTAL	13 herds	29,382		11 herds	15,795

[a]Average number of calves recorded at weaning each year.
[b]Values in parentheses refer to number of years for which records were available.

few herds had a secondary breeding season (weaning in spring) and eight herds (four in each breed) had a tertiary breeding season (weaning during late fall) (table 3). The primary season included almost two-thirds of the weaning records in each breed and the tertiary season constituted less than 6% of the records in each breed. The feeding and management of these herds was typical of purebred beef cattle operation in Virginia. In many herds at least some calves were creep fed in most years but the basis of the decision of which calves would receive creep feed was not clear. Relatively more Hereford calves were receiving creep feed (43%) compared to the 18% of Angus calves receiving creep feed (table 4). In most instances, culling of cows was assumed to be based on age, low fertility and poor performance of offspring.

For the final analyses several restrictions were imposed on the data. Weight records of calves of less than 125 d or greater than 275 d of age at weaning and any records which did not include the identification of the calf's sire or dam were omitted. Also, a few records which did not fall into any of the above-described breeding seasons were excluded. After these restrictions 27,774 Angus and 14,738 Hereford records remained for the final analyses. Actual weaning weights were adjusted for effect of age of dam, sex and age of calf (to 205-d). Age of dam

TABLE 3. HERD BY SEASON[a] DISTRIBUTION OF CALVES WEANED IN EACH BREED OF CATTLE

Breed	Herd no.	No. of calves weaned (by season)		
		Primary	Secondary	Tertiary
Angus	a	674	34	-
	b	1,924	-	-
	c	2,318	467	333
	d	957	-	-
	e	4,709	2,517	624
	f	1,997	-	-
	g	351	364	254
	h	1,257	-	-
	i	1,828	-	-
	j	2,018	325	-
	k	1,136	585	-
	l	864	601	105
	m	1,312	-	-
	overall %	77.5	17.0	5.5
Hereford	n	1,279	357	269
	o	1,345	732	127
	p	622	-	-
	q	853	-	-
	r	1,026	873	-
	s	912	563	-
	t	237	710	-
	u	533	45	-
	v	696	288	10
	w	1,358	-	-
	x	1,472	17	414
	overall %	70.1	24.3	5.6

[a]Primary season = weaning during summer to early fall; secondary season = weaning in spring; tertiary season = weaning during late fall.

TABLE 4. DISTRIBUTION OF CALVES CREEP FED IN EACH HERD FOR EACH BREED OF CATTLE

Angus		Hereford	
Herd no.	% creep fed	Herd no.	% creep fed
a	35.2	n	34.5
b	1.9	o	44.0
c	4.3	p	0.8
d	39.4	q	50.2
e	2.2	r	67.0
f	3.6	s	6.4
g	72.8	t	53.7
h	29.6	u	55.0
i	0.2	v	62.4
j	39.0	w	25.7
k	80.0	x	46.6
l	26.0		
m	2.6		
Overall average for the breed	18.0		43.0

was calculated as the difference between birth date of the calf and birth date of the dam and categorized into 2, 3, 4, 5 to 10, or >10 yr groups and additive factors were used in the adjustment procedure. For calves which did not have birth weights recorded, a breed average appropriate to the sex of the calf was assigned to compute 205-d age adjusted weights. Weaning weight ratio (WWR) for each calf was computed as the ratio of adjusted 205-d weight to the average of the contemporaries adjusted 205-d weights, where the contemporary group was composed of calves of same herd, weaning year, season, sex and management (creep fed or noncreep fed) group for each breed. The adjusted weaning weight (AWWT), WWR, and deviation of AWWT from year-season-creep averages (DEVN) were analyzed separately as independent variables in subsequent analyses.

Since birth dates were not available on many sires, the year in which a sire was introduced for the first time into a herd was defined as sire year (SYR). It was assumed that many young sires were of about 2 yr of age at the time of their first appearance. In order to define a genetic group that produced the calves in this study, the dam birth year was incremented by two to match the sire year time scale and denoted as dam year (DYR). Thus, a genetic group (major class) considered in this study is a HERD-SYR-DYR combination. Within this major class, individual sire-dam combinations (matings) produced the corresponding total number of records in each breed. There were 1,061 sires and 7,732 dams involved in the matings within the Angus breed and 512 sires and 4,304 dams involved within the Hereford breed. The distribution of sires in different years revealed that a sire continued to be used for at least 2 yr in many instances within a herd. Each sire was credited with an average of 29 progeny in both breeds. A subset of these data for each breed considered only repeat matings and was utilized for estimating repeatabilities of the traits of interest. There were 10,085 records representing 3,138 repeat matings in Angus data and 6,342 records representing 2,019 repeat matings in the Hereford data.

Statistical Methods and Concepts. The preliminary analyses were conducted to compute means and yearly phenotypic trends for actual weaning weight, within herds as well as for all herds combined for each breed. A simple regression of actual annual mean weaning weight on weaning year was used to obtain phenotypic trend. Following this, the effect of all known environmental factors such as age of dam, sex and age of calf on weaning weight were evaluated and the resulting constant estimates were used to adjust actual weaning weight to a common base for further analyses. The linear model used for evaluating environmental effects within herds included fixed effects of weaning year, age of dam and sex of calf, age of calf (as a covariate) and the random residual. The fixed effects of herd was added to the above model for the pooled analysis of all herds for each breed. Interactions between effects were assumed to be unimportant. Actual weaning weights were adjusted to a mature cow equivalent (5 to 10 yr old), to a steer base and to 205-d of age.

In the next step, genetic parameters (heritabilities and repeatabilities) of the traits of interest were estimated for the two breeds using the adjusted data. To estimate the sire variance component, a nested model containing sires within weaning year and management was used for the within-herd analyses and sire within herd and weaning year and management was used for the pooled analyses in each breed. The effects of sires were considered random with zero means and variance σ_S^2 equal to one quarter of the additive genetic variance, i.e., $\sigma_S^2 = 1/4\sigma^2A$. Estimate of repeatabilities were obtained for WWR, AWWT and DEVN from the regression of first observation of the traits of interest on second observation of that trait from the repeat matings data. Estimates of sire variance components and repeatabilities were used later in the mixed model equations (Henderson, 1973) for the maximum-likelihood absorption procedure to obtain constants for the estimable unknown vectors.

Two main approaches were taken to obtain estimates of phenotypic, environmental and genetic trends of the traits of interest. The first approach was a series of regression techniques essentially like those developed by Smith (Smith, 1962) and recently used by Zollinger and Nielsen (1984). Total genetic trends were also computed using the modification of Smith's procedure (Powell and Freeman, 1974; Cicogna et al., 1982), which is assumed to eliminate the bias in estimates of genetic trends due to nonrandom mating and culling of females. The expectations of those regressions that were used in these analytical procedures to obtain the respective trends are as follows:

$E[\hat{\beta}AWWT \bullet WNYR/herd] = g + t$, i.e., ΔP

$E[\hat{\beta}AWWT \bullet WNYR/herd, sires, dams] = t$, i.e., ΔE

estimates of genetic trends due to selection of sires as:

$E[\hat{\beta}WWR \bullet WNYR/herd, sires] = -1/2\ g_S$

$E[\hat{\beta}AWWT - \overline{AWWT}_{contemporaries}) \bullet WNYR/herd, sires] = -1/2\ g_S$

estimates of genetic trends due to selection of dams as:

$E[\hat{\beta}(WWR - \overline{WWR}_{paternal\ half\ sibs}) \bullet WNYR/herd, dams] = -1/2\ g_d$

$E[\hat{\beta}(AWWT - \overline{AWWT}_{paternal\ half\ sibs}) \bullet WNYR/herd, dams] = 1/2\ g_d$

and the estimates of sire trends adjusted for nonrandom matings and annual culling levels as:

$-2[-1/2g_s - \Delta D]/1 + \Delta A = \hat{G}$,

where ΔD is a within sire and herd regression of a dam's first progeny weaning performance record (P) deviated from the mean of the progenies of the contemporary dam group ($\bar{P}$) which had calves weaned in the same year on weaning year, multiplied by the heritability value of the trait.

i.e.: $\Delta D = h^2 * \hat{\beta}(P - \bar{P}_{contemp}) \bullet WNYR/herd, sire$

This is a measure of the within sire trend of dam's additive genetic merit relative to all possible mates and, thus, it adjusts for nonrandom mating. The regression is multiplied by the heritability value of the trait to account for the true genetic portion which is transmitted to the offspring.

$\Delta A = [\hat{\beta}$ dam age $\bullet$ WNYR/herd, sire-$\hat{\beta}$ dam age$\bullet$WNYR/herd],

which is the estimate of additive genetic superiority of dams over time that is associated with female culling practices. Thus, weighting the estimate of genetic trend by 1 + ΔA is assumed to adjust for the trends associated with keeping older cows. In the second approach, the respective trends were estimated by the maximum likelihood procedure using the following mixed model.

$Y_{ijklmnp} = \mu + h_i + syr_{ij} + dyr_{ik} + S_{ijl} + d_{ikm} + WNYR_n + E_{ijklmnp}$

where,

$Y_{ijklmnp}$ is the observation AWWT or WWR or DEVN on the p^{th} calf,

μ is the overall mean,

h_i is the fixed effect of the i^{th} herd,

syr_{ij} is the fixed effect of the j^{th} sire year (SYR) in i^{th} herd,

dyr_{ik} is the fixed effect of the k^{th} dam year (DYR) in i^{th} herd,

s_{ijl} is the random effect of the l^{th} sire in the j^{th} (DYR) group of the i^{th} herd,

d_{ikm} is the random effect of the m^{th} cow in the k^{th} (DYR) group of the i^{th} herd,

$WNYR_n$ is the fixed effect of the n^{th} year of weaning and

$e_{ijklmnp}$ is the random error.

The maximum likelihood mixed model computer program (LSML82; W.R. Harvey, 1982) was used to estimate constants for fixed effects and polynomial regression coefficients for estimating trends. To obtain the estimate of phenotypic trends for the traits of interest in the first run, the herd effects were absorbed into the μ equations and only effects of WNYR were fitted. All other effects were ignored. Polynomial regression coefficients for WNYR obtained in this analysis accounted for the phenotypic trend, ΔP/yr. In order to estimate the environmental trend (second run) the herd-syr-dyr (major class) effects, as described in the above mixed model, were absorbed by least-squares and the random effects of all matings (sire and dam) within the major class were absorbed through maximum likelihood into the major class equations. The variance ratio of .40 was added to the diagonal elements of the equations as described by Henderson (1973) to obtain solutions for the weaning year constants. Polynomial regression coefficients obtained in this run for AWWT gave the environmental trend. The regressions for WWR and DEVN similarly estimated the true genetic trend.

In the last two runs an attempt was made to partition the total genetic trends into sire and dam components and these estimates were compared with the corresponding estimates obtained from the former procedures. To obtain the sire trend (run 3), herd and SYR were absorbed by least-squares absorption and the random sires were absorbed by maximum likelihood procedure. A variance ratio of .12 [= 1/4 h^2] was added to the diagonal elements of the equations. The effects of dam were ignored and effects of WNYR were fitted. Alternatively, to obtain the dam trend (run 4), herd and DYR were absorbed by least-squares absorption and the random dams effects were absorbed by maximum likelihood procedure with r = .40. Sire effects were ignored and the model was fitted to WNYR. The polynomial regression coefficients were obtained for the traits of interest in both runs. The property of the estimates of sire and dam trend obtained by this procedure depend upon the assumption that effects of assortative mating were negligible because dam effects were ignored in the estimation of sire trend and sire effects were ignored in estimation of dam trend.

RESULTS AND DISCUSSION

The 13 Angus and 11 Hereford herds used in this study may not fully represent their respective breed populations in Virginia. They were chosen because they had remained in the program for 20 yr or more. Presently, there are 113 Angus and 80 Hereford herds (61 polled Hereford and 19 horned Hereford) enrolled within the Virginia Beef Cattle Improvement Association. In 1983 the Virginia BCIA processed only about 6,000 weaning records from the participating herds, which is less than half the number in many previous years. The reason for this decline is that more of the herd owners are now processing their records through their respective breed associations.

Actual Weaning Weights of Calves. The phenotypic averages and standard deviations for actual weaning weights of individual herds and the overall means of the respective breeds are shown in table 5. The herd means indicate the average performance merit of the several herds within each breed. Average weaning weight of Angus calves was 186.5 ± 39.5 kg, which is 14.2 kg lower than the average weaning weight of Hereford calves (200.7 ± 45.6 kg). Except for one herd in the Angus breed (herd c = 162.7 kg) and one herd in the Hereford breed (herd u = 172.8 kg), all herds produced

TABLE 5. ACTUAL WEANING WEIGHT (KG) MEANS AND STANDARD DEVIATIONS FOR INDIVIDUAL HERDS FOR THE TWO BREEDS OF CATTLE

Herd no.	Angus	Herd no.	Herefords
a	180.8 ± 33.6	n	208.5 ± 45.4
b	186.4 ± 30.8	o	191.8 ± 41.2
c	162.7 ± 36.4	p	184.8 ± 37.6
d	214.5 ± 42.9	q	206.4 ± 34.0
e	181.4 ± 36.9	r	204.0 ± 48.9
f	191.8 ± 43.7	s	184.3 ± 34.5
g	186.1 ± 42.9	t	219.5 ± 53.1
h	184.6 ± 34.4	u	172.8 ± 44.4
i	200.8 ± 34.9	v	195.9 ± 44.9
j	207.3 ± 38.1	w	182.5 ± 38.6
k	188.9 ± 36.8	x	219.9 ± 42.6
l	177.3 ± 35.0		
m	186.5 ± 39.5		
Pooled average	186.5 ± 39.5		200.7 ± 45.6

weaning weights closer to the mean weaning weights of their respective breeds. The highest weaning weights were observed in herd d of the Angus breed (214 kg), and herds t and u of the Hereford breed (220 kg). The mean weaning weights computed for each weaning year (table 6) of the two breeds clearly indicated an increase in weaning weight performance of calves over the study period. The means and standard deviations for the actual weaning weights of Angus and Hereford calves for year 1954 were 167 ± 33 kg and 177 ± 28 kg and for year 1983 were 205 ± 36 kg and 224 ± 42 kg, respectively. Assuming a 5 yr period as a normal generation interval, the weaning weight yearly means of the two breeds were averaged into six generations and presented in table 7. The computed averages for the six generations showed a total increase in weaning weight performance of almost 30 kg in each breed. The pattern of this increase is clearly illustrated in figure 2.

Means and standard deviations of progeny weaning weights for different year replacement dams produced in different years and new sire groups (appendix tables 2a, 2b) show the change that occurred in each breed as a result of the selection of replacement dams and use of superior bulls. In both breeds, the mean actual weaning weight of the progenies for each year indicated that the emphasis placed on sire selection was relatively larger than on heifer

TABLE 6. PHENOTYPIC MEANS AND STANDARD DEVIATIONS OF WEANING WEIGHT (KG) OF CALVES WEANED IN EACH YEAR FOR THE TWO BREEDS

	Angus		Hereford	
Year	No. calves	WWT mean ± SD	No. calves	WWT mean ± SD
1953	13	178 ± 32	-	-
1954	22	167 ± 33	98	177 ± 28
1955	256	178 ± 33	116	175 ± 31
1956	380	176 ± 34	184	172 ± 41
1957	460	173 ± 34	208	198 ± 47
1958	647	182 ± 35	152	207 ± 47
1959	621	170 ± 38	194	186 ± 49
1960	693	176 ± 36	203	205 ± 48
1961	966	173 ± 41	261	186 ± 47
1962	804	175 ± 39	318	187 ± 49
1963	894	178 ± 39	383	189 ± 48
1964	1000	181 ± 41	523	193 ± 50
1965	1012	184 ± 39	555	191 ± 43
1966	1023	179 ± 38	613	190 ± 46
1967	1137	192 ± 39	615	200 ± 45
1968	1190	192 ± 40	667	200 ± 42
1969	1015	190 ± 36	655	200 ± 47
1970	1088	190 ± 35	684	192 ± 41
1971	1144	184 ± 34	712	186 ± 44
1972	1075	190 ± 37	702	192 ± 44
1973	1086	192 ± 36	613	197 ± 41
1974	1223	197 ± 37	783	198 ± 43
1975	1299	189 ± 37	815	196 ± 45
1976	1280	195 ± 38	775	203 ± 41
1977	1244	194 ± 37	778	204 ± 48
1978	1196	188 ± 38	733	205 ± 44
1979	1235	193 ± 39	792	210 ± 45
1980	1310	199 ± 38	836	209 ± 45
1981	1307	198 ± 37	640	212 ± 47
1982	1480	199 ± 38	534	222 ± 41
1983	1284	205 ± 36	582	224 ± 42

TABLE 7. AVERAGE WEANING WEIGHT (KG) PERFORMANCE OF CALVES BORN OVER SIX GENERATIONS[a]

Generation	Angus[b]	Hereford[b]
1 (1953-57)	178 (1,139)	179 (545)
2 (1958-62)	182 (3,746)	195 (1,068)
3 (1963-67)	192 (5,096)	194 (2,596)
4 (1968-72)	192 (5,689)	194 (3,346)
5 (1973-77)	198 (6,305)	198 (3,756)
6 (1978-83)	205 (6,742)	212 (3,812)

[a]Assuming a 5-yr generation interval.
[b]( ) number of observations.

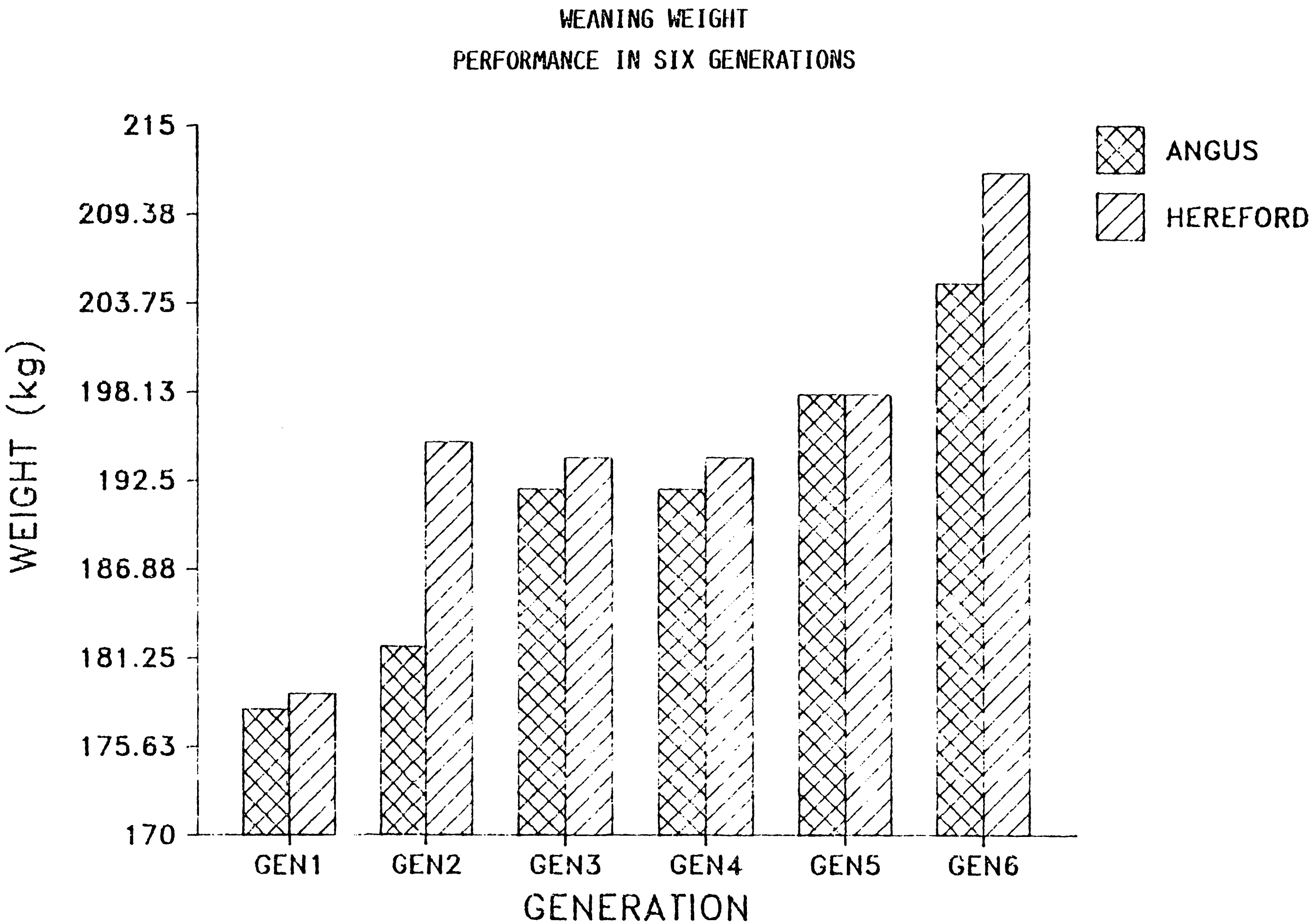

FIGURE 2. WEANING WEIGHT PERFORMANCE IN SIX GENERATIONS IN ANGUS AND HEREFORD CATTLE.

replacements. The reason for this difference is probably due to the small number of females available for culling in each year. The data, which had different age groups of dams at different time intervals, might have had some influence on the progeny weaning weight means in their corresponding weaning years. This was evident from the small differences noticed in the mean adjusted weaning weights among dams and sire groups. However, the progeny AWWT means for dam and sire groups also indicated that the sire contribution for this trait was slightly higher than the dam contribution.

Within Herd and Pooled Phenotypic Trends for Weaning Weight. Table 8 shows the within herd, as well as the pooled estimates of phenotypic regression coefficients of actual weaning weight on year for the respective breeds. The estimates of intraherd phenotypic regression of WWT on year of weaning ranged from -.34 ± .50 to 2.15 ± .31 kg/yr among herds for the Angus breed. The pooled estimate over all herds was 1.0 ± .1 kg/yr. Corresponding phenotypic regression estimates for the Hereford breed ranged from -1.80 ± .21 to 3.07 ± .27 kg/yr among herds; the pooled estimate over all herds was .88 ± .21 kg/yr. In the Angus breed the annual trends were positive for all except two herds and the two negative estimates were not significantly different from zero. In the Hereford breed however, four out of 11 herds showed a negative phenotypic trend; but only

TABLE 8. WITHIN HERD AND POOLED WEANING YEAR REGRESSION COEFFICIENTS FOR ACTUAL WEANING WEIGHT (KG) IN ANGUS AND HEREFORD CATTLE

Angus		Hereford	
Herd no.	Regression coefficients	Herd no.	Regression coefficients
a	0.027 ± .32	n	3.070 ± .27***
b	-0.207 ± .25	o	-0.161 ± .25
c	1.177 ± .37***	p	1.250 ± .28***
d	2.153 ± .31***	q	1.330 ± .35***
e	1.729 ± .34***	r	-1.799 ± .46***
f	1.805 ± .37***	s	0.568 ± .38
g	1.319 ± .34***	t	0.671 ± .46
h	0.598 ± .44	u	-0.866 ± .70
i	-0.344 ± .50	v	2.394 ± .85*
j	1.341 ± .37***	w	-0.191 ± .53
k	1.383 ± .44***	x	0.684 ± .54
l	1.419 ± .72		
m	1.175 ± .52**		
Pooled over all herds	1.0 ± .14***		.875 ± .21***

***P < .005.
**P< .05.
*P < .01.

one of the four herds (herd r = -1.8 kg/yr) was significantly different from zero (P<.005).

<u>Environmental Effects on Weaning Weight</u>. All known environmental factors (herd, year, age of dam, sex of calf, and age of calf at weaning) significantly influenced weaning weight of calves in both breeds (table 9). Variation among herds indicated the variability associated with the different level of management and merit in individual herds. The fluctuations in the environment, associated with the actual improvement in genetic merit realized among herds, was apparent from the highly significant (P<.001) year effect (table 9) and the linear increase in year constants (table 10). Effect of age of dam on calves' weaning weight was quadratic in nature. Mature cows (5 to 10-yr-olds) weaned the heaviest calves (195 kg for Angus and 208 kg for Hereford breeds, respectively; table 11). The corresponding figures for calves weaning weight of 2-yr-old dams were 178 and 189 kg. Many of these environmental influences on weaning weight performance have been previously studied (Swiger, 1961; Marlowe et al., 1965; Sellers et al., 1969; Pabst et al., 1977; Anderson and Willham, 1978; Nelsen and Kress, 1981; Leighton et al., 1982). Marlowe et al. (1965) reported increase of 11 and 15% in weaning weights of calves born to mature Angus and Hereford dams over those born to 2-yr-old dams.

TABLE 9. MEAN SQUARES AND LEVEL OF SIGNIFICANCE FROM THE ANALYSIS OF VARIANCE FOR THE ENVIRONMENTAL EFFECTS ON WEANING WEIGHT

Source of variation	Angus		Hereford	
	df	MS	df	MS
Herd	12	3183987***	10	1801503***
Year	30	1558923***	29	991396***
Age of dam	4	102490***	4	792030***
Sex of calf	2	3474550***	2	2910793***
Age of calf (linear)	1	1215017***	1	7120291***
Residual	27,724	588	14,722	761

***$P < .0001$.

TABLE 10. POOLED WEANING YEAR LEAST SQUARES MEANS AND STANDARD ERRORS (KG) FOR WEANING WEIGHTS FOR THE TWO BREEDS

Weaning year	Angus No. herds	Angus L.S. means ± S.E.	Herefords No. herds	Herefords L.S. means ± S.E.
1953	1	185 ± 12.1	-	-
1954	2	197 ± 5.9	2	192 ± 3.2
1955	5	198 ± 1.6	3	191 ± 2.6
1956	6	197 ± 1.3	5	188 ± 2.2
1957	8	191 ± 1.3	5	186 ± 2.2
1958	10	192 ± 1.0	5	197 ± 2.4
1959	10	190 ± 1.0	5	192 ± 2.2
1960	11	191 ± 1.0	5	193 ± 2.2
1961	11	189 ± 1.0	7	189 ± 2.0
1962	12	191 ± 1.0	7	191 ± 1.7
1963	12	190 ± 1.0	10	194 ± 1.5
1964	13	193 ± .8	11	193 ± 1.3
1965	13	193 ± .8	11	196 ± 1.3
1966	13	186 ± .8	11	191 ± 1.2
1967	13	198 ± .8	11	196 ± 1.2
1968	13	195 ± .8	11	195 ± 1.1
1969	13	192 ± .7	11	192 ± 1.0
1970	13	187 ± .7	11	189 ± 1.1
1971	12	191 ± .7	11	180 ± 1.1
1972	13	195 ± .7	11	191 ± 1.2
1973	13	197 ± .7	11	191 ± 1.2
1974	12	202 ± .7	11	191 ± 1.2
1975	13	193 ± .7	11	188 ± 1.1
1976	13	202 ± .7	11	198 ± 1.0
1977	13	204 ± .7	11	202 ± 1.0
1978	13	199 ± .7	11	202 ± 1.1
1979	13	205 ± .7	11	205 ± 1.0
1980	13	210 ± .7	11	205 ± 1.0
1981	13	210 ± .7	11	208 ± 1.1
1982	13	211 ± .7	8	213 ± 1.1
1983	12	214 ± .7	7	216 ± 1.2

TABLE 11. LEAST SQUARES CONSTANTS AND STANDARD ERRORS (KG) FOR AGE OF DAM AND SEX OF CALF EFFECTS ON WEANING WEIGHT AND REGRESSION COEFFICIENTS (KG) FOR WEANING WEIGHT ON AGE OF CALF AT WEANING FOR THE TWO BREEDS

Effects	Breed	
	Angus	Hereford
Age of dam		
2 yr	177.8 ± .57	187.8 ± .69
3 yr	187.0 ± .59	192.2 ± .76
4 yr	192.4 ± .62	203.9 ± .77
5-10 yr	194.8 ± .49	207.5 ± .51
>10 yr	188.0 ± .61	205.3 ± 1.13
Sex of calf		
Bull	204.0 ± .54	222.2 ± .58
Heifer	175.3 ± .49	188.3 ± .45
Steers	184.8 ± .53	191.2 ± .72
Regression of calf's age	.67 ± .0005	.71 ± .008

In the present study, the mean weaning weight of Angus bull calves was 29 kg heavier than the mean weaning weight of Angus heifers, whereas the Hereford bull calves were 34 kg heavier than Hereford heifers at weaning. The weaning weight of steer calves were intermediate. These differences were slightly higher than that reported by Pabst et al. (1977) for Angus and Hereford and Anderson and Willham (1978) for Angus calves. Pabst et al. (1977) reported a difference of 18 and 15 kg between bull and heifer calves in 200-d weight of Angus and Hereford cattle respectively. Anderson and Willham (1978) found a 10% difference in weaning weight between Angus bulls and heifers. However, the results in this study are in close agreement with the study of Nelson and Kress (1981), who found that Angus bull calves were 13% heavier than Angus heifers at weaning and Hereford bull calves were 10% heavier than Hereford heifers. Even though the sex X management interactions were not included in the analyses of these data, there would have been some variations in growth performance within sexes among management regimes, as was evident from the study of Marlowe et al. (1965), where the steer calves grew approximately 6% faster than heifer calves regardless of whether or not they were creep-fed. Non-creep-fed bull calves grew 6.6% faster than non-creep-fed steer calves and creep-fed bull calves grew 9.7% faster than creep-fed steer calves.

The assumptions made in this study, that the interactions of main effects were unimportant is supported by some studies (Cunningham and Henderson, 1965; Cundiff et al., 1966). But on the other hand, sex and age of dam interactions were found to be an important source of variation in the studies of Schaeffer and Wilton (1974) in Angus and Hereford cattle, and in Angus cattle by Anderson and Willham (1978) and Nelson and Kress (1981).

The regression coefficients estimated for age of calf effect at weaning for the Angus and Hereford breeds were .67 and .71 kg/d, respectively.

Additive adjustment factors obtained from the least squares constants for age of dam and sex of calf and adjustment factors for age of calf obtained from the regression coefficients (appendix table 3) were used to adjust the actual weaning weights of the respective breeds in these data. These adjustment factors were found to be in good agreement with the corresponding adjustment factors used by the respective breed associations to adjust weaning weights. Such adjustments in beef cattle performance data have been found to be very critical for accurate evaluation of selection response (Jones and Hopkins, 1980).

Variance Components and Genetic Parameters. Estimates of variance components and heritability values for the traits of interest of both breeds are presented in table 12.

TABLE 12. MEAN SQUARES FROM NESTED ANOVA AND ESTIMATES OF HERITABILITIES IN ANGUS AND HEREFORD BREEDS

Source of variation		Traits: AWWT (kg^2)	DEVN (kg^2)	WWR (ratio unit^2)
		Angus		
Herd (H)	12	147.69	.09	.004
WNYR (Y)/H	329	68.09	-.12	.036
Season (B)/H,Y	159	-67.52	14.89	5.017
Creep (M)/H,Y,B	104	226.79	-33.76	-11.436
Sire (S)/H,Y,B,M	2,452	68.62	50.09	14.729
Error	24,497	369.25	296.99	96.75
Heritability estimates		.63 ± .08	.58 ± .08	.53 ± .14
		Hereford		
Herd (H)	10	139.31	.24	.020
WNYR (Y)/H	251	58.37	3.79	.986
Season (B)/H,Y	123	-77.35	8.43	2.984
Creep (M)/H,Y,B	127	292.43	-38.91	-12.113
Sire (S)/H,Y,B,M	1,278	71.77	44.86	11.170
Error	12,948	489.31	371.32	110.920
Heritability estimates		.51 ± .06	.43 ± .06	.37 ± .11

The standard errors of the heritability estimates were computed by using the conservative estimation procequre outlined by Dickerson (1969). The effects of herd, WNYR/herd and creep feeding/WNYR,herd accounted for 17, 8 and 28% of the variation in AWWT among Angus and 13, 6 and 26% among Hereford cattle, respectively. Cundiff et al. (1975) reported that variation among herds was about 50% of the total phenotypic variance in weaning weight of Angus and Hereford cattle. However, herd to herd variations accounted for only slightly more than 25% in a study by Kennedy and Henderson (1975) in Angus and Hereford Cattle. The sire variation for AWWT, DEVN and WWR, respectively, was 8, 14 and 13% of the total in Angus, with corresponding values for Herefords of 7, 10 and 9%. Kennedy and Henderson (1975) reported sire variations ranging from 3 to 7% among Angus and Hereford cattle.

The heritability estimates calculated for AWWT, DEVN and WWR were .63 ± .08, .58 ± .08 and .53 ± .14 in Angus and .51 ± .06, .43 ± .06 and .37 ± .11 in Hereford breeds in this study, which are slightly higher than the average values for weaning traits reported in the literature. In general, the heritability estimates for weaning weight have been in the range of .10 to .60 with the majority of reports giving heritability estimates of approximately .30 (Woldehawariat et al., 1977). However, the estimates obtained in this study appear to be much lower than the estimates of .72 ± .33 and .82 ± .12 for weaning weights reported by Francoise et al., (1973) for Angus and Hereford cattle using similar BCIA records from Hawaii, but higher than the estimates of .30 and .31 for weaning weight reported by Nelsen and Kress (1979) for these breeds estimated from Montana Beef Cattle Performance Association's records. The estimates of .51 ± .06 for Hereford AWWT in this study appear to be in full agreement with the paternal half-sib estimates of .50 ± .10 reported by Vesely and Robison (1971) for Hereford weaning weight. Schalles and Marlowe (1971) reported heritability estimates of .57 ± .09 for preweaning average daily gain for Angus cattle using data from a large Angus herd which was also included in the present study. The average estimates for DEVN and WWR from both breeds gave a mean value of .475 and thus, for the maximum likelihood absorption techniques the intraclass correlation ratio of .12 was used to solve the sire equations.

The repeatability estimates for WWR in repeat matings in this study of the Angus and Hereford breeds were obtained by regressing the first progeny WWR on the successive progeny records. The values obtained were .34 and .36, respectively. Petty and Cartwright (1966) reported a value of .44 based on the weighted average of 16 estimates found in the literature. Thus, for solving the maximum likelihood equations for dams a repeatability value of .40 was used in the absorption procedure for this study.

Within Herd Sire and Dam Genetic Trends. Estimates of weaning year constants for WWR and DEVN, which are measures of growth performance deviated from the contemporary group of individuals within year, season and management regimes should include the true genetic change plus any sampling errors associated with each estimate in each herd. The within herd estimates of one half of the genetic trends among sires and dams, obtained from the regression techniques as previously described in materials and methods for the Angus and Hereford breeds, are presented in tables 13 and 14, respectively.

In the Angus breed, estimates of sire trends for the traits of interest were positive in all herds except one. The positive estimates of sire trends for WWR and DEVN, respectively, ranged from .06 ± .19 to 1.25 ± .26 ratio units/yr and from .16 ± .32 to 2.88 ± .53 kg/yr and were significant (P<.05) in nine herds. The negative estimates of sire trend in herd h was -.27 ± .14 ratio units/yr for WWR and -.70 ± .27 kg/yr for DEVN and was significantly different from zero (P<.05). The magnitude of sire trends were generally higher for herds entered in the study during the latter years.

TABLE 13. WITHIN HERD ESTIMATES OF GENETIC TRENDS FOR WWR (RATIO UNITS/YR) AND DEVN (KG/YR) IN ANGUS BREED FROM REGRESSION ANALYSES

Herd no.	Estimates: Traits:	$1/2\Delta g_s$[1] WWR	$1/2\Delta g_d$[2] WWR	$1/2\Delta g_s$[3] DEVN	$1/2\Delta g_d$[4] DEVN
a		.58 ± .22*	.45 ± .12***	.99 ± .43*	1.00 ± .25***
b		.48 ± .18*	-.01 ± .08	.72 ± .35*	-.23 ± .17
c		.06 ± .19	.56 ± .09***	.16 ± .32	1.29 ± .17***
d		.33 ± .50	.30 ± .11*	.57 ± 1.1	.69 ± .28*
e		.46 ± .07***	.27 ± .04***	.93 ± .14***	.39 ± .09***
f		.20 ± .20	.56 ± .10***	.19 ± .39	1.04 ± .21***
g		.57 ± .33	.57 ± .18***	1.27 ± .66	1.66 ± .39***
h		-.27 ± .14*	.21 ± .11	-.70 ± .27**	.12 ± .24
i		.73 ± .13***	.53 ± .06***	1.17 ± .27***	1.09 ± .14***
j		.59 ± .13***	.16 ± .06*	1.05 ± .30***	.01 ± .15
k		.64 ± .16***	.63 ± .08***	1.46 ± .33***	1.62 ± .18***
l		1.25 ± .26***	.47 ± .12***	2.88 ± .53 ***	1.75 ± .26***
m		.69 ± .26*	.42 ± .09***	1.51 ± .53**	.77 ± .18***

*P < .05.
**P < .01.
***P < .001.

1 $1/2\Delta g_s = -\hat{\beta}WWR \cdot WNYR$/herd,sire.

2 $1/2\Delta g_d = -\hat{\beta}(WWR - \overline{WWR}_{\text{paternal half sibs}}) \cdot WNYR$/herd,dams.

3 $1/2\Delta g_s = -\hat{\beta}(AWWT - \overline{AWWT}_{\text{contemp}}) \cdot WNYR$/herd,sires.

4 $1/2\Delta g_d = -\hat{\beta}(AWWT - \overline{AWWT}_{\text{paternal half sibs}}) \cdot WNYR$/herd,dams.

TABLE 14. WITHIN HERD ESTIMATES OF GENETIC TRENDS FOR WWR (RATIO UNIT/YR) AND DEVN (KG/YR) IN HEREFORD BREED FROM REGRESSION ANALYSES

Herd no.	Estimates: Traits:	$1/2\ g_s^1$ WWR	$1/2\ g_d^2$ WWR	$1/2\ g_s^3$ DEVN	$1/2\ g_d^4$ DEVN
n		.24 ± .14	.29 ± .09**	.28 ± .31	.49 ± .23*
o		.21 ± .16	.18 ± .10	.33 ± .32	.27 ± .20
p		.53 ± .33	.62 ± .18***	.96 ± .64	1.39 ± .39***
q		-.16 ± .27	.05 ± .11	-.61 ± .60	.19 ± .26
r		.23 ± .11*	.32 ± .06***	.39 ± .25	.46 ± .15**
s		.11 ± .24	.28 ± .12*	-.16 ± .47	.50 ± .24*
t		.22 ± .15	.10 ± .11	.43 ± .35	.51 ± .29
u		.16 ± .50	.50 ± .21*	-.06 ± .95	.91 ± .41*
v		.23 ± .39	.87 ± .16***	.19 ± .81	1.89 ± .36***
w		.47 ± .20**	.93 ± .15***	1.33 ± .38***	2.15 ± .29***
x		.64 ± .19***	.80 ± .09***	1.59 ± .48***	1.42 ± .25***

*$P < .05$.
**$P < .01$.
***$P < .001$.
1 $1/2\Delta g_s = -\hat{\beta}WWR \cdot WNYR$/herd, sire.
2 $1/2\Delta g_d = -\hat{\beta}(WWR - \overline{WWR}_{\text{paternal half sibs}}) \cdot WNYR$/herd, dams.
3 $1/2\Delta g_s = -\hat{\beta}(AWWT - \overline{AWWT}_{\text{contemp}}) \cdot WNYR$/herd, sires.
4 $1/2\Delta g_d = -\hat{\beta}(AWWT - \overline{AWWT}_{\text{paternal half sibs}}) \cdot WNYR$/herd, sires.

The estimates of dam trends for the traits studied were also positive in all herds except one. The positive dam trends for WWR ranged from .16 ± .06 to .63 ± .08 ratio units/yr and for DEVN from .01 ± .15 to 1.75 ± .26 kg/yr. Eleven of these estimates were significant ($P<.05$). The dam trend of herd h, which had a significant negative sire trend, was positive, but not significant. Also, a nonsignificant negative dam trend was observed in herd b for which the sire trend was positive and significant ($P<.05$).

Zollinger and Nielsen (1984) used a similar regression approach on records from 15 herds of Angus cattle enrolled in the American Angus Association program. The corresponding estimates of genetic trend for WWR in their study ranged from .01 ± .23 to 1.30 ± .24 ratio units/yr for sire and from .06 ± .06 to .68 ± .11 ratio units/yr for dams.

In the Hereford breed most herds exhibited positive sire trends for the traits studied, but the estimates were significant ($P<.05$) in only two herds. The negative estimates obtained for WWR and DEVN in a few herds were substantially large in magnitude but were not significant due to their large standard errors. All herds showed positive dam trends for the traits measured, and eight of those estimates were significant ($P<.05$) for both traits. The dam trend ranged from .05 ± .11 to .93 ± .15 ratio units/yr and from .19 ± .26 to 2.15 ± .29 kg/yr across herds in this breed. This could have come about from the substantial genetic change contributed from dam selection over and above the existing genetic base, or it might have been the result of placing higher selection emphasis for maternal effects following some unusual bottleneck during the early phase of this study. If such a bottleneck had occurred, it would be difficult to speculate any reasons for such an occurrence. A possible reason might be the selection procedures adopted at that time to eliminate the problem of dwarfism. Here, again, those herds which entered the program in the latter years showed substantially larger magnitude of genetic trends among sires and dams than those which had been in the program for longer periods of time.

Wide variations in the individual herd estimates were expected because of the variations in genetic merit among herds and because of different selection practices used in different herds in either breed. The large genetic gains that were noted in some herds could have been those selected and maintained by high selection pressure. The sampling errors of the estimates were large in small herds due to the small number of the sire progeny groups. In contrast, relatively small sampling errors were observed for estimates obtained from the larger herds; for example, herd e in Angus and herds r and o in Herefords.

Estimates of Genetic Trends among Sires and Dams from the Pooled Herd Data.

I. Estimates from Regression Analyses. The estimates of sire and dam genetic trends for WWR and DEVN obtained from data pooled across herds for each breed using the regression procedure are given in table 15 and the corresponding weaning year constants are shown in appendix tables 4a and 4b, respectively. Sire and dam genetic trend estimates for the traits of interest were positive and highly significant ($P<.001$) in both breeds. However, the sire contribution in the Angus breed appeared to be relatively higher than the dam contribution, whereas, the reverse was true in the Hereford breed. The one-half of the sire trends for WWR and DEVN were .44 ± .04 ratio units/yr and .82 ± .09 kg/yr in Angus breed and the corresponding figures for the Hereford breed were .28 ± .02 ratio units/yr and .51 ± .12 kg/yr. The estimates of one half of the dam trend for the corresponding traits in the Angus breed were .36 ± .02 ratio units/yr and .72 ± .05 kg/yr and in the Hereford breed they were .40 ± .03 ratio units/yr and .79 ± .07 kg/yr.

Estimates for the sire trend for WWR observed in the Angus breed were lower than the average estimate of sire trend of .51 ratio units/yr computed from 15 intraherd estimates (Zollinger and Nielsen, 1984), but the dam trend was in good agreement with their average estimate of .34

TABLE 15. LINEAR REGRESSION COEFFICIENTS AND THEIR EXPECTATIONS FOR WEANING PERFORMANCE TRAITS OF ANGUS AND HEREFORD BREEDS FROM THE REGRESSION ANALYSES

Estimates	Expectations	Units	Angus	Hereford
1. $\hat{\beta}_{AWWT \cdot WNYR/herd}$	ΔP	kg/yr	.96 ± .02 ***	.82 ± .03***
2. $\hat{\beta}_{WWR \cdot WNYR/herd,sire}$	$-1/2\Delta g_{sire}$	ratio units/yr	-.44 ± .04***	-.28 ± .06***
3. $\hat{\beta}_{(AWWT - \overline{AWWT}_{contempories}) \cdot WNYR/herd,sire}$	$-1/2\Delta g_{sire}$	kg/yr	-.82 ± .09***	-.51 ± .12***
4. $\hat{\beta}_{(WWR - \overline{WWR}_{paternal\ half\text{-}sibs}) \cdot WNYR/herd,dams}$	$-1/2\Delta g_{dams}$	ratio units/yr	-.36 ± .02***	-.40 ± .03***
5. $\hat{\beta}_{(AWWT - \overline{AWWT}_{paternal\ half\text{-}sibs}) \cdot WNYR/herd,dams}$	$-1/2\Delta g_{dams}$	kg/yr	-.72 ± .05***	-.79 ± .07***

***P < .001.

ratio units/yr, using a similar analytical approach. The simple regression of sire proof constants on year of birth of the calf in the study of Schaeffer et al. (1981) showed genetic gains of .67 kg/yr in Angus and .21 kg/yr in the Hereford breeds, respectively. Thus, the results of this study indicate that the rate of genetic change for weaning performance has been moderate and in the favourable direction for both breeds.

Generally, there is a tendency for older bulls to be mated to older cows. It is also true that the mates of sires are not necessarily of the same genetic merit, even though they may be of the same age. Generally, however, the older cows tend to be the higher producing cows (due to selection at younger ages) and are of above average genetic merit. Thus, an estimate of total genetic trend ($\hat{G}$), incorporated in this study (for the first time in beef cattle data) was to adjust genetic trends for trends in dam's age and merit within herd and sire subclasses. Thus, the total genetic trend was computed as twice the sire genetic trends, after adjusting for nonrandom matings and superiority of the average genetic merit of the dams (table 16) and appear to have given more efficient estimates of genetic trends for the traits of interest in both breed. The estimate of within-herd regression coefficient of dam age on year was -.023 for Angus and -.027 for Hereford. The

TABLE 16. GENETIC TRENDS COMPUTED FOR WWR (RATIO UNITS/YR) AND DEVN (KG/YR) IN ANGUS AND HEREFORD BREEDS AND THE ADJUSTMENT FACTORS USED FOR NONRANDOM MATINGS AND GENETIC MERIT OF THE DAMS

Breed	Traits	$-1/2\Delta g_s$	ΔD	ΔA	$\hat{G} = \frac{-2[-1/2\Delta g_s - \Delta D}{1 + \Delta A}$
Angus	WWR	-.44	-.0230	.21169**	.69
	DEVN	-.82	-.0759	.21169**	1.23
Hereford	WWR	-.28	.0777	.14102**	.63
	DEVN	-.51	.0616	.14102**	1.00

[a] $-1/2\Delta g_s = \hat{\beta}\text{WWR} \cdot \text{WNYR/herd, sire}$ for WWR and
$\hat{\beta}(\text{AWWT} - \overline{\text{AWWT}}_{\text{contemp}}) \cdot \text{WNYR/herd, sire}$ for DEVN.

$\Delta D = h^2 \times \hat{\beta}(\text{WWR}_{\text{cow's first progeny}} - \overline{\text{WWR}}_{\text{same age group cows weaning in the same yr}}) \cdot \text{WWYR/herd, sire}$

which is the factor that adjusts for the superiority of the dams

$\Delta A = [\hat{\beta}\text{dam age} \cdot \text{WNYR/herd, sire} - \hat{\beta}\text{dam age} \cdot \text{WNYR/herd}]$

which is the factor that adjusts for the nonrandom mating.

$^{**}P < .01$.

corresponding within herd and sire regressions for the respective breeds were .189 and .114. Thus ΔA, the adjustment for non-random mating (table 16), indicates that each year a bull remains in service he is likely to be mated to cows averaging nearly .21 yr older in the Angus breed and .14 yr older in the Hereford breed than his mates in the previous year. The adjustment factor ΔD, accounts for the adjustment of genetic superiority of dam's merit, when mated to a particular sire, relative to all possible mates in the herd. The estimates of Δ for WWR and DEVN were -.02 and -.07 for Angus breed and the corresponding estimates in the Hereford breed were .08 and .06, respectively. The total genetic trends estimated, after eliminating the biases due to the above-mentioned factors were .69 ratio units/yr for WWR and 1.23 kg/yr for DEVN in Angus breed. The corresponding figures for the Hereford breed were .63 ratio units/yr and 1.0 kg/yr.

<u>II</u>. <u>Estimates from Maximum Likelihood Procedure</u>. The maximum likelihood estimation procedure described in the materials and methods and denoted by run 2 gave the estimate of environmental trend for AWWT. The runs 3 and 4 produced the estimates of sire and dam genetic trends for WWR and DEVN in each breed. The analyses of variance for the above three runs for Angus and Herefords are presented in tables 17 and 18, respectively. The estimates of genetic trends

TABLE 17. LEAST-SQUARES ANALYSES OF VARIANCE RESULTS FOR WWR (RATIO UNITS) AND DEVN (KG) FROM MIXED-MODEL MAXIMUM LIKELIHOOD (M.L.) ANALYSES TO DETERMINE GENETIC TRENDS IN ANGUS CATTLE

		Mean squares					
		Run #2 M.L. absorption of matings		Run #3 M.L. absorption of sires		Run #4 M.L. absorption of dams	
Source of variation	df	WWR	DEVN	WWR	DEVN	WWR	DEVN
WNYR	28	329.43***	1,248.47***	460.32***	1,885.19***	753.82***	2,363.32***
Linear	1	6,035.61***	15,757.42***	8,889.00***	28,437.95***	16,666.42***	47,969.28***
Quadratic	1	1,451.56***	8,439.18***	1,630.76**	9,232.41***	3,257.69***	14,493.75***
Cubic	1	110.12	68.39	91.06	113.95	123.26	.32
Quardic	1	115.23	1,863.71*	4.71	1,120.68	531.67*	1,555.10*
Quintic	1	696.88**	4,893.28**	369.09	2,886.03*	44.96	.34
Residual	23	35.42	170.52	82.78	478.09	20.99	74.08
Remainder	[a]	65.69	252.64	99.38	385.48	72.09	282.45

***P < .001.
**P < .01.
*P < .05.

[a]The remainder degrees of freedom for the runs 2, 3 and 4 are 24,388, 27,217 and 27,086, respectively, due to the different absorption of subclasses, thus, the within SS df for the corresponding runs are 24,416, 27,245 and 27,114.

TABLE 18. LEAST-SQUARES ANALYSES OF VARIANCE RESULTS FOR WWR (RATIO UNITS) AND DEVN (KG) FROM MIXED-MODEL MAXIMUM LIKELIHOOD (M.L.) ANALYSES TO DETERMINE GENETIC TRENDS IN HEREFORD CATTLE

		Mean squares					
Source of		Run #2 M.L. absorption of matings		Run #3 M.L. absorption of sires		Run #4 M.L. absorption of dam	
variation	df	WWT	DEVN	WWR	DEVN	WWR	DEVN
WNYR	29	124.09*	492.54*	147.90	596.96	438.31***	1,475.22***
Linear	1	222.97	2.16	2,176.41***	7,019.57***	2,969.95***	6,199.91***
Quadratic	1	2,048.06***	8,296.33***	1,278.93**	6,814.69***	7,288.19***	24,252.32***
Cubic	1	1.16	10.32	127.67	395.42	1.13	7.81
Quardic	1	220.02	1,037.55	45.34	283.33	1,378.35***	6,902.16***
Quintic	1	.08	.22	2.45	2.11	312.62*	1,743.25*
Residual	24	46.10	205.57	27.44	116.53	31.70	153.16
Remainder	a	72.63	118.02	110.66	495.54	74.93	339.18

***P < .001.
**P< .01.
*P < .05.

[a]The remainder degrees of freedom for the 2, 3, 4 runs are 12,690, 14,491 and 14,346, respectively, due to the different absorption of subclasses, thus, the within SS df for the corresponding runs are 12,719, 14,520 and 14,375.

(linear coefficients) obtained from the polynomial regression of those analyses for each breed are shown in table 19. The environmental trends for AWWT estimated by fitting weaning year constants on year obtained from run 2 with the maximum likelihood absorption of matings (sire and dam), showed nonsignificant time trends of -.35 ± .10 for Angus and .03 ± .15 for Herefords.

The analyses of variance results for WWR and DEVN in all three runs (table 17) of the Angus data showed highly significant WNYR effect (P<.001), as well as the linear and quadratic effect (P<.001) obtained from the polynomial regressions. In contrast, the corresponding analyses of the Hereford data (table 18) did not show a significant WNYR effect (P<.05) for run 3 (model used to estimate sire trend). However, highly significant linear effect (P<.001) of WWR and DEVN in runs 3 and 4 as well as the significant quadratic effects (P<.01) in all three runs (2, 3 and 4) provided some insight of the pattern of genetic change that had taken place in this breed.

The weaning year least-squares constants for WWR and DEVN obtained from the M.L. analyses for the respective breeds are presented in tables 20 and 21, respectively. The least-squares constants for WWR and DEVN for Hereford (table 21) clearly described the quadratic pattern of the genetic change in this breed. The maximum likelihood

TABLE 19. LINEAR REGRESSION COEFFICIENTS[1] OBTAINED FOR WWR (RATIO UNITS/YR) AND DEVN (KG/YR) IN ANGUS AND HEREFORD CATTLE FROM THE MAXIMUM LIKELIHOOD ESTIMATION PROCEDURE

Analytical procedure	Traits	Linear regression coefficients	
		Angus	Hereford
Run #2: Least-squares absorption of herd-SYR-DYR;	WWR	-.46 ± .05***	-.12 ± .07*
M.L. absorption of matings (sire & dams) (r = .40)	DEVN	-.74 ± .09***	-.01 ± .14
Model fitted to WNYR.			
Run #3: Least-squares absorption of herd and SYR;	WWR	-.40 ± .04***	-.25 ± .06***
M.L. absorption of sires (r = .12)			
Model fitted to WNYR.	DEVN	-.72 ± .07***	-.45 ± .12***
Run #4: Least-squares absorption of herd and DYR;	WWR	-.32 ± .02***	-.21 ± .03***
M.L. absorption of dams (r = .40)			
Model fitted to WNYR.	DEVN	-.55 ± .04***	-.30 ± .07***

*P < .05.
***P < .001.

[1] The expectations of the regression coefficients in runs 2, 3 and 4 for each trait are, respectively, the negative estimates of total, and one-half of the sire and dam genetic trends.

TABLE 20. WEANING YEAR (WNYR) LEAST-SQUARES CONSTANTS FROM M.L. ANALYSES (RUNS 3&4) FOR WWR (RATIO UNITS) AND DEVN (KG) IN ANGUS CATTLE

	WWR		DEVN	
WNYR	Sire effect (run #3)	Dam effect (run #4)	Sire effect (run #3)	Dam effect (run #4)
1955	2.0	2.3	3.5	4.1
1956	3.1	2.7	4.1	4.1
1957	3.4	2.5	5.5	3.6
1958	3.0	2.8	4.7	4.3
1959	4.1	2.4	6.2	3.3
1960	3.5	2.4	5.7	3.9
1961	3.1	2.1	4.8	3.1
1962	3.3	2.0	5.2	3.1
1963	3.0	2.1	5.1	3.6
1964	2.7	2.1	3.8	3.4
1965	1.6	1.7	2.4	2.8
1966	1.0	1.7	1.5	3.1
1967	1.3	1.4	2.6	2.7
1968	1.3	1.4	2.7	2.7
1969	1.3	1.3	3.7	2.5
1970	.5	.9	2.7	2.0
1971	.7	.3	3.3	.7
1972	0	-.2	1.5	.1
1973	-.5	-.2	.2	-.1
1974	-.8	-.9	-.3	-1.0
1975	-1.7	-1.4	-2.5	-2.0
1976	-2.6	-2.0	-4.4	-3.0
1977	-3.0	-2.6	-5.7	-4.0
1978	-3.7	-3.1	-7.2	-5.0
1979	-4.4	-3.7	-8.6	-6.0
1980	-4.4	-4.0	-8.2	-6.7
1981	-5.1	-4.2	-9.3	-7.2
1982	-6.3	-4.8	-11.9	-8.6
1983	-6.4	-5.0	-12.1	-9.5

TABLE 21. WEANING YEAR (WNYR) LEAST-SQUARES CONSTANTS FROM M.L. ANALYSES (RUNS 3&4) FOR WWR (RATIO UNITS) AND DEVN (KG) IN HEREFORD CATTLE

	WWR		DEVN	
WNYR	Sire effect (run #3)	Dam effect (run #4)	Sire effect (run #3)	Dam effect (run #4)
1954	1.2	-1.2	.8	-3.4
1955	1.9	-1.2	2.2	-3.0
1956	1.9	-0.8	2.3	-1.8
1957	2.2	-0.3	2.9	-1.6
1958	1.3	- .6	1.8	-2.0
1959	.5	- .4	.9	-1.4
1960	.5	- .1	1.1	- .6
1961	1.0	.3	1.5	- .4
1962	1.6	.9	2.8	.6
1963	1.4	.9	2.5	1.1
1964	1.4	1.5	2.9	2.6
1965	1.5	1.6	2.9	2.7
1966	1.4	2.0	2.8	3.5
1967	1.2	1.9	2.8	3.4
1968	1.3	2.1	2.8	3.9
1969	1.3	1.8	3.2	3.4
1970	1.1	2.2	2.8	4.2
1971	1.0	2.3	2.7	4.7
1972	.5	2.2	2.0	4.6
1973	.1	1.8	.9	3.9
1974	- .1	1.4	.4	3.3
1975	- .5	.8	- .9	1.9
1976	-1.5	- .2	-2.8	0
1977	-1.7	-1.2	-3.0	-1.9
1978	-1.9	-1.8	-3.2	-3.1
1979	-2.1	-2.5	-3.5	-4.1
1980	-3.1	-3.1	-5.9	-4.9
1981	-3.7	-3.2	-7.3	-4.9
1982	-4.7	-3.2	-9.0	-4.6
1983	-5.0	-3.9	-7.8	-6.0

estimates of one half of the sire genetic trend for WWR and DEVN (table 19) in the Angus breed were .40 ± .04 ratio units/yr and .72 ± .07 kg/yr. The corresponding sire contribution in Herefords were .25 ± .06 ratio units/yr and .45 ± .12 kg/yr. The estimates of the one half of the dam genetic trend in Angus breed for WWR and DEVN were .32 ± .02 ratio units/yr and .55 ± .04 kg/yr. Such maximum likelihood estimates of the dam trend, obtained for Herefords, were .21 ± .03 ratio units/yr and .30 ± .07 kg/yr.

Kennedy and Henderson (1977) estimated sire and dam trends for weaning weight, using maximum likelihood approach, and reported 3.44 ± .83 kg/yr for creep-fed and 1.51 ± .61 kg/yr for non-creep-fed Angus populations as sire trends. The corresponding estimates of dam trends for weaning weight in Angus for the above groups were -.32 ± .67 kg/yr and .80 ± .48 kg/yr, respectively. In their study, the sire trend for weaning weight in the creep-fed Herefords was reported as 1.63 ± .65 kg/yr and in the non-creep-fed group as 1.34 ± .48 kg/yr. The corresponding dam trends were .24 ± .57 kg/yr and .11 ± .42 kg/yr, respectively.

The figures 3 and 4 show the plots for the one half of the sire and dam's genetic trends for WWR and DEVN achieved in the Angus breed based on this study. The corresponding plots for the Hereford breed are shown in figures 5 and 6. It can be seen from these figures that, apart from the

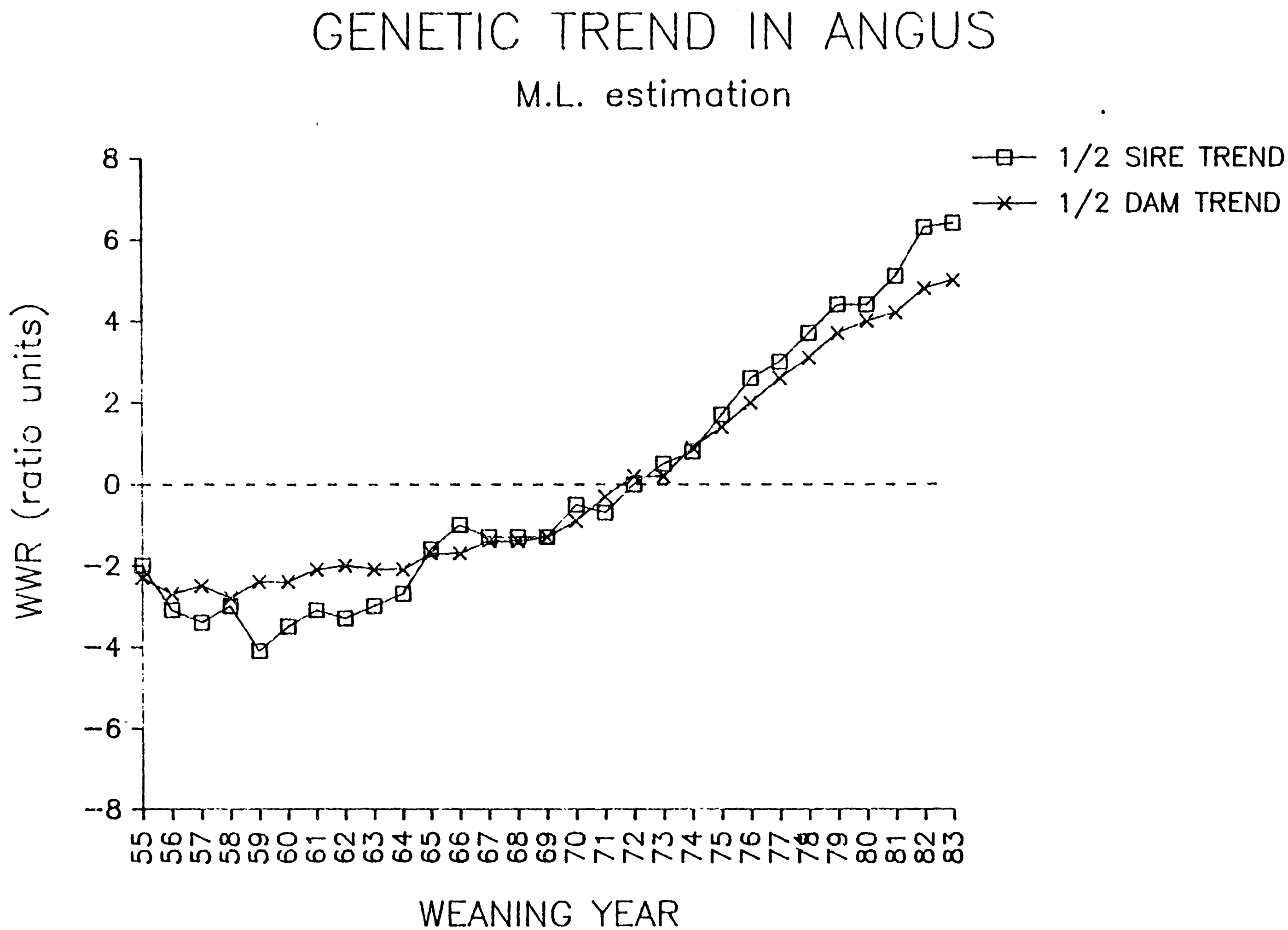

FIGURE 3. SIRE AND DAM GENETIC TRENDS FOR WWR IN ANGUS CATTLE OBTAINED FROM MAXIMUM LIKELIHOOD ESTIMATION.

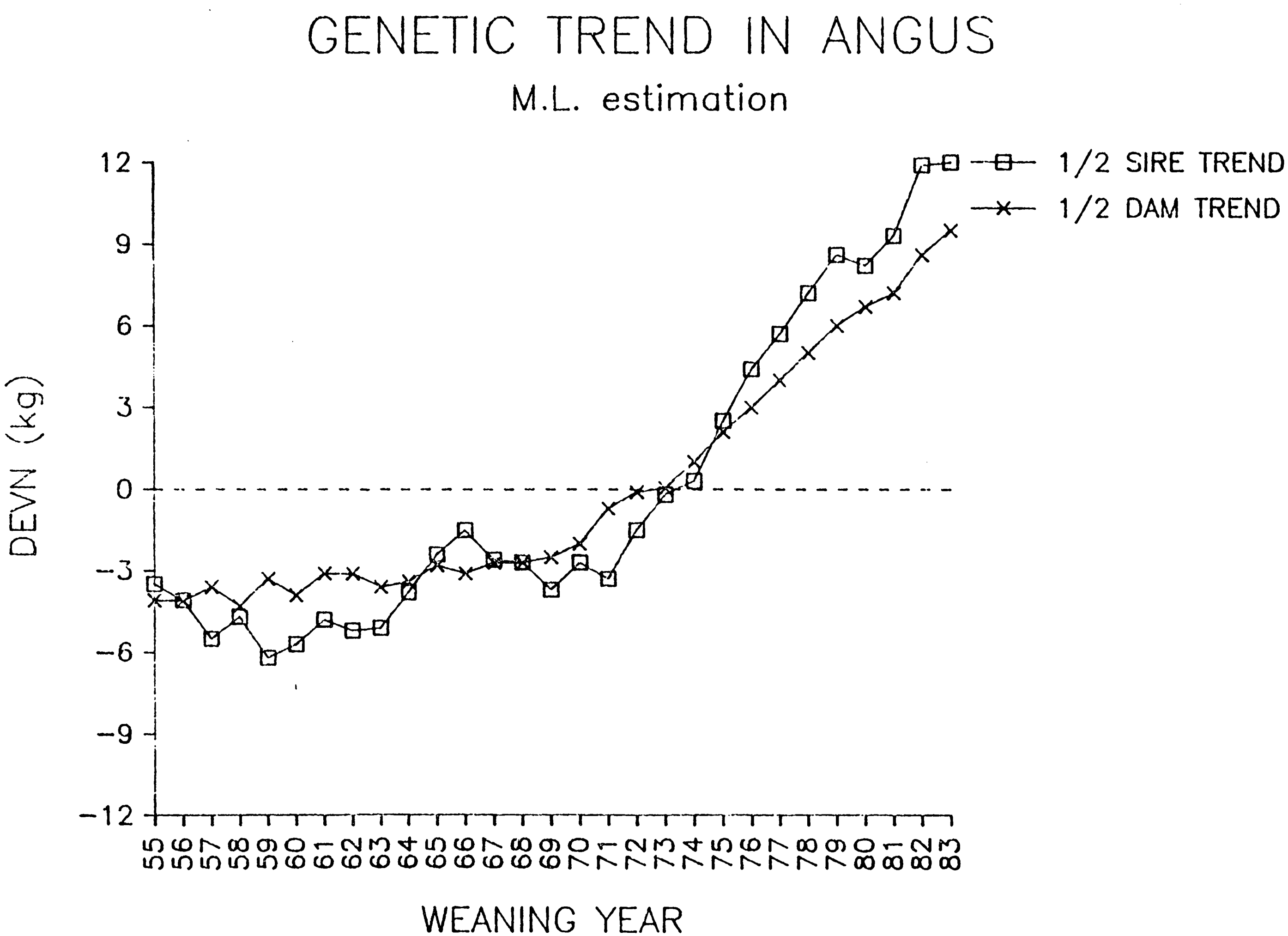

FIGURE 4. SIRE AND DAM GENETIC TRENDS FOR DEVN IN ANGUS CATTLE OBTAINED FROM MAXIMUM LIKELIHOOD ESTIMATION.

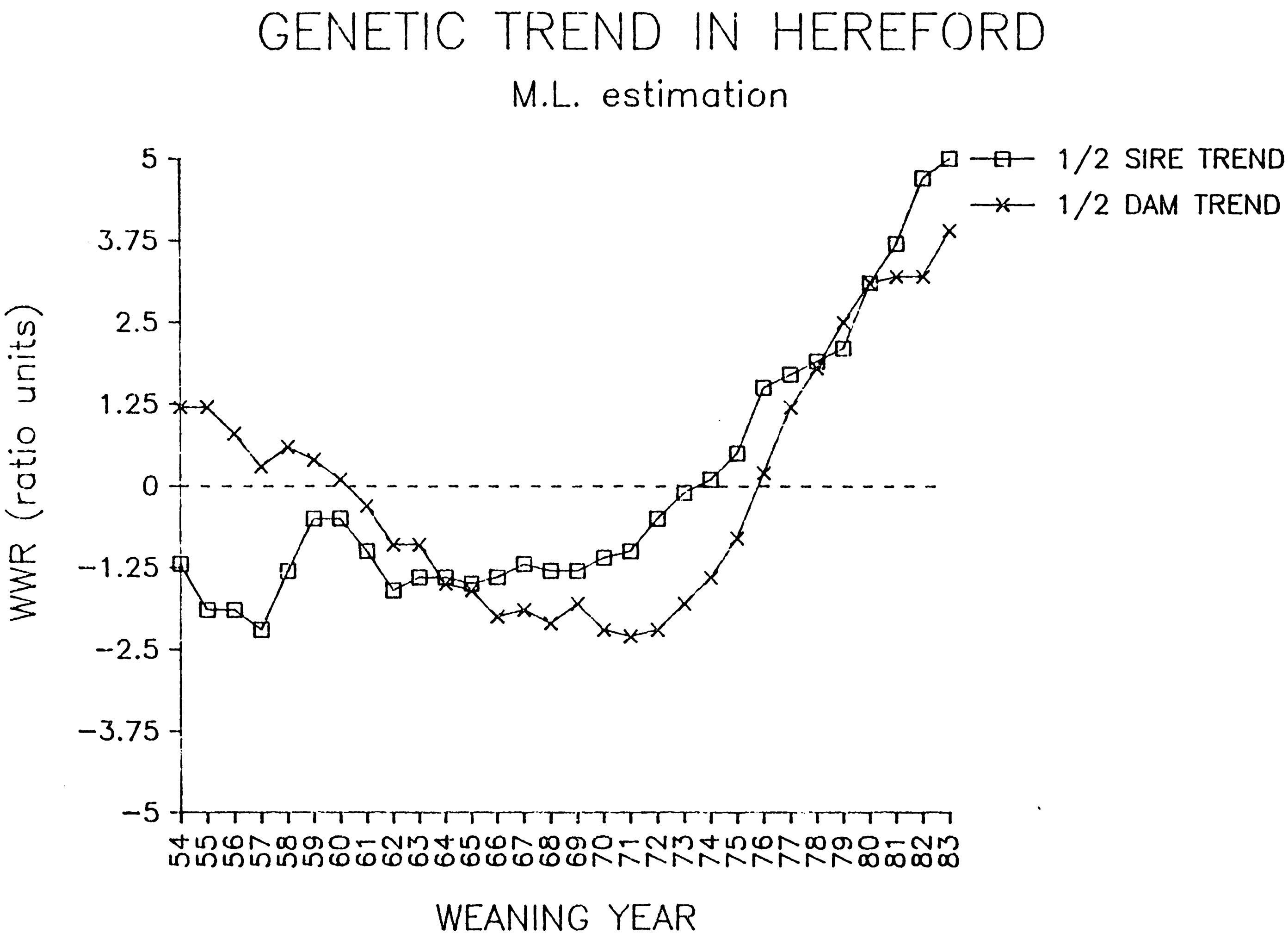

FIGURE 5. SIRE AND DAM TRENDS FOR WWR IN HEREFORD CATTLE OBTAINED FROM MAXIMUM LIKELIHOOD ESTIMATION.

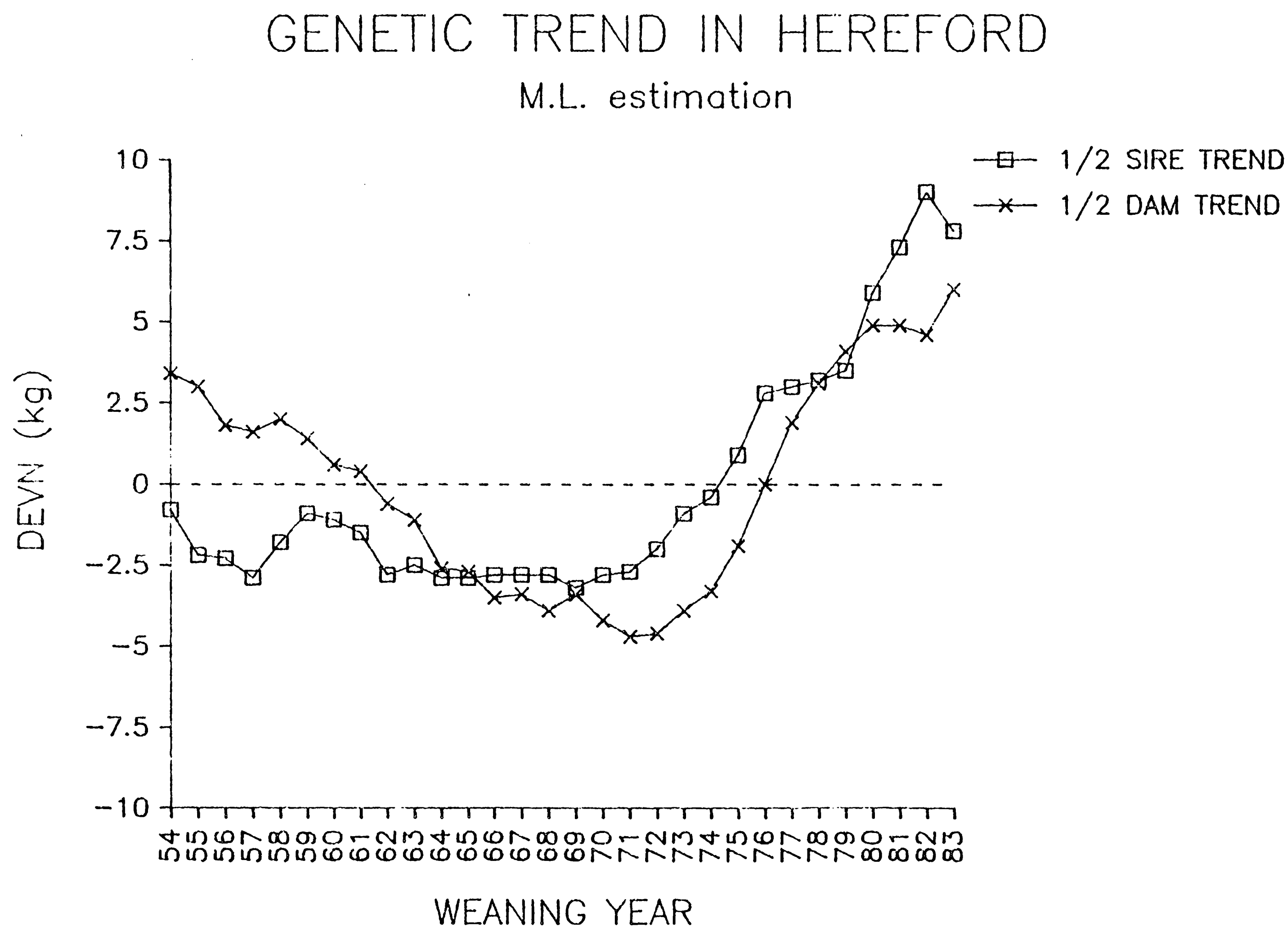

FIGURE 6. SIRE AND DAM GENETIC TRENDS FOR DEVN IN HEREFORD CATTLE OBTAINED FROM MAXIMUM LIKELIHOOD ESTIMATION.

random yearly fluctuations in both breeds, the genetic trends among the sires and dams in the Angus breed seemed to be more uniform than those for Herefords. The varying genetic merit of bulls and cows selected associated with the sampling errors are probably the major reasons for the fluctuations among the year constants. The curves for the Herefords are more of a quadratic nature than those of the Angus. The lesser progress during early phase of this study among Hereford, especially in the dam trend, causes a real decline in the linear coefficients of the total genetic trends for WWR and DEVN. This decline may be due to the selection procedures adopted at that time to eliminate the carriers responsible for the problem of dwarfism. Perhaps during this period, breeders were selecting lines of cows and sires based largely on their pedigree, regardless of their growth performance, so long as they had no history of dwarfism. Furthermore, the sire and dam trends for the traits measured in both breeds showed a slight plateauing effect around 1968 to 1970. After 1971 a rapid improvement of genetic gain for growth and maternal ability can be seen in both breeds. This situation is believed to have come about from greater emphasis on the use of performance tested bulls, open AI and perhaps more efficient evaluation of individual sires.

In the Angus breed the estimates of sire and dam genetic trends prior to year 1971 were positive but substantially lower than the estimates obtained after 1971. The estimates of one-half of the sire and dam genetic trends, respectively, in this breed during the latter phase (1971 through 1983) were .60 and .47 ratio units/yr for WWR and 1.30 and .88 kg/yr for DEVN respectively. However, in the Hereford breed the estimates of sire and dam genetic trends prior to 1971 were negative, especially in the dam trend for which the decline was over .5 kg/yr. But, during the period 1971 through 1983 a three-fold increase in genetic progress relative to the early phase was observed. The estimates of one-half of the sire and dam trends for WWR and DEVN in Herefords during the latter phase (1971 through 1983) were .49 and .58 ratio units/yr and .96 and 1.02 kg/yr, respectively.

Therefore, genetic increase in weaning performance among the progenies of the respective breeds, as shown in both analytical approaches in this study, clearly indicates that the emphasis was placed on selection of breeding bulls and cows which transmitted their genetic merit to their progeny. Furthermore, there is some evidence to suggest that the sire genetic trends are different from the dam genetic trends in both breeds. However, regardless of the emphasis placed on sire and dams selection, the genetic trends of both sires and dams operating in the same direction indicate gross improvement of these breeds simultaneously for growth and maternal ability.

General Discussion. The summary of the estimated genetic trends for WWR and AWWR from both approaches are presented in table 22. The estimates of genetic change/yr among the two breeds were not similar but were comparable to the genetic trends reported from other studies for these breeds.

The probability of achieving net genetic progress within these breeds must have been associated with replacement of better bulls and dams within the individual herds used in this study. Examination of genetic changes at each year in this study (figures 3-6) indicated that the pattern of change in these breeds was quite different. In the Angus breed the rate of change for WWR and AWWT has been slightly higher but relatively uniform (figures 3 and 4); whereas, the patterns of changes in Hereford breed (figures 5 and 6) suggest that at least during the early phase of this study there had been only a little attention given to sire and dam selection for increase growth and maternal ability. Perhaps this situation would have led to some loss in average genetic merit for growth and maternal ability during the early phase of this study in this breed. Another factor that possibly influenced the decline in growth and maternal ability in the Hereford breed may have been

TABLE 22. SUMMARY OF ESTIMATES OF GENETIC TRENDS FOR WWR (RATIO UNITS/YR) AND AWWT (KG/YR) IN ANGUS AND HEREFORD BREEDS FROM REGRESSION ANALYSES AND MAXIMUM LIKELIHOOD PROCEDURE

Type of estimation	Estimate	Trait	Breeds: Angus	Breeds: Hereford
Regression analyses	$1/2\Delta g_s$	WWR	.44	.28
	$1/2\Delta g_d$	WWR	.36	.40
	$1/2\Delta g_s$	AWWT	.82	.51
	$1/2\Delta g_d$	AWWT	.72	.79
	$\left[1/2\Delta g_s + 1/2\Delta g_d\right]$	WWR	.80	.68
		AWWT	1.54	1.30
	$\Delta\hat{G}$*	WWR	.69	.63
		AWWT	1.23	1.00
Maximum likelihood analyses	$1/2\Delta g_s$	WWR	.40	.25
	$1/2\Delta g_d$	WWR	.32	.21
	$1/2\Delta g_s$	AWWT	.72	.45
	$1/2\Delta g_d$	AWWT	.55	.30
	$\left[1/2\Delta g_s + 1/2\Delta g_d\right]$	WWR	.72	.46
		AWWT	1.27	.75

*$\Delta\hat{G}$ is the genetic trend computed after adjusting for nonrandom matings and genetic merit of the dams. Refer to table 16 for details of computations.

associated with the change from horned to polled Herefords in the State during this period.

There was a clear upward trend in both breeds from 1971 onward. The sudden increase in the average genetic merit of both breeds corresponds to the emerging of the national Beef Improvement Federation (BIF) and its active participation in the national beef improvement programs, aided also by the development of breed association programs based on the BIF guidelines.

Another striking point shown in this study was the robustness of the estimates of genetic trend by the maximum likelihood procedure in contrast to the conventional regression procedure. The use of diagonal inverse elements (the intraclass correlations in this case) to obtain maximum likelihood estimates provided more efficient estimates by regressing the corresponding weaning year least-squares means. The mechanics of this process is believed to automatically adjust for the imperfect repeatability and annual culling levels. Thus, the preferred method for estimating genetic trends in this study seemed to be the maximum likelihood estimation procedure.

SUMMARY AND CONCLUSIONS

The phenotypic, genetic and environmental trends for weaning weight performance in the Angus and Hereford breeds were estimated from Virginia BCIA records over a 30 yr period. The estimates of annual phenotypic trend for AWWT in the Angus and Hereford were .96 and .82 kg/yr, respectively.

There has been moderate but relatively steady increase in genetic merit for direct growth and maternal ability in both breeds during the study period. However, this increase was found to be slightly higher in Angus than in Hereford. The improvement in genetic merit, as well as the difference in the magnitude of that improvement, for growth and maternal ability among breeds was probably caused by the general emphasis placed on selection of dams and sires in individual herds.

Although the estimates of genetic trends from both approaches were comparable, the estimates obtained from regression analyses were sightly higher than estimates obtained from the maximum likelihood estimation procedure. The latter method is believed to adjust automatically for the imperfect repeatability and the annual culling levels in the estimation of weaning year constants and, thus, the estimates of trends. The application of adjustment factors for trends in age of dam and genetic merit of the mates to the estimates of sire genetic trends in the regression analysis brought the estimates closer to the estimates obtained from the maximum likelihood procedure. The average annual genetic trends over the study period from maximum likelihood procedure for AWWT for Angus and Hereford breeds were 1.27 and .75 kg, respectively.

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APPENDIX

APPENDIX TABLE 1a. DISTRIBUTION OF WEANING WEIGHT RECORDS OF CALVES IN ANGUS BREED BY HERD AND YEAR

	Herd													
Year	a	b	c	d	e	f	g	h	i	j	k	l	m	Total
1953	13	-	-	-	-	-	-	-	-	-	-	-	-	13
1954	14	8	-	-	-	-	-	-	-	-	-	-	-	22
1955	21	34	48	8	145	-	-	-	-	-	-	-	-	256
1956	17	55	39	12	206	51	-	-	-	-	-	-	-	380
1957	5	64	46	27	217	47	14	40	-	-	-	-	-	460
1958	27	61	76	15	205	81	25	25	50	82	-	-	-	647
1959	23	77	77	24	205	38	17	44	48	68	-	-	-	621
1960	20	77	115	14	194	38	29	44	42	87	33	-	-	693
1961	20	87	167	30	389	51	22	32	53	85	30	-	-	966
1962	33	72	98	20	263	39	43	32	57	64	42	41	-	804
1963	30	63	142	28	317	52	37	34	26	84	44	37	-	894
1964	30	65	152	41	296	51	27	48	62	104	35	48	41	1,000
1965	24	77	134	25	304	49	42	46	59	68	61	58	65	1,012
1966	18	68	125	29	295	39	65	67	62	79	53	61	62	1,023
1967	21	66	151	29	374	56	37	69	64	86	63	44	77	1,137
1968	18	55	140	25	396	58	81	64	73	94	72	21	93	1,190
1969	14	76	111	0	365	52	20	70	82	80	36	11	98	1,015
1970	9	79	110	28	314	51	48	72	73	96	74	35	99	1,088
1971	34	86	146	51	283	47	38	45	76	94	95	55	94	1,144
1972	25	90	171	41	275	47	55	45	81	93	94	58	0	1,075
1973	17	77	174	30	265	45	37	47	79	90	68	58	99	1,086
1974	24	79	174	53	275	58	50	57	74	104	77	92	106	1,223
1975	29	92	135	55	327	56	59	52	77	126	90	102	99	1,299
1976	24	86	128	59	346	76	51	58	87	119	79	51	116	1,280
1977	36	29	148	61	301	80	48	56	82	125	97	91	90	1,244
1978	31	55	115	40	295	102	40	50	89	121	106	77	75	1,196
1979	49	60	132	40	292	128	44	44	92	109	92	125	28	1,235
1980	47	64	122	55	265	166	44	49	101	113	94	147	43	1,310
1981	43	60	101	70	216	193	44	53	101	121	113	147	45	1,307
1982	45	71	139	39	355	234	25	50	107	129	100	145	41	1,480
1983	38	58	127	47	295	186	0	46	102	109	96	130	48	1,284
Total	799	1,991	3,543	996	8,275	2,171	1,042	1,339	1,899	2,530	1,744	1,634	1,419	29,382

APPENDIX TABLE 1b. DISTRIBUTION OF WEANING WEIGHT RECORDS OF CALVES IN HEREFORD BREED BY HERD AND YEAR

Year	Herd											Total
	n	o	p	q	r	s	t	u	v	w	x	
1954	30	68	-	-	-	-	-	-				98
1955	30	63	17	-	-	-	-	-				116
1956	72	72	12	28	-	-	-	-				184
1957	43	76	21	29	39	-	-	-				208
1958	39	36	15	26	36	-	-	-				152
1959	49	70	18	31	26	-	-	-				194
1960	48	58	20	34	43	-	-	-				203
1961	58	79	21	28	32	25	18	-	-	-		261
1962	71	76	13	28	21	43	44	22	-	-	-	318
1963	55	82	22	33	60	63	13	30	25	-	-	383
1964	67	83	29	31	64	72	50	29	28	34	36	523
1965	76	79	25	43	56	81	51	24	31	56	33	555
1966	62	84	40	39	69	78	59	28	29	87	38	613
1967	74	82	25	30	70	88	52	26	30	87	51	615
1968	71	90	33	27	77	94	50	28	29	111	57	667
1969	36	82	27	37	73	112	58	18	26	120	66	655
1970	82	59	32	30	84	87	50	39	28	115	78	684
1971	56	42	25	36	74	76	55	36	23	90	85	712
1972	84	99	30	35	82	61	68	25	40	-	79	702
1973	83	52	14	36	88	88	61	39	-	-	100	613
1974	87	102	20	43	110	66	73	21	58	102	101	783
1974	90	106	20	44	104	74	67	42	66	96	106	815
1976	91	82	15	33	100	99	54	36	41	116	108	775
1977	75	81	24	24	104	93	68	25	45	132	104	778
1976	77	72	21	38	108	62	63	39	75	110	126	733
1979	69	85	35	37	116	-	52	36	74	99	143	792
1980	66	79	20	38	116	42	64	40	84	88	149	836
1981	81	80	18	-	104	98	59	42	95	115	145	640
1982	72	62	23	26	99	40	44	-	81	-	175	534
1983	84	56	21	-	98	-	54	-	111		158	582
	1,984	2,281	656	864	2,053	1,542	1,227	642	1,019	1,559	1,938	15,765

TABLE 2a. PHENOTYPIC AVERAGES AND STANDARD DEVIATIONS OF PROGENY WEANING WEIGHT (KG) OF DAMS[a] AND SIRES[b] IN DIFFERENT YEAR GROUP IN ANGUS BREED

Year	No. progeny	Dam yr mean ± SD	No. sires	No. progeny	Sire year mean ± SD
1947	58	173 ± 28			-
1948	93	171 ± 33			-
1949	111	174 ± 39			-
1950	166	172 ± 36			-
1951	219	178 ± 33			-
1952	407	185 ± 33			-
1953	575	176 ± 33	1	58	198 ± 29
1954	817	176 ± 34	1	16	186 ± 19
1955	770	178 ± 34	29	556	169 ± 28
1956	593	178 ± 37	21	456	171 ± 29
1957	599	176 ± 35	31	766	179 ± 34
1958	593	172 ± 33	27	567	178 ± 35
1959	951	179 ± 38	25	921	171 ± 34
1960	980	176 ± 36	29	1,514	170 ± 31
1961	1,038	180 ± 41	17	843	181 ± 42
1962	994	177 ± 39	20	643	189 ± 40
1963	1,324	184 ± 39	26	1,040	175 ± 40
1964	978	185 ± 39	25	721	171 ± 35
1965	1,074	184 ± 41	32	1,317	177 ± 41
1966	1,233	185 ± 39	26	1,260	193 ± 42
1967	965	184 ± 39	30	907	181 ± 37
1968	879	186 ± 39	28	834	182 ± 38
1969	784	193 ± 40	25	761	186 ± 39
1970	1,128	192 ± 36	38	1,608	189 ± 38
1971	1,146	194 ± 35	43	655	181 ± 37
1972	1,141	197 ± 34	32	1,354	201 ± 34
1973	1,038	198 ± 37	37	908	182 ± 37
1974	1,270	198 ± 37	47	1,237	192 ± 34
1975	968	195 ± 37	41	1,822	196 ± 36
1976	926	199 ± 36	25	645	191 ± 34
1977	967	203 ± 39	62	1,350	196 ± 37
1978	728	199 ± 39	38	649	207 ± 39
1979	628	196 ± 39	79	892	202 ± 38
1980	581	191 ± 37	66	1,312	196 ± 34
1981	470	190 ± 37	60	942	200 ± 39
1982	283	189 ± 38	67	726	207 ± 41
1983	79	168 ± 33	30	274	190 ± 39

[a]Year in which a group of replacement heifers added for breeding in any herd.
[b]Year in which a group of sires introduced first time in any herd.

TABLE 2b. PHENOTYPIC AVERAGES AND STANDARD DEVIATIONS FOR CALVES' WEANING WEIGHTS (KG) OF DAMS[a] AND SIRES[b] IN DIFFERENT YEAR GROUP IN HEREFORD BREED

Year	No. progeny	Dam yr mean ± SD	No. sires	No. progeny	Sire year mean ± SD
1945	6	179 ± 16			-
1946	23	172 ± 35			-
1947	16	179 ± 26			
1948	50	186 ± 31			-
1949	42	193 ± 30			
1950	132	199 ± 34			-
1951	109	189 ± 37			-
1952	112	198 ± 38			-
1953	214	187 ± 36			-
1954	166	194 ± 43	7	274	188 ± 34
1955	165	190 ± 42	7	213	179 ± 30
1956	160	199 ± 39	9	177	203 ± 40
1957	210	208 ± 45	6	157	181 ± 32
1958	541	195 ± 40	9	412	196 ± 41
1959	274	194 ± 42	4	97	188 ± 34
1960	575	191 ± 37	4	96	177 ± 43
1961	422	189 ± 38	16	551	180 ± 35
1962	622	188 ± 38	13	336	210 ± 44
1963	553	188 ± 40	13	692	199 ± 42
1964	647	195 ± 41	18	818	192 ± 42
1965	640	199 ± 45	12	487	188 ± 34
1966	464	193 ± 37	15	1,019	197 ± 44
1967	664	201 ± 42	14	547	193 ± 38
1968	692	199 ± 41	16	302	195 ± 38
1969	594	188 ± 43	17	577	182 ± 35
1970	605	192 ± 43	20	391	191 ± 35
1971	814	200 ± 45	24	547	185 ± 44
1972	706	196 ± 44	19	779	193 ± 39
1973	521	200 ± 45	21	675	204 ± 45
1974	517	201 ± 44	29	797	185 ± 41
1975	594	211 ± 49	20	757	204 ± 46
1976	720	213 ± 44	19	465	211 ± 44
1977	614	209 ± 44	30	1,083	208 ± 40
1978	463	205 ± 45	20	380	222 ± 40
1979	467	210 ± 44	30	515	210 ± 47
1980	249	205 ± 42	30	816	219 ± 45
1981	242	205 ± 40	29	467	209 ± 45
1982	117	217 ± 37	20	228	229 ± 38
1983	16	224 ± 48	21	83	228 ± 44

[a]Year in which a group of replacement heifers added for breeding in any herd.
[b]Year in which a group of sires introduced first time in any herd.

APPENDIX TABLE 3. AGE OF DAM, SEX OF CALF (ADDITIVE) AND AGE OF CALF (MULTIPLICATIVE) ADJUSTMENT FACTORS USED IN ADJUSTMENT OF ACTUAL WEANING WEIGHT

Effects	Angus	Hereford
Age of dam		
2 yr old	+18.6 kg	+19.9 kg
3 yr old	+ 8.8 kg	+10.4 kg
4 yr old	+ 3.6 kg	+ 4.1 kg
5-10 yr old	0	0
>10 yr old	+ 4.1 kg	+ 5.4 kg
Sex of calf		
Bull	-15.4 kg	-24.9 kg
Heifer	+10.9 kg	+ 6.8 kg
Steers	0	0
Age of calf		
205 d age	(Actual age-205 d)*.669 kg	(Actual age-205 d)*.71 kg

APPENDIX TABLE 4a. WEANING YEAR LEAST-SQUARES CONSTANTS FROM REGRESSION ANALYSES FOR WWR (RATIO UNITS) AND DEVN (KG) IN ANGUS CATTLE

WNYR	WWR: Sire effect[a]	WWR: Dam effect[b]	DEVN: Sire effect[c]	DEVN: Dam effect[d]
1955	- 9.1 ± 1.7	-10.0 ± .9	-17.2 ± 3.3	-19.5 ± 2.0
1956	-10.3 ± 1.6	- 9.4 ± .8	-17.9 ± 3.1	-19.1 ± 1.7
1957	-10.8 ± 1.3	- 9.2 ± .8	-19.4 ± 2.6	-18.5 ± 1.7
1958	-10.3 ± 1.3	- 9.2 ± .7	-18.8 ± 2.5	-18.9 ± 1.6
1959	-11.5 ± 1.2	- 8.5 ± .7	-20.3 ± 2.4	-17.1 ± 1.5
1960	-10.7 ± 1.2	- 8.5 ± .7	-19.5 ± 2.3	-17.8 ± 1.4
1961	-10.2 ± 1.1	- 7.9 ± .6	-18.5 ± 2.1	-16.7 ± 1.3
1962	-10.4 ± 1.1	- 7.7 ± .6	-18.9 ± 2.1	-16.5 ± 1.3
1963	-10.3 ± 1.0	- 7.9 ± .6	-18.8 ± 2.1	-17.1 ± 1.3
1964	- 9.8 ± 1.0	- 7.5 ± .6	-17.5 ± 2.0	-16.4 ± 1.2
1965	- 8.8 ± 1.0	- 7.4 ± .5	-15.8 ± 2.0	-15.9 ± 1.2
1966	- 8.1 ± .9	- 7.3 ± .5	-14.9 ± 1.9	-16.2 ± 1.2
1967	- 8.5 ± .9	- 7.0 ± .5	-16.2 ± 1.9	-15.6 ± 1.1
1968	- 8.4 ± .9	- 6.7 ± .5	-16.1 ± 1.9	-15.7 ± 1.1
1969	- 8.3 ± .9	- 6.6 ± .5	-16.9 ± 1.8	-15.6 ± 1.1
1970	- 7.5 ± .8	- 6.3 ± .5	-15.9 ± 1.8	-15.0 ± 1.1
1971	- 7.7 ± .8	- 5.5 ± .5	-16.6 ± 1.7	-13.0 ± 1.1
1972	- 6.9 ± .8	- 5.5 ± .5	-14.4 ± 1.6	-12.5 ± 1.1
1973	- 6.4 ± .7	- 5.3 ± .5	-13.1 ± 1.6	-12.6 ± 1.1
1974	- 6.0 ± .7	- 4.6 ± .5	-12.4 ± 1.5	-11.5 ± 1.0
1975	- 5.2 ± .7	- 4.0 ± .5	-10.1 ± 1.4	-10.2 ± .9
1976	- 4.1 ± .7	- 3.5 ± .5	- 8.1 ± 1.4	- 8.9 ± .9
1977	- 3.8 ± .6	- 2.9 ± .4	- 6.8 ± 1.4	- 7.8 ± .9
1978	- 3.0 ± .6	- 2.6 ± .4	- 5.1 ± 1.3	- 7.1 ± .9
1979	- 2.3 ± .6	- 2.1 ± .4	- 3.5 ± 1.3	- 5.8 ± .9
1980	- 2.3 ± .6	- 1.6 ± .4	- 4.0 ± 1.1	- 5.0 ± .8
1981	- 1.5 ± .5	- 1.2 ± .4	- 2.2 ± 1.1	- 4.1 ± .8
1982	- 0.1 ± .5	- .3 ± .4	- .4 ± .9	- 1.6 ± .8
1983	0	0	0	0

[a] βWWR·WNYR/herd,sire.

[b] $\beta(WWR - \overline{WWR}_{PHS})$·WNYR/herd,dam.

[c] $\beta(AWWT - \overline{AWWT}_{contemp})$·WNYR/herd,sire.

[d] $\beta(AWWT - \overline{AWWT}_{PHS})$·WNYR/herd,dam.

APPENDIX TABLE 4b. WEANING YEAR LEAST-SQUARES CONSTANTS FROM REGRESSION ANALYSIS FOR WWR (RATIO UNITS) AND DEVN (KG) IN HEREFORD CATTLE

WNYR	WWR		DEVN	
	Sire effects[a]	Dam effect[b]	Sire effect[c]	Dam effect[d]
1954	-7.2 ± 2.5	-10.4 ± 1.7	-12.6 ± 5.3	-16.7 ± 3.8
1955	-7.9 ± 2.1	- 9.6 ± 1.5	-13.8 ± 4.5	-15.7 ± 3.4
1956	-7.7 ± 2.0	-10.5 ± 1.4	-13.5 ± 4.3	-17.6 ± 3.1
1957	-8.0 ± 1.9	-10.1 ± 1.3	-14.2 ± 4.0	-16.6 ± 2.8
1958	-7.2 ± 1.9	- 9.5 ± 1.3	-13.3 ± 4.1	-15.9 ± 2.9
1959	-6.2 ± 1.8	- 9.1 ± 1.2	-12.2 ± 3.8	-15.9 ± 2.6
1960	-6.2 ± 1.8	- 9.0 ± 1.1	-12.4 ± 3.7	-16.6 ± 2.5
1961	-6.8 ± 1.7	- 9.2 ± 1.0	-12.9 ± 3.5	-16.3 ± 2.4
1962	-7.3 ± 1.6	- 9.7 ± 1.0	-13.6 ± 3.3	-17.5 ± 2.2
1963	-7.2 ± 1.5	- 9.5 ± .9	-13.9 ± 3.1	-17.7 ± 2.1
1964	-7.1 ± 1.4	- 9.8 ± .9	-14.2 ± 2.9	-19.1 ± 2.0
1965	-7.2 ± 1.4	- 9.5 ± .9	-14.1 ± 2.8	-18.8 ± 1.9
1966	-7.1 ± 1.3	- 9.7 ± .8	-13.9 ± 2.8	-19.3 ± 1.9
1967	-7.0 ± 1.3	- 9.5 ± .8	-14.1 ± 2.7	-19.0 ± 1.9
1968	-7.0 ± 1.3	- 9.5 ± .8	-14.0 ± 2.7	-19.5 ± 1.9
1969	-6.9 ± 1.2	- 8.9 ± .8	-14.1 ± 2.7	-18.5 ± 1.8
1970	-6.7 ± 1.2	- 9.0 ± .8	-13.9 ± 2.6	-19.0 ± 1.8
1971	-6.6 ± 1.2	- 9.0 ± .8	-13.6 ± 2.6	-19.3 ± 1.8
1972	-6.2 ± 1.2	- 8.5 ± .8	-13.2 ± 2.5	-19.2 ± 1.7
1973	-5.8 ± 1.1	- 8.3 ± .7	-12.2 ± 2.5	-18.0 ± 1.7
1974	-5.6 ± 1.0	- 7.7 ± .7	-11.5 ± 2.3	-17.0 ± 1.6
1975	-5.1 ± 1.1	- 6.8 ± .7	-10.2 ± 2.3	-15.1 ± 1.6
1976	-3.9 ± 1.0	- 5.9 ± .7	- 7.9 ± 2.2	-12.6 ± 1.6
1977	-3.7 ± .9	- 5.1 ± .7	- 7.5 ± 2.1	-10.5 ± 1.5
1978	-3.5 ± .9	- 4.4 ± .6	- 7.4 ± 2.0	- 8.8 ± 1.5
1979	-3.3 ± .9	- 3.4 ± .6	- 7.0 ± 2.0	- 7.0 ± 1.4
1980	-2.1 ± .8	- 2.5 ± .6	- 4.0 ± 1.8	- 5.4 ± 1.4
1981	-1.5 ± .8	- 2.1 ± .6	- 2.6 ± 1.7	- 5.0 ± 1.4
1982	- .3 ± .8	- 1.5 ± .6	- .4 ± 1.6	- 4.3 ± 1.4
1983	0	0	0	0

[a] β WWR·WNYR/herd,sire.

[b] $\beta(\text{WWR} - \overline{\text{WWR}}_{\text{PHS}})$·WNYR/herd,dam.

[c] $\beta(\text{AWWT} - \overline{\text{AWWT}}_{\text{contemp}})$·WNYR/herd,sire.

[d] $\beta(\text{AWWT} - \overline{\text{AWWT}}_{\text{PHS}})$·WNYR/herd,dam.

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EVALUATION OF PHENOTYPIC AND GENETIC TRENDS IN WEANING WEIGHT IN ANGUS AND HEREFORD POPULATIONS IN VIRGINIA

by

Kanagasabai Nadarajah

(ABSTRACT)

Total weaning weight records of 29,832 Angus and 15,765 Hereford calves born during 1953 through 1983 in Virginia were used to evaluate phenotypic and genetic trends for adjusted weaning weight (AWWT), weaning weight ratio (WWR) and deviation of AWWT from the mean AWWT of the contemporaries (DEVN). Two approaches, namely the regression techniques and maximum likelihood (ML) procedure were taken to estimate the above trends.

The estimates of annual phenotypic trend for AWWT in the Angus and Hereford breeds were .96 and .82 kg/yr, respectively. The sire and dam genetic trends obtained from both approaches for the traits of interest were positive and significant; however, the estimates from the regression analyses were slightly higher than those from the ML procedure. The estimates of one-half of the sire genetic trends obtained from ML procedure for WWR and DEVN were .40 ± .04 ratio units/yr and .72 ± .07 kg/yr in the Angus breed and the corresponding values for the Hereford breed were .25 ± .06 ratio units/yr and .45 ± .12 kg/yr. The estimates of

one-half of the dam trends for the corresponding traits were .32 ± .02 ratio units/yr and .55 ± .04 kg/yr for Angus and .21 ± .03 ratio units/yr and .30 ± .07 kg/yr for Herefords. The application of adjustment factors (to eliminate the bias due to non-random mating and culling levels) to estimates of sire genetic trends in the regression analyses produced estimates more similar to the estimates obtained from the ML procedure. The average annual genetic trends over the study period from the ML procedure for AWWT were 1.27 kg/yr for Angus and .75 kg/yr for Herefords.