May 15, 1975

To the Graduate Council:

I am submitting herewith a thesis written by J. Frederick Holbert entitled "An Estimation of Genetic Progress in the Angus Herd at Ames Plantation." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

Haley M. Jamison

Haley M. Jamison, Major Professor

We have read this thesis and recommend its acceptance:

J. B. McLaren

Don O. Richardson

Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

AN ESTIMATION OF GENETIC PROGRESS IN THE ANGUS HERD AT AMES PLANTATION

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee

J. Frederick Holbert

June 1975

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation and gratitude to the following persons who have contributed to this graduate study:

Dr. Haley M. Jamison, Major Professor and thesis advisor, for his invaluable assistance and wise counsel during this graduate study, for his untiring efforts with the statistical analysis and interpretation of data, for reviewing the manuscript, and for his encouragement and friendship.

Dr. James B. McLaren for his technical advice in the analysis and interpretation of data, for serving on the graduate committee and for reviewing the manuscript.

Dr. Don Richardson for his assistance with the methods of analysis, for serving on the graduate committee, and for reviewing the manuscript.

To the entire Animal Science Department, secretaries, and fellow students; Hayden Brown, Leland Anderson and Ralph Lovely whose associations have made this study a more pleasant and rewarding experience.

To his family for their support and cooperation throughout this graduate endeavor.

The author acknowledges the use of The University of Tennessee Computer Center, Knoxville, Tennessee, in obtaining the results shown in this thesis.

ABSTRACT

The performance records of 3,144 non-creep fed, purebred heifer and bull calves born at Ames Plantation were utilized in the study. These data were collected over an 18-year period (1957-1974), being divided into two groups, (1957-1966) and (1967-1974). Average daily gain, weaning type score and weaning weight were the factors studied in these analyses. The objectives of this study were to take data from the Ames herd and calculate estimates of the genetic trends within the herd. Also, the influence of age of dam, sex of calf, and season of birth on average daily gain from birth to weaning was evaluated. An analysis was performed for each group for average daily gain, weaning type and weaning weight.

Sex of calf had a highly significant effect ($P < .001$) on average daily gain for both groups. In these analyses, male calves gained 0.17 and 0.18 pound per day greater than their female counterparts.

Sex of calf effects on weaning weight were also highly significant ($P < .001$) with male calves having a weight difference of 44 and 42 pounds greater for the two groups, respectively.

Although sex effects on type score were not significant for the first group, the difference for the second group was significant with the female calves outscoring the male calves by 0.13 of a unit.

The effects of age of dam on gain from birth to weaning were highly significant for both groups. These data show that a cow's individual performance was lowest at 2, 3, 4 and 12 years of age.

Estimates of age of dam effects on type score indicate that the maximum type score of a cow's calves was obtained within the age range of three to nine years.

Season of birth had a highly significant ($P < .001$) influence on average daily gain from birth to weaning for both groups. Calves born in Season II grew faster than did calves born in Season I and IV. While season of birth had a significant effect ($P < .01$) on type score at weaning in both groups, but the effects were not consistant.

Heritability estimates of average daily gain from birth to weaning were 0.33 to 0.32 for groups I and II, respectively, while heritability estimates of type score at weaning were 0.41 and 0.36 for the data groups I and II.

Genetic correlations of average daily gain and weaning type were 0.56 and 0.37 for group I and II, while the phenotypic correlation of these traits was 0.41 for both groups.

Estimates of genetic progress were 0.0078 and 0.0343 pound increase in average daily gain per year for data groups I and II, respectively. These estimations, in terms of progress per generations, would be 0.036 and 0.172 pound increase in average daily gain.

A second analysis was done eliminating season from the model, using only data from Season I. This gave estimations of 0.036 and 0.027 pound increase in average daily gain per year and 0.179 and 0.137 pound progress per generation.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Among the objectives of beef cattle breeding studies, development of selection procedures improving the efficiency of beef production is of utmost importance. Selection is the single most effective tool that a beef breeder can use to improve the genetic quality of his herd. It is a slow, continuous process that requires time and knowledge of the breeder if positive results are to be obtained.

Realization of genetic progress is relatively slow in the beef herd due to a number of contributing factors. The bovine generation interval is longer than in most farm animals, and multiple births, which increase possible selection intensity, are relatively rare in cattle. Only a part of the superiority of the selected animals over the unselected herd average is transmitted to the offspring. Environmental effects contributing to an individual's performance are not transmitted from generation to generation. Therefore, only a portion of the selection differential is ever realized.

Producer awareness of the factors that influence their selection effectiveness is necessary to make the most genetic progress. Formerly, visual appraisal was the only criterion of selection in most herds. However, with performance records, beef producers can reliably compare the production ability of cattle raised on one farm under the same environmental conditions. As such, environmental factors of variation must be accurately and independently analyzed to make precise heritability estimates. Heritability of the traits and the accuracy and intensity of selection determine the progress that is made.

The objectives of this study were to analyze data from a given herd, obtain phenotypic progress and calculate estimates of the genetic trends within the herd. In addition, the influence of age of dam, sex of calf, and season of birth on daily gain from birth to weaning was evaluated, and adjustment factors were calculated to remove as much possible of the influence of these effects.

CHAPTER II

REVIEW OF LITERATURE

The effects of environmental and genetic factors on average daily gain from birth to weaning and type score at weaning in beef cattle have been investigated extensively in various breeding studies. Among these factors, age of dam, sex of calf and year of birth have proven to have highly significant effects on average daily gain. Across these studies lies a good deal of environmental and managerial variation just as such conditions vary from one farm to another. Therefore, variations in the magnitude and intensity of these influences on average daily gain and type score are not surprising.

I. EFFECT OF FIXED SOURCES OF VARIATION ON AVERAGE DAILY GAIN AND TYPE SCORE AT WEANING

Sex of Calf

Practically all studies have shown sex to significantly influence average daily gain from birth to weaning. As a standard, bull calves outgain steers and steers outgain heifers providing that environmental conditions are similar.

Marlowe and Gains (1958), in a study involving 6,173 calves, found that heifer calves had an average daily gain of 0.12 pound less than steer calves. In a later study, Marlowe (1973) reported that bull calves grew about 14 percent faster than heifer calves when no creep-feeding was practiced. Steer calves were intermediate between bulls and heifers, growing at a 7 percent faster rate than heifer calves but 7 percent slower than bull calves.

Loganathan (1962), in a study involving 471 purebred Hereford calves and 196 grade Hereford calves, found that the male purebred calves had an average daily gain of 1.83 pounds and females 1.66 pounds. Corresponding figures for the grade calves produced in the same herd were 1.89 and 1.76 pounds, respectively.

Brinks et al. (1961) found that heifer calves gained 5 percent less than steers and 6 percent less than bulls from birth to weaning. According to Barker (1964), the average daily gain of bull calves was 0.13 pound per day greater than steers and that of steers was 0.12 pound per day greater than heifers.

Cunningham and Henderson (1965) reported that steer calves gained 0.108 pound less than bull calves, but exceeded heifer calves by 0.142 pound. Minyard and Dinkel (1965) showed an overall ratio of 1.082 of mean weight of bulls to that of heifers in their study of 2,351 Hereford and Angus calves.

Bair et al. (1972), in relative agreement with Marlowe (1962), found steer calves to grow at a 6 percent faster rate than heifer calves. Koch et al. (1973) agreed closely with Minyard and Dinkel (1965) showing an overall ratio of 1.084 contrasting weaning weight of bulls to heifers.

A limited number of studies on the influence of sex and type score are reported in the literature. Most of these reports indicate the effect of sex on weaning conformation to be negligible. Marlowe and Gaines (1958) found sex difference in weaning type score to 0.5 unit in favor of heifer calves. Marlowe (1962) repeated this observation of 0.5 unit difference in favor of heifer calves. Loganathan (1962) reported that, among purebred calves, males scored 12.0 and females 11.8. Corresponding figures for grade calves produced in the same herd were 12.1 and 12.0, respectively. These differences, however, were not significant.

Age of Dam

Estimates of age of dam effects on weaning weight and average daily gain from birth to weaning have been made by a number of research workers. These investigations have been carried out with various breeds and under varying environmental conditions. A summary of these effects is shown in Table I. Most reports agree that the age of dam effects on weaning weight and average daily gain were highly significant.

Most studies indicate that 2- and 3-year old cows produced lighter calves at weaning than cows of older ages. Maximum pre-weaning production was observed in cows 6 to 8 years of age.

Petty and Cartwright (1966), whose averaged estimates have become somewhat a standard across the industry, reported averaged adjustments of -0.25, -0.16, -0.07, -0.03, 0.00, 0.02, 0.03, 0.00 pound for 2, 3, 4, 5, 6, 7, 8 and 9 year olds, respectively.

Fewer researchers have concerned themselves with age of dam effects on weaning type scores. However, Marlowe and Gaines (1958) reported type scores at weaning from 2-, 3-, 4-, 5-, 6-, 7-, 8-, 9-, 10-year old cows as 10.7, 11.3, 11.4, 11.6, 11.8, 11.8, 11.7, 11.4, and

TABLE I

A SUMMARY OF ESTIMATED EFFECTS OF AGE OF DAM ON WEANING WEIGHT AND AVERAGE DAILY GAIN

Author	Ages of Dams										
	2	3	4	5	6	7	8	9	10	11	12
	Weaning Weight (lb.)										
Knapp *et al.* (1942)	-	-29.0	-16.0	-5.0	0.0	0.0	-5.0	-10.0	-39.0	-51.0	-
Botkin and Whatley (1953)	-	-35.0	-15.0	-	-	-	-	-	-	-	-
Burgess, Landbolm and Stonaker (1954)	-36.0	-24.0	-16.0	-8.0	0.0	0.0	0.0	-12.0	-24.0	-	-
Rollins and Guilbert (1954)	-	-18.0	-11.0	-5.0	0.0	0.0	-7.0	-13.0	-21.0	-31.0	-
Koch and Clark (1955a)	-	-41.0	-18.0	-6.0	0.0	-7.0	-6.0	-12.0	-24.0	-	-
McCormick, Southwell and Warwick (1956)	-107.0	-68.0	-42.0	22.0	10.0	0.0	-31.0	-31.0	-31.0	-31.0	-
Clark *et al.* (1958)	-	-44.0	-19.0	-7.0	-1.0	0.0	3.0	-3.0	1.0	-	-
Phanish *et al.* (1958)	-	-50.0	-25.0	-	-	-	-	-	-	-	-
Minyard and Dinkel (1960)	-69.0	-33.0	-21.0	-13.0	-4.0	-3.0	0.0	-9.0	-23.0	-24.0	-
Magee *et al.* (1961)	-50.0	-15.0	-10.0	-	-	-	-	-	-	-	-
Hamann, Wearden and Smith (1963)	-64.0	-22.0	-1.0	4.0	23.0	27.0	32.0	-	-	-	-

TABLE I (Cont'd)

Author	Ages of Dams										
	2	3	4	5	6	7	8	9	10	11	12
Minyard and Dinkel (1965)	-80.0	-45.0	-30.0	-21.0	-4.0	-3.0	0.0	-8.0	-16.0	-24.0	-38.0
Cardellino et al. (1971)	-83.6	-38.5	-5.1	0.0	0.0	0.0	0.0	0.0	-	-	-
Cardellino et al. (1971)	-58.7	-32.6	-8.8	0.0	0.0	0.0	0.0	0.0	-	-	-
Hohenboken and Bunks (1971)	-59.0	-32.6	-14.5	0.0	-	-	-	-	-	-	-
Bair et al. (1972)	-70.4	-44.0	-17.6	-8.8	0.0	0.0	0.0	0.0	-22.0	0.0	0.0
Robinson (1974)	-60.1	-27.0	-13.2	-9.2	0.0	-	-	-	-	-4.6	-
Average Daily Gain (lb.)											
Marlowe and Gaines (1958)	-0.30	-0.17	-0.11	-0.08	-0.04	0.00	-0.06	-0.01	-0.07	-	-
Lehmann et al. (1961)[a]	-0.13	0.00	0.10	0.14	0.20	0.13	0.14	0.10	0.10	0.06	-0.03
Loganathan (1962)	-0.18	-0.09	-0.02	0.00	0.01	0.06	0.05	0.03	0.09	0.02	-
Barker (1964)[a]	-0.23	-0.14	-0.08	0.02	0.03	0.03	0.06	0.03	0.05	0.04	0.03
Cunningham and Henderson (1965)	-0.261	-0.159	-0.069	-0.036	-0.025	0.000	0.000	0.000	-0.029	-	-
Jamison (1966)	-0.12	-0.07	-0.05	-0.03	-0.02	0.00	-0.01	-0.03	-0.02	-0.05	-

11.6, respectively. Similar results were reported by Lehmann et al. (1961), Loganathan (1962), Barker (1964) and High (1968). These data indicate that age of dam had little effect on conformation score after the first calf. Marlowe et al. (1962) reported a greater influence of age of dam in non-creep-fed calves than among calves that were creep-fed. Cunningham and Henderson (1965) and Vesely and Robinson (1971) in later reports showed estimates similar to those of Marlowe and Gains (1958). However, type score at weaning is a subjective measure, thus increasing possibility of sampling error. Throughout most reports, effect of age of dam on type score has proven non-significant and as such, no adjustments have been made.

Season of Birth

The environmental surroundings of the calf and its dam during the pre-weaning period depends largely on the season in which the calf is born. The most important influence of seasonal differences is the variation in feed supply. Along with changes in forage availability, there is a change in temperature and the parasite population. These seasonal effects have a good deal of variation among different sections of the country, however.

It must be realized that an increase in calf performance during the suckling period depends upon reaching optimum efficiency of forage utilization for both cow and calf. Maximum efficiency of forage use can be made by correctly matching the month of partuition with a given season in a particular area.

Marlowe and Gaines (1958) found that season of birth had a significant influence on the growth of non-creep-fed calves, but was of no practical importance in the growth of creep-fed calves. This work indicated that non-creep-fed calves born from June through December grew 0.1 pound a day slower than calves born from February through May.

Barker (1964) observed average daily gains of calves born in January, February, and March to be significantly higher ($P < .01$) than those of other months. Loganathan (1962) reported that calves born in April and May made faster gains than those born in January, February and March.

Marlowe et al. (1965), in a study made on Virginia farms, reported that both creep-fed and non-creep-fed calves born in March, April and May, made faster gains than those born in other months. Cavles born in August and September made the slowest gains. McGuire (1969) found that calves born in October were lighter at 180 and 250 days of age than those born in the months of November through March.

Barker (1964) also considered the effect of month of birth on type score at weaning. This data indicates that calves born in August, September, October and November had a lower type score at weaning than calves born during other months. Marlowe and Gains (1958), in a study of some 4,166 non-creep and 2,007 creep-fed calves, found that non-creep calves born in July and August graded 0.9 point less than calves born in December through March 15. Lehman et al. (1961), on 1,987 purebred and grade calves in Virginia, concluded that calves born in April, May and June had a lower type score at weaning than those born in January through March.

Year of Birth

In most studies, year of birth was found to have a significant effect on average daily gain and type score at weaning (Loganathan, 1962; Cunningham and Henderson, 1965; Harwin et al., 1966; and Hohenboken and Brinks, 1969). Botkin and Whatley (1953) theorized that much of the year influence on weaning traits in beef cattle comes from variation in nutrient intake, largely determined by the amount of rainfall during the grazing season.

II. HERITABILITY

Knapp and Nordskog reported the first estimations of heritability in 1946. A number of estimates of genetic parameters in beef cattle have been published since that time. Warwick (1958) made the first attempt to summarize heritabilities in beef cattle. High (1968) summarized estimates of heritablity of measures of pre-weaning growth rate and conformation score reported in the literature between 1958 and 1965. They received estimates of heritability for weaning weight of 0.30 and 0.29, respectively. Estimates of heritabilities of type score were 0.26 and 0.29. These two summaries agree quite closely during the two different periods of study.

Most of the estimates of Warwick's and all of High's summary were made by the paternal half-sib method. Weighted averages of the paternal half-sib estimates for weaning weight indicate that the heritability is about 0.29. Weighted average of heritability of weaning type, in the paternal half-sib studies, gave a heritability of 0.30.

Some of the published estimates of heritability of weaning weight and conformation score are presented in Tables II and III, respectively.

III. GENETIC AND PHENOTYPIC CORRELATION

Phenotypic correlation is the relationship between two traits which can be measured directly. In genetic studies, it is desirable to partition the correlation between traits according to the relative contributions of the components if correlation, genetic and environmental. According to Falconer (1960), the genetic cause of correlation is chiefly pleiotrophy. Environment is a cause of correlation insofar as two traits are influenced by the same differences in environmental conditions.

Primarily, the interest in knowing the genetic correlation among traits stems from the desire to predict how an advance in one trait will affect the other.

Some of the more recent estimates of genetic and phenotypic correlations are presented in Table IV.

IV. GENETIC TREND

Estimation of relative breeding values is of interest in a number of animal breeding studies. Selection, based on the merit of these values, should improve the genetic quality of future generations. Reliable estimates of genetic trend, the annual rate of genetic progress, allow comparison of expected and realized genetic change in experimental situations and allow assessment of progress in that particular trait.

Most of the recent research in this area involves regression

TABLE II

HERITABILITY ESTIMATES OF WEANING WEIGHT IN BEEF CATTLE

Author	Sex[a]	Breed[b]	Number of Calves	Number of Sires	Methods of Estimation: Paternal Half-sib	Maternal Half-sib	Regression of Offspring on: Dam	Sire	Other
Knapp and Nordskog (1946)	S	H	177	23	0.12	-	-	-	-
Gregory *et al.* (1950)	M	H	270	6	0.26	-	-	-	-
Gregory *et al.* (1950)	M	H	69	4	0.52	-	-	-	-
Knapp and Clark (1950)	S	H	613	83	0.28	-	-	-	-
Kidwell (1954)	M	H	155	9	1.00	-	-	-	-
Dawson *et al.* (1954)	M	B	74 prs.	-	-	-	0.15	-	-
Shelby, Clark and Woodward (1955)	S	H	635	88	0.23	-	-	-	-
Koch and Clark (1955b)	M	H	4553	137	0.24	-	-	-	-
Koch and Clark (1955c)	M	H	4234	1231	-	-	0.11	-	-
Koch and Clark (1955c)	M	H	1105	85	-	-	-	0.25	-
Koch and Clark (1955d)	M	H	-	-	-	-	-	-	0.19
Hitchcock *et al.* (1955)		H	-	-	-	-	0.17	-	0.39
Rollins and Wagnon (1956)	M	H	321	-	0.09	-	-	-	-
Rollins and Wagnon (1956)	M	H	256	-	0.54	-	-	-	-
Lasley and Pugh (1956)	M	H	323	8	0.33	-	-	-	-
McCormick, Southwell and Warwick (1956)	B	H	167	16	0.25	-	-	-	-
McCormick, Southwell and Warwick (1956)	H	H	187	18	0.33	-	-	-	-

TABLE II (Cont'd)

Author	Sex[a]	Breed[b]	Number of Calves	Number of Sires	Methods of Estimation: Paternal Half-sib	Maternal Half-sib	Regression of Offspring on: Dam	Sire	Other
McCormick, Southwell and Warwick (1956)	S	H	173	17	0.26	-	-	-	-
McCormick, Southwell and Warwick (1956)	H	H	152	21	-0.06	-	-	-	-
Shelby et al. (1957)	B	H	542	116	0.43	-	-	-	-
Lindholm and Stonaker (1957)	S	H	118	19	0.81	-	-	-	-
Brown (1958)	M	H	-	-	0.26	0.52	-	-	-
Brown (1958)	M	A	-	-	0.11	1.10	-	-	-
Carter and Kincaid (1959)	S	H,A,S	212	24	0.08	-	-	-	-
Carter and Kincaid (1959)	H	H,A,S	212	24	0.69	-	-	-	-
Wagnon and Rollins (1959)	H	H	140	12	0.42	-	-	-	-
Wagnon and Rollins (1959)	H	H	165	12	0.57	-	-	-	-
Kieffer, Chambers and Stephens (1959)	M		295 prs.	-	-	-	0.32	-	-
Kieffer, Chambers and Stephens (1959)	M		495	68	0.39	-	-	-	-
Minyard and Dinkel (1960)	M	H,A	2351	120	0.32	-	-	-	-
Swiger (1961)	M	H	748	23	0.25	-	-	-	-
Lehmann et al. (1961)	M	H,A,S	1987	115	0.21	-	-	-	-
Pahnish et al. (1961)	B	H	329	11	0.28	-	-	-	-
Pahnish et al. (1961)	H	H	329	11	0.57	-	-	-	-
Magee et al. (1961)		H,A	-	-	0.30	-	-	-	-

TABLE II (Cont'd)

Author	Sex[a]	Breed[b]	Number of Calves	Number of Sires	Methods of Estimation				
					Paternal Half-sib	Maternal Half-sib	Regression of Offspring on		
							Dam	Sire	Other
Lasley, Day and Comfort (1961)	M	H	414	8	-	-	-	-	0.11
Blackwell _et al_. (1962)	S	H	499	36	0.08	-	-	-	-
Blackwell _et al_. (1962)	H	H	420	42	0.31	-	-	-	-
Gregory and Stewart (1962)	M		425	29	-	-	-	0.54	-
Swiger _et al_. (1962)	M	H	2092	48	-0.16	-	-	-	-
Swiger _et al_. (1962)	M	A,S	647	-	-0.02	-	-	-	-
Hamann, Wearden and Smith (1963)	M		334	25	0.48	-	-	-	-
Hamann, Wearden and Smith (1963)	M	A	332	-	-	-	-	-	0.49
Christian (1963)	M	H	828	54	0.19	-	-	-	-
Christian (1963)	M	A	253	18	0.58	-	-	-	-
Gacula and Brown (1963)	B	H,A,S	179	19	-	-	-	0.11	-
Swiger _et al_. (1963)	M	H,A,S	1671	240	0.28	-	-	-	-
Shelby _et al_. (1963)	S	H	616	87	0.24	-	-	-	-
Pahnish _et al_. (1963)	B	H	-	17	0.05	-	-	-	-
Pahnish _et al_. (1963)	H	H	-	17	0.23	-	-	-	-
Mahmud and Cobb (1963)	M	H	1306	28	0.24	-	-	-	-
Wilson (1963)	S	H	473	56	0.38	-	-	-	-
Sewell _et al_. (1963)	M		942	12	0.18	-	-	-	-
			308 prs.	-	-	-	0.08	-	-
Brinks _et al_. (1964)	H	H	3548	-	0.43	-	-	-	-

TABLE II (Cont'd)

Author	Sex[a]	Breed[b]	Number of Calves	Number of Sires	Methods of Estimation: Paternal Half-bib	Maternal Half-bib	Regression of Offspring on: Dam	Sire	Other
Loganathan (1962)	M	H	471	34	0.39	-	-	-	-
Loganathan (1962)	M	H	196	26	1.28	-	-	-	-
Cunningham and Henderson (1965)	M	A	3190	121	0.47	-	-	-	-
Cunningham and Henderson (1965)	M	H	1648	55	0.43	-	-	-	-
Marlowe and Vogt (1965)	B	A	1813	-	0.49	-	-	-	-
Marlowe and Vogt (1965)	S	A	4257	-	0.43	-	-	-	-
Marlowe and Vogt (1965)	H	A	6075	-	0.31	-	-	-	-
Marlowe and Vogt (1965)	M	A	12145	580	0.38	-	-	-	-
Marlowe and Vogt (1965)	B	H	1324	-	0.33	-	-	-	-
Marlowe and Vogt (1965)	S	H	2802	-	0.27	-	-	-	-
Marlowe and Vogt (1965)	H	H	4153	-	0.31	-	-	-	-
Marlowe and Vogt (1965)	M	H	8279	409	0.31	-	-	-	-
Minyard and Dinkel (1965)	M	A	436	-	0.32	-	-	-	-
Minyard and Dinkel (1965)	M	H	1915	-	0.33	-	-	-	-
Jamison (1966)	M	A,H	3503	-	-	0.39	-	-	-
Dunn et al. (1970)	M	A,H,S	737	-	0.18	-	-	-	-
McLaren (1970)	M	A,H	19547	-	0.40	-	-	-	-
Vesely and Robinson (1971)	M	H	1692	49	0.50	0.31	0.31	-	-
Koch et al. (1973)	B	H	1769	-	0.15	-	-	-	-
Koch et al. (1973)	H	H	1963	-	0.25	-	-	-	-

TABLE II (Cont'd)

Author	Sex[a]	Breed[b]	Number of Calves	Number of Sires	Methods of Estimation				
					Paternal Half-sib	Maternal Half-sib	Regression of Offspring on		
							Dam	Sire	Other

[a]Sex Code: S = steers, B = bulls, H = heifers and M = mixed.

[b]Breed Code: A = Angus, H = Hereford and S = Shorthorn.

TABLE III

HERITABILITY ESTIMATES OF TYPE SCORE AT WEANING IN BEEF CATTLE

					Method of Estimation				
							Regression of Offspring on		
Author	Sex[a]	Breed[b]	Number of Calves	Number of Sires	Paternal Half-sib	Maternal Half-sib	Dam	Sire	Other
Koger and Knox (1952)	M	A	715	15	0.30	-	0.50	-	-
Shelby et al. (1957)	B	H	542	116	0.60	-	-	-	-
Carter and Kincaid (1959)	S	H,A,S	190	-	0.41	-	0.70	0.16	-
Carter and Kincaid (1959)	H	H,A,S	200	-	0.51	-	-	-	-
Meyerhoeffer, Carter and Priode (1963)	M	H,A,S	1682	-	0.21	-	-	-	-
Lehmann et al. (1961)	M	H,A,S	1987	-	0.33	-	-	-	-
Blackwell et al. (1962)	S	H	499	-	0.38	-	-	-	-
Blackwell et al. (1962)	H	H	420	-	0.26	-	-	-	-
Shelby et al. (1963)	S	H	616	87	0.23	-	-	-	-
Brinks et al. (1964)	H	H	3584	-	0.28	-	-	-	-
Mahmud and Cobb (1964)	M	H	1306	-	0.36	-	-	-	-
Meyerhoeffer, Carter and Priode (1963)	H	H,A,S	908	-	0.20	-	-	-	-
Meyerhoeffer, Carter and Priode (1963)	B	H,A,S	-	-	0.29	-	-	-	-
Christian (1963)	M	H	253	18	0.34	-	-	-	-
Christian (1963)	M	A	828	54	0.79	-	-	-	-

TABLE III (Cont'd)

Author	Sex[a]	Breed[b]	Number of Calves	Number of Sires	Method of Estimation: Paternal Half-sib	Maternal Half-sib	Regression of Offspring on: Dam	Sire	Other
Cunningham and Henderson (1965)	M	A	3190	121	0.48	-	-	-	-
Cunningham and Henderson (1965)	M	H	1648	55	0.43	-	-	-	-
Marlowe and Vogt (1965)	B	A	1813	-	0.27	-	-	-	-
Marlowe and Vogt (1965)	S	A	4257	-	0.37	-	-	-	-
Marlowe and Vogt (1965)	H	H	6075	-	0.39	-	-	-	-
Marlowe and Vogt (1965)	M	A	12145	580	0.36	-	-	-	-
Marlowe and Vogt (1965)	B	H	1324	-	0.69	-	-	-	-
Marlowe and Vogt (1965)	S	H	2802	-	0.19	-	-	-	-
Marlowe and Vogt (1965)	H	H	4153	-	0.33	-	-	-	-
Marlowe and Vogt (1965)	M	H	8279	409	0.33	-	-	-	-
Jamison (1966)	M	A,H	3503	-	-	0.34	-	-	-
Dunn et al. (1970)	M	A,H,S	737	-	0.42	-	-	-	-
McLaren (1970)	M	A,H	19547	-	0.29	-	-	-	-
Vesely and Robinson (1971)	M	H	1692	49	0.36	0.19	0.09	-	-

[a]Sex Code: S = steer, B = bulls, H = heifer and M = mixed.

[b]Breed Code: A = Angus, H = Hereford and S = Shorthorn.

TABLE IV

ESTIMATES OF PHENOTYPIC AND GENETIC CORRELATIONS
OF AVERAGE DAILY GAIN AND WEANING TYPE

Author	Number of Animals	Breed[a]	Correlation Phenotypic	Correlation Genetic
Cunningham and Henderson (1965)	7,971	A,H,S	0.32	0.48
Marlowe and Vogt (1965)	20,424	A,H	0.23	0.23
Harricheran et al. (1967)	17,023	A	-	0.18
High (1968)	2,747	A,H	0.40	0.54
McGuire (1969)	-	A,H	0.32	0.24
Dunn et al. (1970)	737	A,H,S	0.33	0.42
McLaren (1970)	19,547	A,H	0.31	0.39
Vesely and Robinson (1971)	1,692	H	0.54	0.11

[a]Angus, Hereford, Shorthorn.

approaches. These methods based on the following expectations of regression, as proposed by Smith (1962) and presented by Powell and Freeman (1974)

$$E\ (b_{p.T}) = g + t$$

$$E\ (b_{p.T/s}) = .5_g + t$$

$$E\ (b(p - \bar{p}).T/s) = -.5g$$

E means the expectation of the equation that follows. Regression estimates are represented by b. The regression of performance (p) on time T, bp.T represents the total trend, g + t, while expectation of the regression within sires ($b_{p.T/s}$) represents t + .5g, because the sires are not allowed to vary and only dams contribute to genetic progress. The expected value of the regression within sires on time of deviations from the population mean ($\bar{p}$), $b(p - \bar{p}).T/s$, could be written as (t + .5g) - (t + g), thus the regression is equal to -.5g.

One of the possible combinations of these equations to estimate total genetic trend is: $g = 2(b_{p.T} - b_{p.T/s})$.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE OF DATA

The data used in this study were collected over a 18-year period (1957-1974) from the purebred Angus herd of Ames Plantation, a field station of the University of Tennessee. The station is located just north of Grand Junction in West Tennessee. It is about 60 miles east of Memphis and 10 miles north of the Mississippi state line. The climate is humid and temperate. The normal growing season averages 209 days. The mean seasonal temperature varies from approximately 42 degrees Fahrenheit in winter to 78 degrees in summer.

The herd was established in 1912 by Mr. Hobart Ames. When the University of Tennessee and the Trustees of the plantation entered into an agreement in 1955, it was decided that the Angus breeding program be expanded and an intensive progeny testing program initiated. During the early period, dwarfism occurred. To eliminate dwarfism, a program was started whereby all animals producing dwarfs or their relatives were gradually eliminated and replaced by animals that by pedigree analysis were believed to be free of dwarfism. The animals purchased were predominantly General and Bardolier breeding. This rebuilding program extended into the early 1960's.

Very little selection pressure, if any, was exerted on females prior to 1965. In the fall of 1965, 123 females, in consideration of performance and productivity records, were culled from the herd. During the last 10 years considered, sufficient numbers were available to allow some selection among both replacement heifers and older breeding females. Selection among replacement heifers was on type score and average daily gain, with a preliminary selection made at weaning and final selection made the following spring. It was estimated that about 80 percent of the heifer calves weaned were added to the herd during the period under study. Selection among cows was on the basis of both reproductive and progeny performance. Cows which were designated open at a pregnancy check in the fall following a failure to calve the previous spring were usually culled. The progeny record considered was the average performance of all calves from a cow.

Sire selection was similar to that practiced among heifers. All sires used in the herd were evaluated for gain and type at weaning and at the end of a postweaning performance test. Prospective bulls from outside sources were selected on the basis of their weaning records. These bulls usually purchased at weaning and placed on postweaning test with the calves selected from the Ames herd. One outside bull, Kintyremere 10, was purchased in Mississippi in the summer of 1958 from Kintyremere Farms. Born in 1957, he was sired by Eileenmere 1480 (grand champion several times at large shows) and out of a McHenry Barbara cow. He had laminitis as a calf and was purchased for $500. He sired approximately 385 calves in the University system and had as many as 66 daughters in the Ames herd at one time. Kintyremere 10 died in the summer of 1968, but he, along with two sons, and his daughters are considered to be a main influence on the Ames herd.

The cow herd had access to pasture the year round and were fed hay, silage and protein supplement as required during the winter months.

For breeding purposes the cows were classified on the basis of age and past performance records, then randomly assigned to sire groups. Cows were bred in single-sire groups and were reassembled into larger groups following the breeding season.

The records of 3,144 purebred Angus calves were found suitable for this study. They were sired by purebred bulls. Only records of non-creep fed heifer and bull calves were used in this study.

II. CLASSIFICATION OF DATA

Data recorded for each calf at birth included birth date, birth weight, sex, sire and dam. Weaning data included weaning weight and weaning type score. Weaning data were usually recorded in September; however, it was usually October when the calves were actually weaned. This allowed time for an index based on rate of gain and type score to be computed in order that selection of bull calves to be performance tested could be made at weaning.

All calves were graded by two or more staff members of the Animal Science Department of The University of Tennessee. Each grader worked independently. However, since these men worked together in grading a large number of calves each year, the means and variances of their grades were similar. The coded scores of the two graders were averaged to obtain the type score and condition grade for the individual calves.

The grades were coded by giving Good a numerical value of 10 and adding or subtracting one (1) for each one-third of a grade above or below Good.

The coded scores of the two graders were averaged to the nearest 0.1 grade point (1/30th of a grade). The numberical codes were: fancy plus (17), fancy (16), fancy minus (15), choice plus (14), choice (13), choice minus (12), good plus (11), good (10), good minus (9), medium plus (8), medium (7), and medium minus (6). The effective range of type scores in these data was 10 through 15. Very few animals were given scores outside this range.

Age of dam at calving was arbitrarily divided into discrete classes on the one-half year; therefore, the age of dam 3 would be that for an animal whose dam was between 2-1/2 and 3-1/2 years of age. All animals 11-1/2 years old or older were classified as age of dam 12.

The data was divided into the respective groups, (1957-1966) and (1967-1974), as this was a time when the first culling was being done and there was a change in management in the herd.

The average daily gain for each individual calf was calculated by subtracting an actual birth weight from the recorded weaning weight and dividing this weight by age in days.

Animals in this study were divided into three groups according to season of birth. December, January and February were Group I; March, April and May were Group II; and September, October and November were classified as Group III. Group III is referred to as Season IV to correspond to the quarter of the year.

No calf was included that was not part of a sire group of three or more.

III. METHOD OF ANALYSIS

Least squares estimates of the effects of sire, age of dam, season of birth, sex, year of birth and continuous variables for weaning age, with cubic and quadratic effects considered, were obtained for average daily gain from birth to weaning, weaning weight and type score at weaning.

The model on which the analyses were based was:

$$Y_{imklm} = \mu + s_i + a_j + se_k + sx_l + b_1 WA_{jklm} + b_2 WA^2_{ijklm} + b_3 WA^3_{ijklm} + e_{ijklm}$$

Y_{ijklm} = is the observed values of a given trait, ijklmth individual

μ = the population mean with equal subclass number, i, e, j on effect common to all individuals in the population sampled

s_i = effect of the i-th sire, i = 1, 2, . . . n

a_j = effect of the j-th age of dam, j = 2, . . . 12

se_k = effect of the k-th season of birth, k = 1, 2, 3

sx_l = effect of the l-th sex, l = 1, 2

$b_1 WA_{ijklm}$ = partial regression of Y on Weaning Age

$b_2 WA_{ijklm}$ = partial regression of Y on Weaning Age^2

$b_, WA_{ijklm}$ = partial regression of Y on Weaning Age^3

The data were subjected to eight different analyses in order to determine estimates of the effects of the independent variables on the performance traits. Data comprising the first 10 years (1957-1966) and the last nine years (1967-1974), were analyzed for statistics of fit for the dependent variables, average daily gain and weaning type with the aforementioned model. These same two groups were analyzed with the effects of weaning age removed from the model for weaning weight.

The data again were analyzed as two groups according to methods as described by Harvey to obtain heritabilities of weaning type score and average daily gain. Estimates of genetic and phenotypic correlations were also made for average daily gain and weaning type.

An additional analysis was made with one model fitted with sire and one without to provide an estimation of genetic progress in the herd. The respective regressions on time and sire were fitted to the expectations $2(b_{p.T} - b_{p.T/s})$ to give the estimation of total genetic trend.

CHAPTER IV

RESULTS AND DISCUSSION

To aid in the discussion of the analyses of the three dependent variables, average daily gain, type score, and weaning weight, the data will be divided and referred to as Analyses I, II, III, and IV, respectively. Analysis I considers the dependent variable, average daily gain and type score of the data from 1957-1966. The analysis of weaning weight with weaning age as a continuous independent variable for the same period will be Analysis II. The same respective models for the period 1967-1974 will be specified Analyses III and IV.

The least squares estimates of the environmental and sire effects on average daily gain and type score from birth to weaning are presented in Tables V and VII, respectively. Least squares estimates of the environmental and sire effects on weaning weight are presented in Tables VI and VIII, respectively. The corresponding analysis of variance for Analyses I through IV are presented in Tables IX throubh XII, respectively.

I. SEX EFFECTS

In Analyses I and III, sex of calf had a highly significant effect ($P < .001$) on average daily gain. In these analyses, male calves gained 0.17 and 0.18 pounds per day greater than their female counterparts. These estimates are well within the range of the findings of other workers: 0.17 by Loganathan (1962), 0.15 by Petty and Cartwright

TABLE V

LEAST SQUARES ESTIMATES[a] AND STANDARD ERROR OF THE EFFECTS STUDIED FROM 1957-1966, ANALYSIS I

Variable	Average Daily Gain	Weaning Type
Least Squares Mean	1.611 ± 0.011	11.943 ± 0.067
Sire		
1009	-0.012 ± 0.060	-1.564 ± 0.368
1084	0.082 ± 0.032	0.275 ± 0.200
1234	-0.029 ± 0.065	0.569 ± 0.399
2593	-0.059 ± 0.078	1.022 ± 0.478
5097	-0.073 ± 0.098	-1.378 ± 0.608
5133	-0.182 ± 0.055	-0.968 ± 0.338
8027	-0.053 ± 0.055	-1.319 ± 0.342
8090	-0.051 ± 0.076	-0.515 ± 0.466
8192	-0.028 ± 0.060	0.645 ± 0.372
8205	-0.239 ± 0.088	-0.706 ± 0.544
8251	-0.045 ± 0.047	0.902 ± 0.292
8290	0.056 ± 0.034	0.070 ± 0.210
8208	0.082 ± 0.059	-0.368 ± 0.361
8310	0.016 ± 0.028	0.012 ± 0.175
8412	0.138 ± 0.040	0.228 ± 0.244
8500	-0.009 ± 0.051	-0.749 ± 0.316
8657	0.019 ± 0.027	0.004 ± 0.166
8660	0.025 ± 0.030	-0.043 ± 0.185

TABLE V (Cont'd)

Variable	Average Daily Gain	Weaning Type
Sire Cont'd		
8688	0.019 ± 0.029	-0.006 ± 0.177
8720	-0.051 ± 0.081	0.521 ± 0.502
8722	0.110 ± 0.082	0.919 ± 0.507
8813	-0.219 ± 0.068	-0.689 ± 0.417
8951	-0.002 ± 0.071	-0.305 ± 0.440
9009	0.103 ± 0.072	0.175 ± 0.445
9025	0.043 ± 0.032	0.382 ± 0.199
9035	-0.072 ± 0.100	-0.412 ± 0.619
9102	0.014 ± 0.036	0.126 ± 0.222
9132	0.126 ± 0.113	0.237 ± 0.699
9137	-0.140 ± 0.060	0.030 ± 0.368
9148	-0.030 ± 0.029	0.324 ± 0.177
9162	0.091 ± 0.100	0.731 ± 0.617
9163	0.000 ± 0.068	-0.167 ± 0.422
9176	-0.001 ± 0.048	0.515 ± 0.298
9193	0.054 ± 0.029	-0.402 ± 0.177
9203	-0.110 ± 0.065	-1.024 ± 0.400
9257	-0.010 ± 0.033	0.502 ± 0.201
9291	-0.107 ± 0.035	-0.841 ± 0.216
9295	-0.045 ± 0.026	-0.274 ± 0.160
9305	0.029 ± 0.051	0.560 ± 0.313

TABLE V (Cont'd)

Variable	Average Daily Gain	Weaning Type
Sire Cont'd		
9380	0.139 ± 0.032	0.663 ± 0.200
9385	0.002 ± 0.022	0.113 ± 0.135
9480	0.245 ± 0.098	1.676 ± 0.607
9537	0.012 ± 0.036	0.031 ± 0.219
9709	0.096 ± 0.042	0.040 ± 0.257
9777	0.066 ± 0.021	-0.458 ± 0.167
Age of Dam		
2	-0.167 ± 0.017	-0.636 ± 0.107
3	-0.057 ± 0.014	-0.049 ± 0.085
4	0.003 ± 0.014	0.225 ± 0.086
5	0.063 ± 0.015	0.363 ± 0.093
6	0.023 ± 0.016	0.144 ± 0.099
7	0.064 ± 0.017	0.223 ± 0.104
8	0.078 ± 0.017	0.354 ± 0.105
9	0.014 ± 0.020	0.215 ± 0.120
10	0.027 ± 0.021	-0.097 ± 0.128
11	0.006 ± 0.028	-0.156 ± 0.171
12	-0.054 ± 0.016	0.586 ± 0.098

TABLE V (Cont'd)

Variable	Average Daily Gain	Weaning Type
Season of Birth		
I	-0.022 ± 0.009	0.182 ± 0.053
II	0.045 ± 0.009	-0.011 ± 0.058
IV	-0.023 ± 0.011	-0.171 ± 0.054
Sex		
Male	0.085 ± 0.005	0.061 ± 0.031
Female	-0.085 ± 0.005	-0.061 ± 0.029
Year of Birth		
1957	0.078 ± 0.038	1.025 _ 0.237
1958	0.020 ± 0.027	-0.009 ± 0.166
1959	-0.109 ± 0.023	-0.576 ± 0.140
1960	-0.043 ± 0.019	-0.115 ± 0.116
1961	0.052 ± 0.018	0.261 ± 0.110
1962	0.078 ± 0.018	0.097 ± 0.111
1963	-0.064 ± 0.019	0.009 ± 0.120
1964	-0.028 ± 0.022	-0.083 ± 0.139
1965	-0.051 ± 0.023	-0.240 ± 0.143
1966	0.067 ± 0.018	0.369 ± 0.173

[a]Estimates are deviations from the overall means adjusted for unequal numbers per subclass. The overall arithmetic means for average daily gain and weaning type were 1.62 and 12.06, respectively, for Group I.

TABLE VI

LEAST SQUARES ESTIMATES[a] AND STANDARD ERROR OF WEANING WEIGHT FROM 1957-1966, ANALYSIS II

Variable	Weaning Weight
Intercept	353.313
Sire	
1009	-8.836 ± 14.095
1084	18.456 ± 7.666
1234	-9.131 ± 15.286
2593	-13.346 ± 18.337
5097	-17.597 ± 23.313
5133	-47.365 ± 13.004
8027	-13.002 ± 13.075
8090	-10.456 ± 17.835
8192	-3.354 ± 14.287
8205	-71.497 ± 20.859
8251	-2.745 ± 11.241
8290	12.142 ± 8.119
8308	14.176 ± 13.852
8310	2.048 ± 6.697
8412	34.350 ± 9.380
8500	-2.793 ± 12.118
8657	-0.912 ± 6.365
8660	5.503 ± 7.137

TABLE VI (Cont'd)

Variable	Weaning Weight
Sire Cont'd	
8688	4.568 ± 6.762
8720	-18.627 ± 19.198
8722	21.338 ± 19.519
8813	-42.743 ± 16.154
8951	7.761 ± 16.857
9009	15.673 ± 17.056
9025	8.964 ± 7.612
9035	-5.818 ± 23.695
9102	3.809 ± 8.496
9132	34.346 ± 26.738
9137	-32.023 ± 14.063
9148	-4.388 ± 6.807
9162	27.324 ± 23.628
9163	9.651 ± 16.168
9176	1.328 ± 11.433
9193	11.325 ± 6.759
9203	-23.299 ± 15.298
9257	-3.249 ± 7.747
9291	-30.126 ± 8.266
9295	-12.983 ± 6.133
9305	8.222 ± 11.949

TABLE VI (Cont'd)

Variable	Weaning Weight
Sire Cont'd	
9380	34.109 ± 7.683
9385	-1.676 ± 5.246
9480	55.983 ± 23.202
9537	4.644 ± 8.393
9709	20.584 ± 9.917
9777	19.648 ± 6.722
Age of Dam	
2	-46.510 ± 4.107
3	-16.355 ± 3.246
4	-0.691 ± 3.294
5	14.777 ± 3.544
6	5.866 ± 3.791
7	15.947 ± 3.987
8	19.621 ± 3.998
9	5.739 ± 4.599
10	7.476 ± 4.893
11	5.977 ± 6.525
12	-11.847 ± 4.596
Season of Birth	
I	-0.176 ± 2.489

TABLE VI (Cont'd)

Variable	Weaning Weight
Season of Birth Cont'd	
II	1.601 ± 3.370
IV	1.425 ± 2.766
Sex	
Male	22.029 ± 1.213
Female	-22.029 ± 1.315
Year of Birth	
1957	20.355 ± 9.107
1958	9.730 ± 6.424
1959	-23.241 ± 5.449
1960	-8.961 ± 4.576
1961	14.897 ± 4.289
1962	18.795 ± 4.229
1963	-14.088 ± 4.722
1964	-11.426 ± 5.392
1965	-26.534 ± 5.745
1966	20.473 ± 4.354
Weaning Age	
Linear	-1.542 ± 2.909
Cubic	0.011 ± 0.013
Quadratic	-0.000 ± 0.000

[a]Estimates are deviations from the overall means adjusted for unequal numbers per subclass. The overall arithmetic mean for weaning weight is 433.19 pounds for Group I.

TABLE VII

LEAST SQUARES ESTIMATES[a] AND STANDARD ERROR OF THE EFFECTS STUDIED FROM 1967-1974, ANALYSIS III

Variable	Average Daily Gain	Weaning Type
Least Squares Mean	1.801 ± 0.010	13.462 ± 0.056
Sire		
1000	0.095 ± 0.035	0.875 ± 0.201
5736	-0.014 ± 0.027	-0.341 ± 0.152
8023	0.045 ± 0.032	-0.013 ± 0.185
8049	0.002 ± 0.030	-0.124 ± 0.170
8087	-0.015 ± 0.039	0.138 ± 0.226
8178	-0.091 ± 0.046	0.214 ± 0.261
8192	0.048 ± 0.036	0.129 ± 0.206
8250	0.118 ± 0.049	0.585 ± 0.282
8251	-0.018 ± 0.025	0.106 ± 0.142
8290	-0.037 ± 0.106	-1.037 ± 0.606
8310	0.012 ± 0.064	-0.966 ± 0.364
8320	0.066 ± 0.040	-0.297 ± 0.228
8354	-0.107 ± 0.105	0.231 ± 0.603
8365	0.063 ± 0.038	-0.173 ± 0.215
8412	0.120 ± 0.028	-0.269 ± 0.161
8416	-0.011 ± 0.026	0.107 ± 0.147
8456	-0.038 ± 0.039	-0.152 ± 0.222
8464	-0.146 ± 0.076	0.277 ± 0.435

TABLE VII (Cont'd)

Variable	Average Daily Gain	Weaning Type
Sire Cont'd		
8527	0.038 ± 0.021	-0.061 ± 0.120
8535	-0.121 ± 0.042	-0.508 ± 0.240
8566	-0.030 ± 0.067	-0.748 ± 0.382
8577	0.057 ± 0.023	0.078 ± 0.133
8648	0.035 ± 0.026	-0.163 ± 0.150
8688	0.052 ± 0.053	-0.302 ± 0.301
8703	0.025 ± 0.023	-0.191 ± 0.129
8710	0.087 ± 0.035	0.711 ± 0.200
8757	0.104 ± 0.059	0.104 ± 0.335
8771	0.016 ± 0.054	1.562 ± 0.311
8868	-0.019 ± 0.026	-0.042 ± 0.146
9000	0.126 ± 0.024	0.753 ± 0.140
9009	0.037 ± 0.022	-0.166 ± 0.124
9031	-0.045 ± 0.045	-0.920 ± 0.260
9092	-0.109 ± 0.024	-0.216 ± 0.139
9100	-0.026 ± 0.034	-0.146 ± 0.195
9102	0.043 ± 0.047	0.647 ± 0.267
9134	-0.012 ± 0.078	1.254 ± 0.448
9145	-0.196 ± 0.053	-1.221 ± 0.301
9163	0.001 ± 0.062	0.349 ± 0.357
9218	-0.020 ± 0.043	0.175 ± 0.245

TABLE VII (Cont'd)

Variable	Average Daily Gain	Weaning Type
Sire Cont'd		
9626	-0.105 ± 0.075	-0.572 ± 0.428
9709	0.020 ± 0.106	0.183 ± 0.605
9777	-0.050 ± 0.022	0.122 ± 0.245
Age of Dam		
2	-0.212 ± 0.017	-0.727 ± 0.099
3	-0.104 ± 0.013	-0.324 ± 0.077
4	-0.055 ± 0.013	-0.094 ± 0.074
5	0.008 ± 0.013	-0.043 ± 0.074
6	0.040 ± 0.014	0.187 ± 0.080
7	0.072 ± 0.015	0.119 ± 0.085
8	0.071 ± 0.017	0.164 ± 0.095
9	0.083 ± 0.018	0.209 ± 0.105
10	0.079 ± 0.018	0.384 ± 0.103
11	0.039 ± 0.020	0.145 ± 0.113
12	-0.021 ± 0.014	-0.020 ± 0.096
Season of Birth		
I	-0.002 ± 0.007	0.008 ± 0.042
II	0.035 ± 0.008	-0.150 ± 0.048
IV	-0.033 ± 0.006	0.142 ± 0.046

TABLE VII (Cont'd)

Variable	Average Daily Gain	Weaning Type
Sex		
Male	0.089 ± 0.005	-0.065 ± 0.027
Female	-0.089 ± 0.007	-0.065 ± 0.032
Year of Birth		
1967	0.087 ± 0.020	-0.127 ± 0.117
1968	-0.037 ± 0.020	-0.383 ± 0.112
1969	0.040 ± 0.016	-0.037 ± 0.094
1970	0.010 ± 0.014	0.409 ± 0.081
1971	-0.021 ± 0.015	0.197 ± 0.085
1972	-0.021 ± 0.016	0.243 ± 0.092
1973	-0.030 ± 0.018	0.069 ± 0.101
1974	-0.106 ± 0.020	-0.371 ± 0.098

[a]Estimates are deviations from the overall means adjusted for unequal numbers per subclass. The overall arithmetic means for average daily gain and weaning type were 1.809 and 13.409, respectively, for Group II.

TABLE VIII

LEAST SQUARES ESTIMATES[a] AND STANDARD ERROR OF WEANING WEIGHT FROM 1967-1974, ANALYSIS IV

Variable	Weaning Weight
Intercept	441.702
Sire	
1000	27.727 ± 7.961
5736	-3.199 ± 6.050
8023	8.750 ± 7.389
8049	-0.229 ± 6.758
8087	-2.692 ± 8.930
8178	-20.480 ± 10.341
8192	14.218 ± 8.242
8250	29.751 ± 11.188
8251	-4.669 ± 5.699
8290	-11.316 ± 24.003
8310	-7.072 ± 14.470
8320	14.696 ± 9.030
8354	-29.648 ± 23.986
8365	9.515 ± 8.513
8412	24.216 ± 6.369
8416	-6.171 ± 5.837
8456	-4.884 ± 8.814
8464	-22.701 ± 17.222

TABLE VIII (Cont'd)

Variable	Weaning Weight
Sire Cont'd	
8527	8.982 ± 4.770
8535	-28.581 ± 9.521
8566	-5.241 ± 15.138
8577	12.070 ± 5.286
8648	5.298 ± 5.961
8688	6.146 ± 11.971
8703	5.472 ± 5.143
8710	20.612 ± 7.918
8757	23.972 ± 13.264
8771	7.075 ± 12.364
8868	-4.811 ± 5.804
9000	33.384 ± 5.561
9009	6.163 ± 4.928
9031	-6.744 ± 10.431
9092	-25.096 ± 5.516
9100	-7.368 ± 7.929
9102	7.739 ± 10.605
9134	2.087 ± 17.795
9145	-34.581 ± 11.982
9163	0.863 ± 14.172
9218	-3.069 ± 9.725

TABLE VIII (Cont'd)

Variable	Weaning Weight
Sire Cont'd	
9626	-28.662 ± 16.978
9709	3.344 ± 23.965
9777	-13.266 ± 5.136
Age of Dam	
2	-53.531 ± 3.917
3	-27.475 ± 3.038
4	-13.582 ± 2.933
5	3.121 ± 2.932
6	10.502 ± 3.187
7	18.115 ± 3.361
8	17.458 ± 3.750
9	20.620 ± 4.154
10	20.537 ± 4.098
11	8.681 ± 4.470
12	-4.446 ± 3.016
Season of Birth	
I	1.210 ± 1.823
II	7.527 ± 2.354
IV	-8.737 ± 1.976

TABLE VIII (Cont'd)

Variable	Weaning Weight
Sex	
Male	21.109 ± 1.050
Female	-21.109 ± 1.120
Year of Birth	
1967	18.892 ± 4.620
1968	-6.878 ± 4.464
1969	8.708 ± 3.747
1970	1.658 ± 3.278
1971	-3.734 ± 3.390
1972	13.142 ± 3.657
1973	-8.962 ± 4.074
1974	-22.826 ± 3.824
Weaning Age	
Linear	-4.185 ± 3.584
Cubic	0.031 ± 0.017
Quadratic	0.000 ± 0.000

[a]Estimates are deviations from the overall adjusted means for unequal numbers per subclass. The overall arithmetic mean for weaning weight is 453.186 pounds for Group II.

TABLE IX

ANALYSIS OF VARIANCES OF THE EFFECTS STUDIED (1957-1966), ANALYSIS I

Source	Degrees of Freedom	Mean Square: Average Daily Gain	Mean Square: Weaning Type
Sire	46	0.1360***	6.2511***
Age of Dam	10	0.5692***	12.8501***
Season	2	0.6123***	8.7257**
Sex	1	10.4782***	5.2859
Year of Birth	9	0.4081***	8.9049***
Residual	1435	0.0381	1.4498
R^2		0.381	0.200

**P < .01

***P < .001

TABLE X

ANALYSIS OF VARIANCES FOR WEANING WEIGHT (1957-1966), ANALYSIS II

Source	Degrees of Freedom	Mean Square
Sire	46	8,200.37***
Age of Dam	10	40,664.37***
Season	2	257.42
Sex	1	698,262.47***
Year of Birth	9	30,736.32***
Weaning Age		
Linear	1	595.22
Cubic	1	1,537.81
Quadratic	1	1,110.80
Residual		2,118.13
R^2		0.6

***$P < .001$

TABLE XI

ANALYSIS OF VARIANCES OF THE EFFECTS STUDIED (1967-1974), ANALYSIS III

Source	Degrees of Freedom	Mean Square: Average Daily Gain	Mean Square: Weaning Type
Sire	43	0.1349***	4.8783***
Age of Dam	10	0.9304***	9.7283***
Season	2	0.2860***	5.3418**
Sex	1	12.4435***	6.6354*
Year of Birth	7	0.4527***	9.2134***
Residual	1580	0.0335	1.0985
R^2		0.426	0.2329

*P < .05

**P < .01

***P < .001

TABLE XII

ANALYSIS OF VARIANCES FOR WEANING WEIGHTS (1967-1974), ANALYSIS IV

Source	Degrees of Freedom	Mean Square
Sire	43	7,208.08***
Age of Dam	10	59,938.55***
Season	2	10,783.89**
Sex	1	695,339.28***
Year of Birth	7	20,742.39***
Weaning Age		
Linear	1	2,345.88
Cubic	1	5,422.57
Quadratic	1	6,032.82
Residual	1580	1,720.14
R^2		0.7

**P < .01

***p < .001

(1966), and 0.15 by Cunningham and Henderson (1965). Other published estimates of sex of calf effects are either larger or smaller than those calculated from this data.

The sex of calf effects on weaning weight were also highly significant ($P < .001$) with male calves having a weight difference of 44 and 42 pounds greater than females for Analyses II and IV, respectively.

Sex of calf effect for Analysis I was 0.12 unit, while Analysis III had a value of 0.13 unit in favor of female calves. This difference was significant ($P < .05$). Marlowe and Gaines (1958) found sex difference in weaning type score was 0.05 unit greater for heifer calves. Marlowe (1962) again repeated this observation of 0.05 unit in favor of female calves.

Least squares means for the sex effects of Analyses I through IV are repeated in Tables XIII through XVI, respectively.

II. AGE OF DAM

Age of dam was considered a discrete variable in all of the analyses as it is thought by most researchers that neither a straight line nor a quadratic curve can adequately describe the biology of the aging process.

The effects of age of dam on gain from birth to weaning were highly significant ($P < .001$) in both Analyses I and III. These data show that a cow's individual performance was lowest at 2, 3, 4, and 12 years of age, with there being relatively little difference in the 5 through 10 year old age period. These estimates were in general agreement with most of the research published.

TABLE XIII

LEAST SQUARES MEANS OF AVERAGE DAILY GAIN AND WEANING TYPE, ADJUSTED FOR AGE OF DAM, SEASON OF BIRTH, AND SIRE (1957-1966), ANALYSIS I

Source	No. of Observations	Mean: Average Daily Gain	Mean: Weaning Type
Male	739	1.70	12.00
Female	762	1.53	11.88

TABLE XIV

LEAST SQUARES MEANS OF WEANING WEIGHT ADJUSTED FOR AGE OF DAM, SEASON OF BIRTH, SIRE, WEANING AGE: LINEAR, CUBIC, AND QUADRATIC (1957-1966), ANALYSIS II

Source	No. of Observations	Mean Weaning Weight
Male	739	454.76
Female	762	410.71

TABLE XV

LEAST SQUARE MEANS OF AVERAGE DAILY GAIN AND WEANING TYPE, ADJUSTED FOR AGE OF DAM, SEASON OF BIRTH, AND SIRE (1967-1974), ANALYSIS III

Source	No. of Observations	Mean: Average Daily Gain	Mean: Weaning Type
Male	842	1.89	13.40
Female	801	1.71	13.53

TABLE XVI

LEAST SQUARES MEANS OF WEANING WEIGHT ADJUSTED FOR AGE OF DAM, SEX, SEASON OF BIRTH, SIRE, WEANING AGE: LINEAR, CUBIC, AND QUADRATIC (1967-1974), ANALYSIS IV

Source	No. of Observations	Mean Weaning Weight
Male	842	472.27
Female	801	430.05

The estimates of age of dam effects on type score for Analysis I indicate that the maximum type score of a cow's calves was obtained within the age range of 3 to 9 years, and decreased as she became older. In Analysis III, an improvement in type score performance occurred between the ages of two and three years, but there was little difference in the cow's performance as she grew older. This can be attributed somewhat to the fact that in Analysis III, there was a heavier culling level on inferior aged animals. The effects of age of dam for both analyses were highly significant ($P < .001$).

Least squares estimates of age of dam effects for Analyses I through IV are presented in Tables XVII through XX, respectively.

Least squares estimates adjustment factors for age of dam were calculated for both groups of data. They were adjusted to a 6-year old age constant and are presented opposite the average of Petty and Cartwright (1966) in Table XXI.

III. SEASON OF BIRTH

Season of birth had a highly significant ($P < .001$) influence on average daily gain from birth to weaning in both Analyses I and III. Calves born in Season II grew faster than did calves born in Seasons I and IV. This seems quite logical as calves born in Season II, primarily March and early April, arrive at the time of greatest forage utilization for their dams. This is in agreement with Marlowe et al. (1965), who reported that calves born in March, April, and May made faster gains than those born in other months.

TABLE XVII

LEAST SQUARES MEANS OF AVERAGE DAILY GAIN AND WEANING TYPE, ADJUSTED FOR YEAR OF BIRTH, SEX, SEASON OF BIRTH AND SIRE (1957-1966), ANALYSIS I

Source	No. of Observations	Mean	
		Average Daily Gain	Weaning Type
Age of Dam			
2	190	1.44	11.31
3	229	1.55	11.89
4	206	1.61	12.17
5	171	1.67	12.31
6	146	1.63	12.09
7	129	1.67	12.17
8	128	1.69	12.30
9	95	1.63	12.16
10	83	1.64	11.85
11	45	1.62	11.79
12	79	1.56	11.36

TABLE XVIII

LEAST SQUARES MEANS OF WEANING WEIGHT ADJUSTED FOR YEAR OF BIRTH, SEX, SEASON OF BIRTH, SIRE, WEANING AGE: LINEAR, CUBIC, AND QUADRATIC (1957-1966), ANALYSIS II

Source	No. of Observations	Mean Weaning Weight
Age of Dam		
2	190	386.22
3	229	416.38
4	206	432.04
5	171	447.51
6	146	438.60
7	129	448.68
8	128	452.36
9	95	438.47
10	83	440.21
11	45	438.71
12	79	420.89

TABLE XIX

LEAST SQUARES MEANS OF AVERAGE DAILY GAIN AND WEANING TYPE, ADJUSTED FOR YEAR OF BIRTH, SEX, SEASON OF BIRTH AND SIRE (1967-1974), ANALYSIS III

Source	No. of Observations	Mean Average Daily Gain	Mean Weaning Type
Age of Dam			
2	168	1.59	12.73
3	217	1.70	13.14
4	207	1.75	13.37
5	201	1.81	13.42
6	169	1.84	13.65
7	146	1.87	13.58
8	116	1.87	13.63
9	91	1.88	13.67
10	93	1.88	13.85
11	78	1.84	13.61
12	156	1.78	13.44

TABLE XX

LEAST SQUARES MEANS OF WEANING WEIGHT ADJUSTED FOR YEAR OF BIRTH, SEX, SEASON OF BIRTH, SIRE, WEANING AGE: LINEAR, CUBIC, AND QUADRATIC (1967-1974), ANALYSIS IV

Source	No. of Observations	Mean Weaning Weight
Age of Dam		
2	169	397.63
3	217	423.69
4	207	437.58
5	201	454.28
6	169	461.66
7	146	469.28
8	116	468.62
9	91	471.78
10	93	471.70
11	78	459.84
12	156	446.71

TABLE XXI

AGE OF DAM CORRECTION FACTORS (LB./DAY)

Petty and Cartwright (1966)		Group I (1957-1966)	Group II (1967-1974)
Age of Dam			
2	-0.25	-0.19	-0.25
3	-0.16	-0.08	-0.14
4	-0.07	-0.02	-0.09
5	-0.03	0.04	-0.03
6	0.00	0.00	0.00
7	0.02	0.04	0.03
8	0.03	0.06	0.03
9	0.00	0.00	0.04
10		0.01	0.04
11		-0.01	0.00
12		-0.07	-0.06

Season of birth had a significant effect ($P < .01$) on type score at weaning in both Analyses I and III. In Analysis I, calves born in Season I scored higher than calves born in Seasons II and IV; although in Analysis III calves born in Season IV scored higher than the other two seasons. Least squares estimates of the effects of season of birth are presented in Tables XXII through XXIX, respectively.

IV. YEAR OF BIRTH

Least squares estimates for the effects of year for Analyses I through IV are in Tables XXVI through XXIX, respectively. The effects of year of birth were significant ($P < .001$) in all analyses. It has long been known that yearly differences in environment constitute a good deal of the variation in a herd's performance from year to year.

V. HERITABILITY

Heritability estimates of average daily gain from birth to weaning were 0.33 and 0.32 for the data groups I and II, respectively. This is in close agreement with Marlowe and Vogt (1965) with 0.31, Minyard and Dinkel (1965) with 0.32, and High (1968) whose summarized estimates from 1958 through 1965 were 0.30 and 0.29, respectively. Although there is quite a degree of variation throughout published data of heritability estimates, most reports show 0.33 to be an average estimate.

Heritability estimates of type score at weaning were 0.41 and 0.36 for data groups I and II, respectively. This again is in relative

TABLE XXII

LEAST SQUARES MEANS OF AVERAGE DAILY GAIN AND WEANING TYPE, RESPECTIVELY, ADJUSTED FOR YEAR OF BIRTH, AGE OF DAM, SEX, AND SIRE (1957-1966), GROUP I

Source	No. of Observations	Mean: Average Daily Gain	Mean: Weaning Type
Season of Birth			
I	779	1.59	12.12
II	541	1.66	11.93
IV	181	1.59	11.77

TABLE XXIII

LEAST SQUARES MEANS OF WEANING WEIGHT ADJUSTED FOR YEAR OF BIRTH, AGE OF DAM, SEX, SIRE, WEANING AGE: LINEAR, CUBIC, AND QUADRATIC (1957-1966), GROUP I

Source	No. of Observations	Mean Weaning Weight
Season of Birth		
I	779	432.56
II	541	434.34
IV	181	

TABLE XXIV

LEAST SQUARES MEANS OF SEASON OF BIRTH ADJUSTED FOR YEAR OF BIRTH, AGE OF DAM, SEX, AND SIRE (1967-1974), GROUP II

Source	No. of Observations	Mean	
		Average Daily Gain	Weaning Type
Season of Birth			
I	930	1.80	13.47
II	482	1.84	13.31
IV	223	1.77	13.60

TABLE XXV

LEAST SQUARES MEANS OF WEANING WEIGHT ADJUSTED FOR YEAR OF BIRTH, AGE OF DAM, SEX, SIRE, WEANING AGE: LINEAR, CUBIC, AND QUADRATIC (1967-1974), GROUP II

Source	No. of Observations	Mean
		Weaning Type
Season of Birth		
I	938	452.37
II	482	458.69
IV	223	442.42

TABLE XXVI

LEAST SQUARES MEANS OF AVERAGE DAILY GAIN AND WEANING TYPE, RESPECTIVELY, ADJUSTED FOR AGE OF DAM, SEX, SEASON OF BIRTH, AND SIRE (1957-1966), ANALYSIS I

Source	No. of Observations	Mean	
		Average Daily Gain	Weaning Type
Year of Birth			
1957	70	1.69	12.97
1958	129	1.63	11.93
1959	128	1.50	11.37
1960	167	1.57	11.83
1961	203	1.66	12.20
1962	173	1.69	12.04
1963	154	1.55	11.95
1964	161	1.58	11.86
1965	152	1.56	11.70
1966	164	1.68	11.57

TABLE XXVII

LEAST SQUARES MEANS OF WEANING WEIGHT ADJUSTED FOR AGE OF DAM, SEX, SEASON OF BIRTH, SIRE, WEANING AGE: LINEAR, CUBIC, AND QUADRATIC (1957-1966), ANALYSIS II

Source	No. of Observations	Mean Weaning Weight
Year of Birth		
1957	70	453.09
1958	129	442.46
1959	128	409.49
1960	167	423.77
1961	203	447.63
1962	173	451.53
1963	154	418.65
1964	161	421.31
1965	152	406.20
1966	164	453.21

TABLE XXVIII

LEAST SQUARES MEANS OF AVERAGE DAILY GAIN AND WEANING TYPE, RESPECTIVELY, ADJUSTED FOR AGE OF DAM, SEX, SEASON OF BIRTH, AND SIRE (1967-1974), ANALYSIS III

Source	No. of Observations	Mean	
		Average Daily Gain	Weaning Type
Year of Birth			
1967	188	1.89	13.33
1968	234	1.76	13.08
1969	217	1.84	13.42
1970	201	1.81	13.87
1971	193	1.78	13.66
1972	208	1.85	13.71
1973	206	1.77	13.53
1974	196	1.69	13.09

TABLE XXIX

LEAST SQUARES MEANS OF WEANING WEIGHT ADJUSTED FOR AGE OF DAM, SEX, SEASON OF BIRTH, SIRE, WEANING AGE: LINEAR, CUBIC, AND QUADRATIC (1967-1974), ANALYSIS IV

Source	No. of Observations	Mean Weaning Weight
Year of Birth		
1967	188	470.05
1968	234	444.28
1969	217	459.87
1970	201	452.82
1971	193	447.43
1972	208	464.30
1973	206	442.19
1974	196	428.33

agreement with Marlowe and Vogt (1965) with 0.39, Dunn et al. (1970) with 0.42, and Vesely and Robinson (1971) with 0.36.

VI. GENETIC AND PHENOTYPIC CORRELATION

Genetic correlations of average daily gain and weaning type were 0.56 and 0.37 for the data groups I and II, respectively. This agrees somewhat with Cunningham and Henderson (1965) with 0.48 and High (1968) whose averaged estimate was 0.54.

Phenotypic correlations of average daily gain and weaning type was 0.41 for both groups. This, again, is in close agreement with High (1968) whose averaged estimate was 0.40.

VII. GENETIC TREND

Estimations of genetic progress by the method given were 0.0078 and 0.0343 pound increase in average daily gain per year for data groups I and II, respectively. These estimations, in terms of progress per generation interval, would be 0.039 and 0.172 pound increase in average daily gain.

It was felt that there could be a possible confounding effect of season in the model, which included age of dam, sex, season of birth, and sire. Therefore, a second analysis was done using only data included in Season I. This gave estimations of 0.036 and 0.027 pound increase in average daily gain per year for data groups I and II. In terms of progress per generation interval, this would be 0.179 and 0.137 pound progress per generation.

These estimations appear to be somewhat inflated but there are a number of problems involved. First of all, there was no control to the data. No estimation of the progress made in management was provided. Furthermore, this was not a random mating situation, with better bulls being bred to the better cows.

One of the most significant factors involved was the fact that this study covered a complete type change in the beef industry, favoring the longer, taller, growthier cattle with heavier mature weights. This was coupled with the fact that performance testing was also becoming more of a breeding tool throughout this period. A number of outside bulls have been used in the breeding program at Ames. It is highly probable that the ability to go and buy a bull that will increase the performance standards of a herd is also a part of the overall progress made, and this progress becomes more evident when a bull's sons and daughters are introduced into the herd.

With the combination of these factors, it is thought that estimations of 0.036 and 0.027 pound progress per year could be entirely possible.

In these data (1957-1966) average daily gain from birth to weaning was 1.62 pounds. It is conceivable to select a bull with similar genetic make up where average daily gain was 2.50 pounds per day. Heritability from this same body of data for this trait was 0.32. The selection differential of 0.14 would be the result. Therefore, if generation interval was five years, the progress expected is realistic.

CHAPTER V

SUMMARY

The performance records of 3,144 non-creep fed, purebred heifer and bull calves born at Ames Plantation were utilized in the study. These data were collected over an 18-year period (1957-1974), being divided into two groups, (1957-1966) and (1967-1974). Average daily gain, weaning type score and weaning weight were the factors studied in these analyses. The objectives of this study were to take data from the Ames herd and calculate estimates of the genetic trends within the herd. Also, the influence of age of dam, sex of calf, and season of birth on average daily gain from birth to weaning was evaluated. An analysis was performed for each group for average daily gain, weaning type and weaning weight.

Sex of calf had a highly significant effect ($P < .001$) on average daily gain for both groups. In these analyses, male calves gained 0.17 and 0.18 pound per day greater than their female counterparts.

Sex of calf effects on weaning weight were also highly significant ($P < .001$) with male calves having a weight difference of 44 and 42 pounds greater for the two groups, respectively.

Although sex effects on type score were not significant for the first group, the difference for the second group was significant with the female calves outscoring the male calves by 0.13 of a unit.

The effects of age of dam on gain from birth to weaning were highly significant for both groups. These data show that a cow's individual performance was lowest at 2, 3, 4 and 12 years of age.

Estimates of age of dam effects on type score indicate that the maximum type score of a cow's calf was obtained within the age range of three to nine years.

Season of birth had a highly significant ($P < .001$) influence on average daily gain from birth to weaning for both groups. Calves born in Season II grew faster than did calves born in Seasons I and IV. While season of birth had a significant effect ($P < .01$) on type score at weaning in both groups, but the effects were not consistant.

Heritability estimates of average daily gain from birth to weaning were 0.33 and 0.32 for groups I and II, respectively, while heritability estimates of type score at weaning were 0.41 and 0.36 for the data groups I and II.

Genetic correlations of average daily gain and weaning type were 0.56 and 0.37 for group I and II, while the phenotypic correlation of these traits was 0.41 for both groups.

Estimates of genetic progress were 0.0078 and 0.0343 pound increase in average daily gain per year for data groups I and II, respectively. These estimations, in terms of progress per generations, would be 0.036 and 0.172 pound increase in average daily gain.

A second analysis was done eliminating season from the model, using only data from Season I. This gave estimations of 0.036 and 0.027 pound increase in average daily gain per year and 0.179 and 0.137 pound progress per generation.

LITERATURE CITED

LITERATURE CITED

Bair, L. G., L. L. Wilson and J. H. Ziegler. 1972. Effects of calf sex and age of dam on pre- and post-weaning performance of calves from an Angus-Holstein crossbred herd. J. Animal Science 35:1155.

Barker, J. E. 1964. Factors influencing weaning performance of beef calves in commercial and purebred herds in Tennessee. M. S. Thesis. University of Tennessee, Knoxville, Tennessee.

Benyshek, L. L. and T. J. Marlowe. 1973. Estimating heritability of Hereford cow weights. J. Animal Science 36:854.

Blackwell, R. L., J. H. Knox, C. E. Shelby and R. T. Clark. 1962. Genetic analyses of economic characteristics of young Hereford cattle. J. Animal Science 21:101.

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

Brinks, J. S., R. T. Clark, N. M. Kieffer, and J. R. Quesenberry. 1962. Genetic and environmental factors affecting performance traits of Hereford bulls. J. Animal Science 21:777.

Brinks, J. S., R. T. Clark, N. M. Kieffer and J. C. Urich. 1964. Estimates of genetic, environmental, and phenotypic and parameters in range Hereford females. J. Animal Science 23:711.

Brown, C. J. 1958. Heritability of weight and certain body dimensions of beef calves at weaning. Ark. Agr. Exp. Sta. Bul. 597.

Burgess, J. B., Nellie L. Landblom and H. H. Stonaker. 1954. Weaning weights of Hereford calves as affected by inbreeding, sex, and age. J. Animal Science 13:843.

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

Christian, L. L. 1963. Analysis of growth and production traits in twin and non-twin beef cattle data. Ph.D. Dissertation. University of Wisconsin, Madison, Wisconsin.

Clark, R. T., C. E. Shelby, J. R. Quesenberry, R. R. Woodward and F. S. Willson. 1958. Production factors in range cattle. U.S.D.A. Tech. Bul. 1118.

Cunningham, E. P. and C. R. Henderson. 1965. Estimation of genetic and phenotypic parameters of weaning traits in beef cattle. J. Animal Science 24:182.

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

Dunn, R. J., W. T. Magee, K. E. Gregory, L. V. Cundiff, and R. M. Koch. 1970. Genetic parameters in straightbred and crossbred beef cattle. J. Animal Science 31:656.

Falconer, D. S. 1960. Introduction to Quantitative Genetics (First Edition). The Ronald Press, New York, N.Y.

Gacula, Maximo and C. J. Brown. 1963. Heritability of feedlot performance of beef bulls. J. Animal Science 22:238 (Abstr.).

Gregory, Keith E., Cecil T. Blunn and H. L. Baker. 1958. A study of some of the factors influencing the birth and weaning weights of beef calves. J. Animal Science 9:338.

Hamann, H. K., S. Wearden and W. H. Smith. 1963. Estimation of genetic and environmental factors affecting weaning weights of creep-fed cattle. J. Animal Science 22:316.

Harwin, G. O., J. S. Brinks and H. H. Stonaker. 1966. Genetic and environmental interactions of Hereford calves. J. Animal Science 25:779.

High, J. W., Jr., 1968. Selection indexes for beef cattle. Unpublished Ph.D. Dissertation. Iowa State University, Ames, Iowa.

Hitchcock, G. H., W. A. Sawyer, R. Bogart and L. Calvin. 1955. Rate and efficiency of gains in beef cattle. III. Factors affecting weight and effectiveness of selection for gains in weight. Ore. State Agr. Exp. Sta. Bul. 34.

Hohenboken, W. D. and J. S. Brinks. 1969. Effect of environmental corrections on repeatability of weaning weight in Angus. J. Animal Science 29:534.

Jamison, H. M. 1966. Factors affecting intra-cow variation in production of beef cattle. Unpublished Ph.D. Thesis. University of Tennessee, Knoxville, Tennessee.

Kidwell, J. F. 1954. Some growth relations in range cattle. J. Animal Science 13:54.

Kieffer, N. M., Doyle Chambers and D. F. Stephens. 1959. Inheritance of certain maternal traits in beef cattle. J. Animal Science 18:1464 (Abstr.).

Knapp, Bradford, Jr., A. L. Baker, J. R. Quesenberry and R. T. Clark. 1942. Growth and production factors in range cattle. Mont. State Col. Agr. Exp. Sta. Bul. 400:1.

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

Knapp, B., Jr. and R. T. Clark. 1950. Revised estimates of heritability of economic characteristics in beef cattle. J. Animal Science 10:365.

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

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

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

Koch, R. M. and R. T. Clark. 1955d. Genetic and environmental relationships among economic characters in beef cattle. III. Evaluating maternal environment. J. Animal Science 14:979.

Koch, R. M., K. E. Gregory, J. E. Ingalls and R. L. Arthaud. 1959. Evaluating the influence of sex on birth and preweaning in beef cattle. J. Animal Science 18:738.

Koch, R. M., L. V. Cundiff, K. E. Gregory and G. E. Dickerson. 1973. Genetic and phenotypic relations associated with preweaning and postweaning growth of Hereford bulls and heifers. J. Animal Science 36:235.

Koger, Marvin and J. H. Knox. 1947. The repeatability of the yearling production of range cows. J. Animal Science 6:461.

Lasley, J. F., B. N. Day and J. E. Comfort. 1961. Some genetic aspects of gestation length and birth and weaning weights in Hereford cattle. J. Animal Science 20:737.

Lasley, J. F. and W. E. Pugh. 1956. Some genetic aspects in intra-uterine and post-uterine growth in beef cattle. J. Animal Science 15:1219 (Abstr.).

Lehmann, R. P., J. A. Gaines, R. C. Cater, K. P. Bovard and C. M. Kincaid. 1961. Selection indexes for weaning traits in beef calves. J. Animal Science 20:53.

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

Loganathan, S. 1962. The genetic and environmental factors affecting the performance of Hereford calves from birth to weaning. M.S. Thesis. University of Tennessee, Knoxville, Tennessee.

Magee, W. T., J. Brinks, R. H. Nelson and G. A. Branaman. 1961. Some factors affecting weaning weight and score of beef calves. Mich. Agr. Exp. Sta. Quarterly Bul. 43:556.

Mahmud, Anuwar and E. H. Cobb. 1963. Factors affecting weaning weight, preweaning gains, and conformation scores of beef calves in Hawaii. J. Animal Science 22:820 (Abstr.).

Marlowe, T. J. and James A. Gaines. 1958. The influence of age, sex, and season of birth of calf, and age of dam on preweaning growth rate and type score of beef calves. J. Animal Science 17:706.

Marlowe, T. J. 1962. Weights and grades of beef cattle and their relation to performance. Va. Agr. Exp. Sta. Bul. 537.

Marlowe, T. J. and D. W. Vogt. 1965. Heritabilities, phenotypic correlations, and genetic correlations involving preweaning gains and weaning grades of beef cattle. J. Animal Science 24:502.

McCormick, W. C., B. L. Southwell and E. J. Warwick. 1956. Factors affecting performance in herds of purebred and grade polled Hereford cattle. Ga. Exp. Sta. Bul. 5:1.

McLaren, J. B. 1970. Procedures for developing selection indexes from BCIA data. Unpublished Ph.D. Dissertation. University of Tennessee, Knoxville, Tennessee.

Meyerhoeffer, D. C., R. C. Carter and B. M. Priode. 1963. Sex differences in heritability of traits in beef cattle. J. Animal Science 22:240 (Abstr.).

Minyard, J. A. and C. A. Dinkel. 1960. Factors influencing weaning weight of beef calves. J. Animal Science 19:1223 (Abstr.).

Minyard, J. A. and C. A. Dinkel. 1965. Weaning weight of beef calves as affected by age and sex of calf and age of dam. J. Animal Science 24:1067.

Pahnish, C. F., Ralph Bogart, E. B. Stanley, C. B. Roubicek and C. E. Shelby. 1958. Adjustment of weaning weights of range calves to a standard age of 270 days. Proc. Western Section Am. Soc. An. Prod. 9:XLVII.

Pahnish, C. F., E. B. Stanley, Ralph Bogart and C. B. Roubicek. 1961. Influence of sex and sire on weaning weights of Southwestern range calves. J. Animal Science 20:454.

Petty, R. R., Jr., and T. C. Cartwright. 1966. A summary of genetic and phenotypic parameters of growth and conformation characteristics of beef cattle. Texas Agr. Exp. Sta. Animal Sci. Tech. Rpt. 5.

Powell, R. L. and A. E. Freeman. 1974. Genetic trend estimates. Iowa Agr. and Home Ec. Exp. Sta. Bul. J-7780:1067.

Rollins, W. C. and H. R. Guilbert. 1954. Factors affecting the growth of beef calves during the suckling period. J. Animal Science 13:517.

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

Sewell, H. B., J. E. Comfort, B. N. Day and J. F. Lasley. 1963. Genetic and environmental factors influencing the weaning weight of beef calves. Mo. Agr. Exp. Sta. Res. Bul. 823.

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

Shelby, C. E., W. R. Harvey, R. T. Clark, J. R. Quesenberry and R. R. Woodward. 1963. Estimates of phenotypic and genetic parameters in ten years of Miles City ROP steer data. J. Animal Science 22:346.

Smith, C. 1962. Estimation of genetic change in farm livestock using field records. Animal Prod. 4:239.

Swiger, L. A. 1961. Genetic and environmental influences on gain of beef cattle during various periods of life. J. Animal Science 20:183.

Swiger, L. A. K. E. Gregory, R. M. Koch, W. W. Rowden, V. H. Arthaud and J. E. Ingalls. 1963. Evaluating post-weaning gain of beef calves. J. Animal Science 22:514.

Vesely, J. A. and O. W. Robinson. 1971. Genetic and maternal effects on preweaning growth and type score in beef calves. J. Animal Science 32:825.

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

Warwick, E. J. 1958. Fifty years of progress in breeding of beef cattle. J. Animal Science 17:922.

Wilson, L. L. 1963. Beef cattle selection indexes involving conformation and weight. J. Animal Science 22:1086.

VITA

J. Frederick Holbert, II, was born July 30, 1951, in Grainger County, Bean Station, Tennessee. He received his elementary education at the Bean Station Grammar School, and in 1968, graduated from Rutledge High School, Rutledge, Tennessee.

In June, 1968, he entered The University of Tennessee, Knoxville, in the College of Agriculture and received his Bachelor of Science degree in Agriculture Mechanization in March, 1973. While attending the University, Mr. Holbert was a member of FarmHouse Fraternity, serving as Rush Chairman and Scholarship Chairman for that organization. As a senior, he received the Doane Award, which is presented to the outstanding senior annually by FarmHouse.

He was also a member of the Agriculture Mechanization Club, member of Block and Bridle Club, served on the College of Agriculture Student Faculty Council, and was a member of the Meats Judging Team, winning the annual Madden Contest held at the University.

Mr. Holbert enrolled in The University of Tennessee Graduate School in 1973 and in June, 1975, received the Master of Science degree majoring in Animal Breeding.

He is a member of the Honor Society of Gamma Sigma Delta at The University of Tennessee.