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A Study of Sex Differences in Various Statistics Calculated from Data on Growing Angus Bulls and Heifers Fed at Different Levels.

Moyassar Yehya Al-Mallah

To the Graduate Council:

I am submitting herewith a dissertation written by Moyassar Yehya Al-Mallah entitled "A Study of Sex Differences in Various Statistics Calculated from Data on Growing Angus Bulls and Heifers Fed at Different Levels.." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

Robert R. Shrode, Major Professor

We have read this dissertation and recommend its acceptance:

J. B. McLaren, C. C. Chamberlain, W. W. Overcast, C. C. Melton

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A STUDY OF SEX DIFFERENCES IN VARIOUS STATISTICS CALCULATED FROM DATA ON GROWING ANGUS BULLS AND HEIFERS FED AT DIFFERENT LEVELS

A Dissertation

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Degree

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Moyassar Yehya Al-Mallah

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ABSTRACT

The objective of this study was to assess the relative importance of sire differences, sex differences and sire by sex interaction influence on variation among individuals in various recorded variables and to estimate the heritability of these variables.

Data were obtained from 858 Angus calves sired by 85 sires over a period of 6 years (1968-1973) from the purebred Angus herd at the Plateau Experiment Station of The University of Tennessee. The traits recorded on each animal at weaning (at an average age of 231 days) and after post-weaning feeding (at an average age of 385 days) were Body Weight, Type Score, Condition Score, Average Daily Gain, Heart Girth, Body Length and Hip Width. Lifetime (to a year of age) average daily gain also was calculated. Restricted feeding of heifer calves and full feeding of bull calves were followed during the post-weaning period. Heifers were restricted to prevent the excessive fattening which can occur on a high plane of feeding from jeopardizing their future reproductive and milking abilities.

Nested within-year analyses were performed on these data. Least-square estimates of the effects of sex, sire (within year) and sire-sex (within year) interaction on the various traits were obtained. Results showed highly significant sire effects on all

the traits studied. Sex effects also were highly significant ($P < .01$) with respect to all traits but two, Type Score measured at both stages and Hip Width at weaning. Sire by sex interaction effects were non-significant in all traits except for Type and Condition Scores measured at weaning and Average Daily Gain at post-weaning. These interactions, however, were probably due to sampling because of a small number of sires or a small number of progeny per sire. Bartlett's test of homogeneity of variance was conducted in order to justify statistically the pooling of the data over the six-year period. Results of the test indicate homogeneity of variances of all traits except one, Condition Score at post-weaning. Level of significance of differences in variances between sexes was tested by a simple F-test, using variance components of pooled data for each sex. This test showed highly significant ($P < .01$) sex differences with respect to variances due to differences between offspring of the same sire (s_W^2). However, some of the sex differences in variances due to sire differences (s_S^2) were not significantly ($P > .05$) different. All of the sex differences in total variance (s^2) were highly significant ($P < .01$).

Heritability estimates were calculated for each sex separately, at weaning and at a year of age, using the method of half-sib correlations. The results indicate higher heritability estimates in heifers than in bulls which suggests that heifer progeny provide more effective genetic discrimination between sires than would bull progeny at early ages of the calves and that selection among females may be more nearly as effective as that among males than is usually believed, the higher heritability in females offsetting, to some extent, the lower intensity of selection among females as compared to that among males. In general, data from heifers yielded higher heritability estimates, especially at weaning. These differences, however, were smaller at post-weaning and even reversed in the case of body dimension traits for which post-weaning data from bulls yielded higher estimates of heritability than did post-weaning data from heifers.

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CHAPTER I

INTRODUCTION

The beef industry is in great need of knowledge of the factors that affect economic traits such as average daily gain, weight and time of maturity. These traits are dependent on both genetic and environmental variation estimated in different ways, one of which is the estimate of heritability. Except for sex linked heredity, an individual receives half of his genetic material from his sire and the other half from his dam. There have been many studies dealing with the relative effects of sire and dam difference on the variation in performance of progeny. Sex differences also cause great variation among individuals.

In this study both environmental factors (nutrition) and genetic factors were involved in the conduct of the experiment. The objective was to assess the relative importance of sire differences, sex differences and sire by sex interaction influence on variation among individuals in various recorded variables.

CHAPTER II

LITERATURE REVIEW

I. NUTRITION EFFECTS

The level of feeding early in the life of an animal is very important. Many beef cattle producers believe that a relatively low level of feeding, mainly on roughages, during the second year of life improves the carcass of the animal and also increases the rumen development. Some breed societies discourage feeding heifers on very high plane of nutrition for show purposes in the belief that this adversely affects their future milking ability.

An early study done by Lush *et al*. (1930) on the normal growth of range cattle, showed that lowering the level of feeding retards growth as measured by daily gain and skeletal development.

Joubert (1954) and Crichton, Aitken and Boyne (1960), reported that there were differences in body size between animals fed different planes of nutrition up to 4 or 5 years of age. Crichton, Aitken and Boyne (1960) further reported that changing growth rate by changing level of nutrition will influence later developing tissue relatively more than earlier developing tissues.

Pope *et al*. (1955), Pinney, Stephens and Pope (1972) in two separate studies indicated that plane of nutrition during the time of rapid growth of the bovine influences the rapidity and economy of subsequent growth and possibly the ultimate size of an animal.

It has been shown that the plane of nutrition of heifer calves also will affect their milking ability and reproductive ability. Swanson and Spann (1954), using twin Jersey heifers, studied the effect of fattening on rate of growth and milk yield. They found heifers fed concentrates to appetite produced less milk during the first two lactations than their mates reared on a controlled and restricted ration. According to Joubert (1954), restricted feeding of heifers delays the onset of the first estrus and increases the length of the post-partum anoestrus period but improves conception rate.

Hughes (1971), using sixty weanling Hereford heifers to study the effect of winter nutrition on growth and milk production of females and the birth date and growth of their calves, reported that high-energy-fed cows gave more milk than low-energy-fed cows; however, the milk production of the low-energy-fed cows increased at a faster rate later. Advantages in calf weight during lactation generally paralleled milk yield of the dam. He added that "the low level of winter supplemental nutrition tended to delay attainment of maximum milk producing capacity while the very high level of nutrition fed during the early life of the female suppressed milk flow."

Harris, Brown and Anthony (1965), studying the effects of plane of nutrition upon performance of beef cows and their calves, reported that calves dropped by restricted-fed heifers were lighter in weight at weaning and post-weaning than those dropped by optimum-fed heifers. Only 3 of 14 restricted-fed heifers calved at 2 years of age, as compared with 17 of 22 optimum-fed heifers. However, animals on the two levels were essentially the same size at 4 years of age. Restricted-fed cows secreted less milk than optimum-fed cows during the winter; however, restricted-fed cows produced slightly more milk than optimum-fed cows after they were on lush spring pasture.

Level of energy intake can markedly alter reproductive performance in 2-year-old heifers nursing their first calves, accoridng to Dunn _et al_. (1969). They reported also that pregnancy rate 120 days after calving was directly related to the post-calving energy level. Eighty-seven percent of the cows fed the high energy level after calving were pregnant as compared to 72% of those fed the moderate level and 64% of those fed the low energy level ($0.01 < P < 0.05$). The onset of estrus was delayed in cows receiving the low level of energy before calving. They suggested that the low pregnancy rate in the cows fed the low energy level after calving occurred because 30% of the Hereford cows and 9% of the Angus cows failed to show estrus.

Energy level significantly ($P < .01$) affected cow and calf condition, calf conformation, cow weight loss and milk production (Gillooly _et al_., 1967). Christenson _et al_. (1967), who fed 58 yearling Hereford heifers on different levels of nutrition, (196, and 127 K cal of digestible energy/kg body weight per day), reported that heifers fed the high energy ration gained more weight during the last half of the gestation period and produced heavier calves at birth but experienced more calving difficulty than heifers fed the low energy ration.

Most of a calf's nutrient intake during the first few months of its life is supplied by milk from its dam. The effect of different winter feed levels on performance of fall-calving range-fed cows was studied by Furr and Nelson (1964). They reported that winter weight losses of cows were decreased and spring weights of their calves were increased by the higher level of supplemental feeding. Milk production generally decreased during the winter, but a marked recovery in milk flow occurred with availability of spring grass and then declined until weaning in July. The increase in milk production in the spring was greatest for cows wintered on the low level. Also, they reported high correlations (0.75 to 0.91) between milk production of cows and average daily gains of their claves. Significant ($P < .01$) correlations ranging from (0.67 to 0.81) between milk yield and calf weight at various milking dates in an Angus herd were found by Klett, Mason and Riggs (1965). The digestible energy level (7.7 or 17.4 meg cal per day) at post-calving feed to cows did not affect the weight gains of their calves (Dunn et al., 1965). They reported also that calves reared by dams fed the high pre-calving digestible energy level gained 90 kg in 109 days compared to 83 kg gained by calves reared by cows fed the low pre-calving digestible energy level.

Anthony et al. (1961), studying the effect of winter feeding on milk production of beef cows, reported that after cows were turned on excellent spring pasture, those which had been fed on a low energy level during the winter showed a greater increase in milk production than did those fed more liberally during the winter.

Kress, Hauser and Chapman (1971), in an experiment including identical and fraternal twin female beef cattle differing in age, to study the effects of two diets, one high and one low in energy. Both diets were formulated so that with ad Libitum feeding they would provide the animals with two levels of energy. They found about 100 kg difference in weight at 24 months of age, but there was little difference in some measure of skeletal size. They reported that set-diet interaction was seldom a significant source of variation in growth from 210 to 701 days of age.

Holloway and Totuset (1973) conducted four trials with Angus and Hereford females to determine the effects of three pre-weaning planes of nutrition imposed by (1) weaning at 140 days, (2) weaning at 240 days and (3) creep-feeding and weaning at 240 days. After weaning, all females were treated alike under range conditions. They found that body weight, length of body, height at hooks and withers and heart girth were significantly ($P < .05$) affected by treatment to 1.5 years. The creep-fed females gained the least and the 140-day-weaned females the most in structural size between 240 days and 2.0 years of age. The creep-fed females lost more weight and condition during their first pregnancy than did those on the other treatments and showed also a greater decrease in rate of skeletal growth than those on the other treatments during this period. No significant difference ($P > .10$) in any measurement of height between 240-day-weaned and creep-fed groups was ever noted, although a significant ($P < .05$) difference between extreme treatments was apparent through 1.5 years of age. The 140-day-weaned group tended to remain smaller with respect to all variables studied, but differences after 1.5 years of age were small.

II. SIRE EFFECTS

Evaluation of sires on the basis of the performance of their offspring is a good way to measure genetic worth. Genetic influences measured by sire differences have been shown to affect beef traits. Panish _et al_. (1961), using 329 bull calves and 332 heifer calves produced by 11 sires on two ranches over a period of 6 years, to study the effects of sire and sex on weaning weights, found differences among sires within ranches and years to be significant ($P < .05$) in the analysis involving male progeny and also in the analysis involving female progeny ($P < .01$). According to Bradley _et al_. (1966), calves sired by high-gaining sires gained significantly faster during the pre-weaning period and exhibited significantly heavier weaning and final weights than did calves sired by low-gaining sires. They found also that calves sired by higher-gaining sires had significantly less fat thickness at the 12th rib, larger ribeye areas, and a higher and lower percent of lean and fat, respectively, in the 9-10-11th rib than did calves sired by low-gaining sires. Suess _et al_. (1966), in a study to determine the effect of sire, sex and weight upon beef carcass traits and palatability, found within herd sire differences to be significant with respect to initial age ($P < .05$), on initial weight ($P < .01$) and daily gain ($P < .05$). They suggested, however, that these differences might have been caused by sire differences in initial age and initial weight.

Wilson _et al_. (1969), in a study on the effect of sex and sire upon growth and carcass traits of beef cattle, found significant sire differences with respect to adjusted 205-day weight, meat tenderness, Longissimus dorsi muscle area, cutability and weights and percentages of untrimmed and trimmed loin and round. They reported further that sire effects on degree of fatness and indicators of carcass quality were less important than sire effects on muscling criteria.

Calo _et al_. (1973), in a study involving 504 bulls to determine the genetic aspects of beef production by Holstein Friesians, found that sire accounted to 10% of the variation in average daily gain, 10% of that in daily gain per 100 kg body weight and 16% of that in body weight, indicating substantial genetic variability in beef traits. They found also that sire variance components for beef traits varied with age. There was a wide range in estimated breeding value (EBV) and estimated transmitting ability (ETA) for beef traits. Selecting the top 10% and 20% showed high selection differentials, empirically reflecting the potential for genetic improvement from selection.

Thrift _et al_. (1970) reported that sire was a significant source of variation in weaning weight and grade, pre-weaning average daily gain, cold carcass weight, carcass weight per day of age, ribeye area/100 kg carcass and estimated percent fat from the kidney and pelvic regions.

According to Tanner et al. (1970), sire effects were a significant source of variation in all performance traits and carcass traits studied except percent trimmed round, single fat thickness at 12th rib and carcass cutability. They stated that those results indicated important additive genetic variation in most of the traits analyzed. The magnitude of within-year sire differences ranged from 13.2 to 21.2 kg for 205-day weaning weight, from 0.07 to 0.2 kg for post-weaning average daily gain and from 0.04 to 0.09 kg for carcass weight per day of age.

Wilson (1973), having studied the effects of sire and sex on the birth weight and body dimension at one and three days of age of bull and heifer calves, reported low heritability estimates (0.12 to 0.18) for hook width and rump length, moderate to high heritability (0.41 to 0.55) for heart girth, cannon circumference and length and body length when weight was not held constant. The estimate for birth weight was 0.39. He concluded that moderate sire effects exist for certain birth measurements (especially cannon bone dimensions) when the effects of weight have been removed.

All reports reviewed are in agreement that sire differences are an important source of variation on various performance and carcass traits of beef cattle.

III. SEX EFFECTS

Sex difference is one of the major sources of variation in economic traits of beef cattle, regardless of whether sex is determined at conception or by post-natal castration.

According to Dahl (1962), castration retards growth, slows down activity and increases deposition of fat in the body. Laflamme and Burgess (1973) reported that castration had a significant effect on rate of gain, feed intake and feed efficiency of beef cattle fed different rations. Bulls grew significantly more rapidly and more efficiently than did steers.

The age or stage of development at which the male is castrated has been investigated with respect to effect on growth rate, feed efficiency and carcass composition. Klosterman et al. (1954) reported no differences in carcass quality and in rate of gain during a 250-day feeding trail, between Hereford males castrated at one month and those castrated at seven months of age.

Sex differences were reported by Wilson (1973) to affect birth weight and body dimensions also. Bull calves were 2.1 kg (5.8%, $P < .01$) heavier than were heifer calves.

Average Daily Gain

Studies conducted to assess sex effects have generally shown that bulls gain significantly faster than steers and steers faster than heifers. Anderson, High and Chapman (1964) found that steers generally gained significantly faster than heifers. However, steers took longer to reach desired market condition than did heifers, regardless of grade. Kennedy (1958) found that steers and heifers maintained similar rates of gain early in the feeding period. Steers maintained a high rate of gain for 140 days in the feed lot, but heifer gain rate decreased after 84 days. When steers and heifers were slaughtered with a similar degree of finish, the differences in rate of gains were not significant. Table 1 shows results of a number of investigations generally indicating that bulls gain faster than steers and steers faster than heifers. Daily gain differences due to sex appear to be consistent, regardless of breed, type, age or weight in any given group.

Studies of carcass traits of different sexes have generally shown that heifers have higher grade and finish, and steers rank above bulls in these respects. However, bulls have larger *L. dorsi* muscle area and higher cutability than do steers and heifers.

Dressing Percentage

Kennedy (1958) reported dressing percent of heifers to be significantly higher than that of steers when they were slaughtered at the same age. However, when slaughter was at the stage of similar finish, the differences between the two sexes were small and nonsignificant. Branman, Hankins and Alexander (1936) reported that, within reasonable limits, the fatter the animal is, the higher will be the dressing percent. Table 2 shows a comparison between sexes with respect to dressing percent. It appears that no definite conclusions can be drawn concerning dressing percent, and observed

TABLE 1

RATE OF GAIN COMPARISON OF BULLS, STEERS AND HEIFERS

Reference	Daily Gain (lb./day)		
	Bulls	Steers	Heifers
Anderson, High and Chapman (1964)	--	2.04 (150)[a]	1.79 (120)
Bogart et al. (1963)	2.49	--	1.92
Bradley et al. (1966)	--	2.26 (34)	1.96 (33)
Champagne et al. (1964)	2.80 (20)	2.30 (20)	--
Dyer and Weaver (1955)	--	2.16 (16)	1.93 (17)
Field, Schoonver and Nelms (1964)	2.21 (19)	1.97 (19)	--
Klosterman et al. (1954)	2.23 (10)	2.00 (10)	--
Koch et al. (1973)	2.15 (1652)	--	1.31 (1265)
Nichols et al. (1964)	2.20 (15)	1.95 (15)	--
Thrift et al. (1970)	--	2.05 (-)	1.85 (-)
Wierbicki et al. (1955)	2.36 (20)	2.07 (8)	--
Wipf et al. (1964)	2.55 (12)	1.84 (12)	--

[a]Number of animals in a study is shown in parentheses below the average found.

TABLE 2

A COMPARISON OF DRESSING PERCENT OF BULLS, STEERS AND HEIFERS

Reference	Dressing Percent		
	Bulls	Steers	Heifers
Anderson, High and Chapman (1964)	--	60.2	60.8
Bradley *et al.* (1966)	--	62.2	62.0
Champagne *et al.* (1964)	61.1	50.3	--
Dahl (1962)	52.0	50.4	--
Dyer and Weaver (1955)	--	57.3	59.1
Field, Schoonver and Nelms (1964)	63.8	62.9	--
Klosterman *et al.* (1954)	59.8	60.9	--
Laflamme and Burgess (1973)	61.7	59.9	--
Nichols *et al.* (1964)	57.9	58.3	--
Thrift *et al.* (1970)	--	58.8	58.7
Wierbicki *et al.* (1955)	58.5	59.5	--
Wilson *et al.* (1969)	--	62.0	62.5

differences between sexes are inconsistent, suggesting that dressing percent is affected by factors other than sex.

Carcass Grade

The sex of an animal has a great influence on factors affecting carcass grade. Table 3 shows a comparison of bulls, steers and heifers with respect to carcass grade. Bulls graded lower than steers or heifers when slaughtered at similar weights, ages or times on test. No conclusion, however, can be drawn with respect to difference between steers and heifers from this table. However, Kennedy (1958) observed steers and heifers to be of similar grade when slaughtered at similar finish. But when slaughtered after an equal period on feed, heifers graded significantly higher than steers.

In another study, however, Anderson, High and Chapman (1964) reported that steers and heifers within the same group or the same weight had differences in carcass grades. Choice steers graded significantly higher than choice heifers after the feedlot feeding.

Ribeye Muscle Area

The cross-sectional area of the logissimus muscle has often been used as a criterion for comparing animals.

Field, Schoonver and Nelms (1964) found that bulls had significantly ($P < .01$) larger longissimus muscle area per cwt of carcass than steers even though bull carcasses weighed from 28 to 60 pounds more. Klosterman (1963) observed that when longissimus muscle area

TABLE 3

A COMPARISON OF CARCASS GRADE OF BULLS, STEERS AND HEIFERS

Reference	Carcass Grade[a]		
	Bulls	Steers	Heifers
Anderson, High and Chapman (1964)	--	19.3	18.7
Dyer and Weaver (1955)	--	17.0	18.0
Field, Schoonver and Nelms (1964)	18.0	20.0	--
Klosterman _et al_. (1954)	18.0	22.0	--
Nichols _et al_. (1964)	13.9	14.3	--
Tanner _et al_. (1970)	21.3	21.3	20.7
Thrift _et al_. (1970)	--	20.1	19.0
Wierbicki _et al_. (1955)	18.0	21.0	--
Wilson _et al_. (1969)	--	19.3	19.6

[a]16-18, Good; 19-21, Choice.

was expressed on cwt carcass basis, steers averaging 49 pounds more than heifers had only 0.02 square inches more muscle area.

According to Nichols et al. (1964), 800-lb steers had larger longissimus muscle area than 1,000 lb. bulls when expressed on a cwt basis.

The findings enumerated above, therefore, show that the effect of weight differences should be taken into consideration when making comparison either on a cwt basis or when comparing actual areas.

Table 4 shows some results of investigations of longissimus muscle area in bulls, steers and heifers. Generally, bulls have larger longissimus muscle area than steers, and steers have a larger area than heifers.

Finish

Many studies have indicated that sex has an influence on the finish of the animal. According to Helser et al. (1932), as the length of feeding period increased, the proportion of fat also increased in steers and heifers, but the increase was at a faster rate in heifers.

Kennedy (1958) observed that steers had less finish than heifers when both sexes were slaughtered after the same length of time on feed. When steers were fed 50 days longer than heifers they appeared to be very similar in finish.

According to Trowbridge and Moffett (1932), heifers reached suitable market finish 30 to 40 days sooner than steers.

TABLE 4

A COMPARISON OF LONGISSIMUS MUSCLE AREA OF
BULLS, STEERS AND HEIFERS

Reference	Longissimus Muscle Area (sq in) Bulls	Steers	Heifers
Anderson, High and Chapman (1964)	--	11.22	10.88
Bradley *et al*. (1966)	--	12.36	11.81
Brown, Bartee and Lewis (1962)	12.00	10.00	--
Field, Schoonver and Nelms (1964)	13.38	10.54	--
Nichols *et al*. (1964)	9.33	8.20	--
Tanner *et al*. (1970)	12.16	10.54	10.08
Thrift *et al*. (1970)	--	11.78	11.16
Wilson *et al*. (1969)	--	10.85	10.39

Cramer, Hecker and Cornforth (1973), in a study involving two sets of twin steers and two sets of twin heifers, found that fat deposition in steers and heifers begins at about the same age, but it is a much more rapid process in heifers.

Table 5 presents a summary of data reported by a number of investigators, indicating that bulls have less external and internal fat than do steers or heifers, and steers have less than heifers. It indicates also that bulls have considerably less finish than steers and heifers, regardless of whether they are compared on the basis of days on feed, age or live slaughter weight.

Carcass Cutability

Studies have indicated that bulls have more untrimmed chuck than steers, but less loin and rib (Brown *et al*., 1962, Field, Schoonver and Nelms, 1964). Other untrimmed wholesale cuts were not affected by sex. However, Field, Schoonver and Nelms (1964) indicate that when the individual cuts were trimmed of excess fat, bulls had a higher yield of edible meat in all individual cuts. In general, bulls have less finish than steers and heifers and, consequently, a higher yield of retailable meat.

Table 6 shows a summary of studies of carcass cutability as influenced by sex. These results indicate that bulls have a higher yield of meat from major cuts than steers or heifers and steers higher than heifers, when compared on total carcass basis.

TABLE 5

A COMPARISON OF FINISH OF BULLS, STEERS AND HEIFERS

Criteria and Reference	Bulls	Steers	Heifers
Fat Thickness (in)			
Anderson, High and Chapman (1964)	--	.50	.53
Champaign et al. (1964)	.25	.40	--
Field, Schoonver and Nelms (1964)	.34	.67	--
Klosterman (1963)	--	.50	.58
Laflamme and Burgess (1973)	.28	.49	--
Nichols et al. (1964)	.12	.15	--
Thrift et al. (1970)	--	.55	.61
Percent Trim Fat			
Klosterman (1963)	--	14.8	18.5
Klosterman et al. (1954)	5.4	10.4	--
Wierbicki et al. (1955)	7.7	11.3	--
Percent Separable Fat			
Nichols et al. (1964)	18.8	23.9	--
Percent Kidney Fat			
Field, Schoovner and Nelms (1964)	2.7	3.5	--
Klosterman (1963)	--	2.9	3.7
Thrift et al. (1970)	--	3.1	3.7
Wilson et al. (1969)	--	3.8	4.3

TABLE 6

CUTABILITY COMPARISON OF BULLS, STEERS AND HEIFERS

Reference	Carcass Cutability			Pertinent Information
	Bulls	Steers	Heifers	
Bradley *et al*. (1966)	--	45.4	42.1	Percent total lean
Breidenstein *et al*. (1963)	--	62.86	59.95	Total retail yield
Champagne *et al*. (1964)	74.3	69.2	--	Percent edible portion
Field, Schoonver and Nelms (1964)	47.7	42.7	--	Percent chuck, rib, loin and cushion round
Klosterman (1963)	--	69.8	67.4	Percent edible portion
Klosterman et al. (1954)	77.7	73.7	--	Percent edible portion
Laflamme and Burgess (1973)	77.0	74.2	--	Percent edible portion
Suess *et al*. (1966)	--	43.86	40.20	Percent chuck, rib, loin and round
Wierbicki *et al*. (1955)	77.5	74.1	--	Percent edible portion

IV. SIRE-SEX INTERACTIONS

Knowledge of existence of sire-sex interaction effect is important in order to determine whether the testing of progeny of a single sex can accurately rank the breeding values of prospective herd sires. If sire-sex interaction is an important source of variation, then the estimated relative breeding value of a sire would be affected by the sex of the progeny evaluated. However, if sire-sex interactions are non-significant, or negligible, then sire evaluation can validly based on any one sex of progeny when accurate sex adjustments are available.

There have been some studies on this subject, the majority of which have indicated that sire-sex interactions are negligible and non-significant. However, some workers have reported significant sire-sex interactions.

Bradley et al. (1966), in a two-year study using 34 Hereford and 33 Hereford-Red Poll steers and heifers, found small, non-significant sire-sex interactions with respect to birth weight, pre-weaning average daily gain, weaning weight, weaning type score, post-weaning average daily gain and adjusted final weight. However, they reported that heifer calves sired by high-gaining sires were significantly more efficient in their feed conversion than were those sired by low-gaining sires, while there was essentially no difference between the steer progeny of sires of varying gains. They suggested further that certain sires may be capable of producing higher grading calves of one sex than another. Slaughter grades of calves sired by low-gaining sires were essentially the same in both sexes, while heifers calves sired by high gaining sires graded significantly ($P < .05$) higher than their steer progeny. They concluded finally that to evaluate validly in a progeny test the breeding values of sires for feed efficiency and slaughter grade, it may be necessary to consider both heifer and steer progeny. In general, they found that by including both sexes, calves sired by high-gaining sires were significantly ($P < .05$) more efficient than those sired by low gaining sires. However, a progeny test using steers alone would not have revealed this. They found non-significant sire-sex interaction with respect to all carcass traits studied.

Wilson et al. (1967) in an experiment involving 80 steers and 94 heifers sired by 13 selected Polled Hereford bulls over a three-year period, found highly significant ($P < .01$) sire-sex interaction with respect to trimmed loin weight.

According to Knapp and Phillips (1942), there was no significant sire-sex interaction with respect to gain to weaning. However, there was a significant sire-sex interaction with respect to gain after weaning. They concluded that, in respect to gains after weaning, some sires apparently produced heifers which gained better than their steer progeny, while others produced steers which gained better than their heifer progeny. Thus, if true superiority of a given sire is to be demonstrated, data on both sexes are desirable.

Koger and Knox (1945), in studying the effect of sex on weaning weight of range calves found the sire-sex interaction within year to be small and non-significant, that is, that sex differences within sire did not vary significantly among sires.

Three-way interaction of sire by weight by sex with respect to both length of test period ($P < .01$) and age ($P < .05$) was found by Suess et al. (1966), which suggested that steers and heifers at different weights and from different sires responded differently to differences in length of test period and final age. They concluded, however, that those differential responses might have been partly due to the same three-way interaction ($P < .05$) in initial weight, and the sire-sex interaction ($P < .05$) with respect to gain on test was possibly a result of the same interaction ($P < .05$) in initial weight.

Thrift et al. (1970) reported no significant sire-sex interactions with respect to any of the performance or carcass traits they studied and, therefore, suggested that if sires were to be progeny tested for the traits considered in their study, either steers or heifers or both could be used in the progeny test.

According to Tanner et al. (1970), there was no significant sire-sex interactions observed with respect to any of the performance on carcass traits studied. They concluded that the absence of significant sire-sex interactions indicate that sex differences within sire tend to be similar for different sires and that observed discrepancies can be attributed to random variation.

Wilson et al. (1969) found little practical sire-sex interaction with respect to any performance or carcass traits studied with the exception of 205-day weight.

V. HERITABILITY

Planning selection for economic traits, which are nearly all quantitative, requires a knowledge of the estimates of heritability of those traits. An accurate estimate of heritability indicates the fraction of the phenotypic superiority of selected parents which is transmitted to the offspring.

Lush (1945) pointed out that the importance of heritability is its predictive role in expressing the reliability of phenotypic value as an estimate of breeding value. He defined two kinds of heritability, heritability in the broad sense which is the proportion of phenotypic variation cased by all kinds of genetic variation type and heritability in the narrow sense which is the proportion of phenotypic variation caused by additively genetic variation.

Heritability Estimates for Different Sexes

Published comparisons of heritability estimates for different sexes are not all in agreement, but the majority of them indicate heritability estimates for certain traits in beef cattle to be higher in heifers than in steers or bulls (Guilbert and Gregory, 1952; Brown *et al*., 1956; Synar, 1958; Carter and Kincaid, 1959; Diven *et al*., 1960; Pahnish *et al*., 1961; Blackwell *et al*., 1962; Roberson *et al*., 1963; and Pahnish *et al*., 1964). Others showed values derived from bull data to be higher or about the same as from heifer data (Meyerhoeffer, Carter and Proide, 1963; Swiger *et al*., 1963; Marlowe and Vogt, 1965). However, in none of these studies were the corresponding estimates significantly different. Possible reasons for these differences might be sex-linked genes or the fact that heifers mature faster physiologically than do steers or bulls.

In a study to compare heritability estimates for bull and heifer calves, Koch et al. (1973) reported heritabilities of different traits to be consistently smaller from bull data than from heifer data. However, they found birth weight and pre-weaning daily gain to be 7% to 8% more highly heritable in bulls than in heifers. They concluded that differential weight should be given to bull or heifer records in assessing genetic merit of individuals or parents.

Pahnish et al. (1961) reported within-sex estimates of the heritability of weaning weight by the paternal half-sib method, with approximate 95% confidence intervals, were 0.28 ± 0.32 and 0.57 ± 0.41 for bulls and heifers, respectively. However, the difference between the two estimates was considered non-significant.

Francoise, Vogt and Nolan (1973) found within-sex heritability of weaning weight per day of age to be higher in heifers in both Angus (.49 vs. 1.04) and Hereford (.76 vs. .86). However, the sex differences were not significant.

Table 7 shows estimates of heritability at weaning of different traits in bulls, steers and heifers which generally indicate that heifers yield higher heritability estimates than do steers or bulls.

TABLE 7

ESTIMATES OF HERITABILITY AT WEANING IN BULL, STEER AND HEIFER CALVES
(CALCULATED FROM CORRELATION AMONG HALF-SIBS)

Author	Breed	Trait	Heritability Estimates[a]		
			Bulls	Steers	Heifers
Blackwell et al. (1962)	Hereford	Weaning Weight	--	0.08 ± (499)	0.31 ± (420)
Carter and Kincaid (1959)	--	180-day weight	--	0.08 ± (212)	0.69 ± (212)
Diven *et al.* (1960)	Hereford	230-day, liver vitamin A	0.44 ± .49 (-)	--	0.72 ± .62 (-)
Francoise, Vogt and Nolan (1973)[b]	Hereford	Weaning weight/day of age	0.49 ± .40 (-)	--	1.04 ± .55 (-)
	Angus	Weaning weight/day of age	0.76 ± .17 (-)	--	0.86 ± .16 (-)
Marlowe and Vogt (1965)	Angus	Weaning grade	0.27 ± .06 (1813)	0.37 ± .03 (4257)	0.39 ± .03 (6075)
	Hereford	Weaning grade	0.69 ± .08 (1324)	0.19 ± .03 (2802)	0.33 ± .03 (4153)
Pahnish *et al.* (1961)	Hereford	Weaning weight	0.28 ± .32 (329)	--	0.57 ± .41 (332)

TABLE 7 (continued)

Author	Breed	Trait	Heritability Estimates[a]		
			Bulls	Steers	Heifers
Pahnish *et al.* (1964)	Hereford	Weaning weight	0.05±.08 (370)	--	0.23±.13 (350)
Roberson *et al.* (1963)	Hereford	Weaning grade	0.08±.09 (-)	--	0.24±.14 (-)
Swiger *et al.* (1963)	Cross-bred	200-day weight	0.47±.16 (543)	-0.06±.14 (288)	0.42±.12 (740)

[a]Number of animals in study is presented in parentheses.

[b]Mixed (1108) bulls and (1442) heifers Hereford and Angus.

Heritability As A Tool of Selection

Heritability of body weight reported by Calo *et al.* (1973) to increase with age of animals from 6 to 30 months but to decline gradually thereafter. The trends for average daily gain and daily gain per 100 kg body weight were almost opposite those for body weight. The overall average estimate of heritability of body weight, average daily gain and daily gain per 100 kg body weight were 0.83, 0.44 and 0.46, respectively.

Swiger *et al.* (1963) reported estimates of heritability of weight to increase with increasing age of animals. They stated that the post-weaning gain was more highly heritable (0.65 ± 0.10) from 200 to 550 days in all calves of different sexes.

Various reported estimates of heritability of different traits in different sexes after weaning are listed in Table 8 which shows decreases in the differences in heritability estimates between sexes with increasing age of animals. Other studies have indicated the heritabilities differed between stage of maturity as well as between ages.

From four years' data on post-weaning rate of gain of 149 bull calves sired by 22 bulls, Dinkel (1958) estimated heritability of this trait for three periods post-weaning (140, 168 and 196 days). He found heritability estimates after adjustment for inbreeding of the individuals to be 0.45 ± 0.22, 0.52 ± 0.23 and 0.65 ± 0.25 for the 140, 168 and 196-day periods, respectively. He stated that since some of the calves were produced in single-sired inbred lines,

TABLE 8

ESTIMATES OF HERITABILITY AT POST-WEANING FOR BULL, STEER AND HEIFER CALVES (CALCULATED FROM CORRELATION AMONG HALF-SIBS)

Author	Breed	Trait	Heritability Estimates[a]		
			Bulls	Steers	Heifers
Blackwell _et al._ (1962)	Hereford	18-month weight	--	0.10± (499)	0.71± (420)
		Final weight	--	0.70± (499)	--
Carter and Kincaid (1959)	--	Post-weaning daily gain	--	0.38± (192)	0.54± (202)
Diven _et al._ (1960)	Hereford	350-day, liver vitamin A	0.20±.48 (-)	--	0.21±.53 (-)
Francoise, Vogt and Nolan (1973)[b]	Hereford	Yearling weight/day of age	0.65±.19 (-)	--	0.78±.18 (-)
	Angus	Yearling weight/day of age	0.06±.42 (-)	--	0.29±.49 (-)
Robenson _et al._ (1963)	Hereford	Yearling grade	0.04±.10 (-)	--	0.13±.11 (-)
Swiger _et al._ (1963)	Cross-bred	550-day weight	0.63±.19 (543)	0.37±.20 (288)	0.55±.13 (740)

[a]Number of animals in study is presented in parentheses.

[b]Mixed (780) bulls and (979) heifers Hereford and Angus.

these estimates may be biased because of the confounding of line effect and sire effect. He suggested further that by using the product of the heritability estimates and the phenotypic standard deviations for each period as a measure of the progress to be made, selection on the basis of 104-day gain would make 79% of the improvement expected from the use of 196-day gain and 84% of that expected using 168-day gain. However, selection on 140-day gain would be expected to make 94% of the improvement expected from selection on 168-day gain.

Averdunk (1968) studied heritabilities and phenotypic and genotypic correlations of weights at 140, 280, 364, 420 and 500 days of age, using 38 sire progeny groups of the Simmental breed with a total of 418 individuals involved. He found within-year-and station estimates of heritability of the weights to be 0.51, 0.91, 0.79, 0.65 and 0.46, respectively. Corresponding values for gain in different periods were 0.60 (141 to 500) and 0.81 (365 to 500). The genetic correlation between weight at 1 year and gain from 1 year until 500 days was -0.54. He suggested that high heritability estimates might be due to environmental correlations within progeny groups. Least-squares adjustments for height at withers of the dam within parity, year and station did not reduce heritability estimates. He suggested also that selecting on yearling weight would favor early maturing bulls with lower subsequent growth rates, while selection on 500-day-weight would favor bulls with a larger growing capacity.

Dinkel and Busch (1973) in a study involving 679 grade Hereford steers raised on 18 private ranches in South Dakota obtained estimates of heritability of beef traits and estimates of genetic correlations among traits and reported that final weight (adjusted yearling weight in breeding stock) was the single most important trait in a selection program to improve the production and carcass traits studied. They obtained a heritability estimate of 85% for final weight, which indicates that considerable progress can be made for this economically important trait through mass selection. They expected improvement in weaning weight, daily gain and carcass muscling because of the high positive genetic correlations between final weight and these traits.

Heritability of Body Dimensions

Body dimensions have been used as an indication of maturity of animals. Guilbert and Gregory (1952) showed that the linear skeletal growth increases faster and matures (maximizes) earlier than thickness growth. Thus, width of hooks and weight are later maturing than height and length. According to Hammond (1932), shortening and thickening of bones is associated generally with shortening and thickening of muscles, resulting in plump cuts of meat. McMeekan (1943) predicted grade accurately from the relation of thickness and length of cannon bone.

Estimates of heritability of body measurements have been used extensively in prediction and selection studies. Christian, Hauser and Chapman (1965) found estimates of heritability of body measurements at 6 to 12 months of age to be moderate to high, when variation in weight was not statistically controlled. However, Wilson *et al.* (1971) found low heritability estimates at slaughter when weight was physically and statistically controlled.

Wilson (1973), studying the heritability of body measurements at one and three days of age, reported heritability estimates for heart girth circumference, cannon circumference, hook width, rump length, body length, and cannon length to be 0.41 ± 11, 0.55 ± .12, 0.18 ± .08, 0.12 ± .07, 0.51 ± .12, and 0.46 ± .11, respectively, when the weight was not held constant. He reported also highly significant ($P < .01$) sex differences in all these measurements with the exception of cannon length.

Tyler *et al.* (1948) in a study to determine the heritability of body size as indicated by height at withers, circumference of shin bones, heart girth and width of hips of Holstein-Friesian cattle at different ages, and of body size as indicated by weight and height at withers of Ayrshire cattle at different ages also. They used intra-sire regressions of daughter's measurements on dam's measurements and parternal half-sib correlations to estimate heritability. They found approximately 15% of the variation in body size at six months, 35% to 65% at 18 months and between 30% and 60% at maturity to be attributable to heritability differences between individual Holstein-Friesians. The heritability estimate for the Ayrshire were 20% to 35% at 12 months, 20% to 40% at 18 months and 15% to 30% at 36 months of age. They stated that these results indicate that selection for body size in dairy cattle could be effective in changing body size in subsequent generations.

Published estimates of heritability of body measurements of beef cattle and dairy cattle from as early as 1933 to as recently as 1973 are shown in Table 9.

VI. PRESENT STATUS OF KNOWLEDGE IN THIS AREA

The level of nutrition early in the life of an animal has a great influence on growth. It is well accepted today that growing heifers should be fed on a moderately low plane of nutrition to prevent any adverse effects of excessive fat deposition on a high plane of nutrition might have on future milking and reporductive abilities. Restricted feeding during the first year of life, however, has shown its effects, such as lower body weight, smaller body size and possibly slower growth up to four or five years of age, as compared to animals which are not restricted.

Sire effects on performance with respect to several traits have been well established. Researchers have generally agreed on the order of magnitude of heritability of most beef cattle traits, and it appears that post-weaning growth traits are about twice as heritable as pre-weaning traits because of considerable maternal environmental variance in pre-weaning traits.

Sex effects on growth are known to be important and consistent. It is well known that, in general, heifers, bulls and steers are different in almost all economic traits and carcass characteristics.

TABLE 9

ESTIMATES OF HERITABILITY OF BODY MEASUREMENTS

Author	Breed	Number of Observations	Basis of Estimate[a]	Trait					
				Body Length	Heart Girth	Wither Height	Hip Height	Hook Width	Chest Depth
Brown (1958)	Angus calves	212	(3)	0.00	0.06	0.38	--	0.32	0.17
	Hereford calves	255	(3)	0.10	0.44	0.29	--	0.15	0.33
Brown and Franks (1964)	Hereford and Angus calves	74	(2)	0.48	0.46	0.41	0.69	0.11	0.71
Gowen (1933)	Jersey cows	6,000	(1)	0.68	0.65	0.60	--	0.81	0.61
Johnson (1958)	Holstein cows	128	(2)	0.77	--	0.76	--	0.21	--
Schutte (1935)	Cross-bred	176	(2)	0.48	0.34	0.76	--	0.62	0.20
Touchberry (1951)	Holstein cows	187	(2)	0.58	0.61	0.73	--	--	0.80
Wilson (1973)	Cross-bred	471	(3)	0.51	0.41	--	--	0.18	--

[a]Basis of estimate: (1) = Parent-offspring correlation.
(2) = Intra-sire regression of offspring on dam.
(3) = Paternal half-sib correlation.

In studying sex differences, previous workers have observed large differences; however, they have included no consideration of differences between sexes with respect to variances and variance components.

Information as to the importance of sire-sex interaction is needed in order to make valid use of information on both sexes of progeny in bull testing. Findings of studies of this phenomenon are not in complete agreement as to whether or not the sire-sex interaction is a significant source of variation among animals. However, the majority of the workers have concluded that this source of variation is not significant and not practically important. If this is true, it is possible to judge rank sires by studying only one sex of their progeny and that phenotypic selection among heifers, which may be fed a restricted ration, can be effective, as well as that among bulls, which are usually fed on a higher plane of nutrition.

The majority of the studies reviewed have indicated estimates of heritability of some beef traits to be higher in heifers than in bulls or steers. Heritability estimates of various traits in all sexes tend to increase with increasing age of the animals as a result of declining maternal effects. No comparison of heritability estimates of body dimension traits of different sexes has been published. These traits have important implications in beef cattle breeding with the increasing attention being given to shape and composition as well as weight.

Sex differences in heritability of various traits, if these differences are real, need to be taken into account in determining the relative contributions of selection among males and selection among females to changes in a herd.

CHAPTER III

PRESENT STUDY

Source and Description of Data

Data used in this study was collected over a 6-year period (1968-1973) from the purebred Angus herd at the Plateau Experiment Station of The University of Tennessee. A general description of the foundation of the herd was given by Butts (1966).

Data on 858 calves were included. The calves were the offspring of 85 sires over the 6-year period. Total number of calves, number of bull calves, number of heifer calves and number of sires in each year are shown in Table 10. The following variables were recorded on each animal at weaning (average of 231 days of age) and after post-weaning feeding (average of 365 days of age):

1. Body Weight (actual) (BW)
2. Type Score (T)
3. Condition Score (C)
4. Average Daily Gain (ADG)
5. Heart Girth (HG)
6. Body Length (BL)
7. Hip Width (HW)

Lifetime average daily gain (LTADG) was calculated by dividing the sum of both pre- and post-weaning gain by the total number of days from birth to the end of the post-weaning period.

TABLE 10

TOTAL NUMBER OF SIRES, CALVES, BULL CALVES AND HEIFER CALVES IN EACH YEAR

Year	Number of Sires	Number of Calves	Number Bull Calves	Number of Heifer Calves
1968	13	155	76	79
1969	12	120	59	61
1970	15	142	71	71
1971	14	137	77	60
1972	16	154	72	82
1973	15	150	79	71
Total	85	858	434	424

The total herd was maintained as three separate 60-cow, 4-sire groups. Mating of bulls and cows was planned to retard the increase in inbreeding. The age distribution of cows within mating groups was approximately the same in all mating groups.

Feeding and Management

The cows are bred to calve in January, February and March. The cow herd winters outside and receives hay and whatever pasture is available to them until about two to three weeks after calving when corn silage feeding is begun and continued until sufficient pasture is available. In years when quality of silage and hay is low, cows are supplied protein block during the winter feeding period.

Calves receive only their mother's milk and grass during the pasture period of about 225 days. After "weaning" data are collected, calves are left with their dams for about two weeks during which time some feed is supplied to get them accustomed to eating it before they are actually weaned.

After weaning, heifer calves are fed daily corn silage *ad libitum*, plus 2 pounds of hay, 2 pounds of grain and 1/2 pound of protein supplement. This wintering ration is designed to produce an average daily gain of no more than one pound which will be composed of very little fat and will consist mostly of growth. Post-weaning (yearling) data are collected in March. After April 1, the beginning of the breeding season, females in the herd receive no grain.

Bull calves after weaning are wintered on pasture with daily feeding of silage _ad libitum_, plus about 2 pounds of good hay and about one pound of a 14% protein, grain mixture per cwt of live weight.

Variables Recorded

Average daily gain was calculated for each stage by dividing the total gain for each animal by the number of days. Grades of Type and Condition were conventional subjective scores given by graders. Body dimensions were measured as described below:

1. Heart Girth (HG) - the distance along a tape drawn around the body immediately posterior to the shoulders.
2. Body Length (BL) - the distance along the back from the wither prominence to the posterior prominence of the pin bone.
3. Hip Width (HW) - the horizontal distance between the prominences of the hip bones.

Methods of Statistical Analysis

Nested within-year analyses were performed on these data. Least-square estimates of the effects of sex, sire (within year) and sire-sex (within year) interaction on the various traits were obtained. The following general additive model was used to describe the data:

$$Y_{ijk} = \mu + SE_i + S_j + (SE \times S)_{ij} + e_{ijk}$$

Where: Y_{ijk} = the observed value for an animal of the i^{th} sex in the j^{th} sire group.

μ = the overall mean of the population.

SE_i = effect of the i^{th} sex, i = 1, 2.

S_j = effect of the j^{th} sire, j = 1, 2, ..., 85.

$(SE \times S)_{ij}$ = effect of the interaction of the i^{th} sex and the j^{th} sire.

e_{ijk} = random error portion of an individual record.

In order to justify statistically the pooling of the data over the six-year period, Bartlett's test (Bartlett, 1937) of homogeneity of variance was conducted using the following formulas:

$$\chi^2 = 2.3026 \ [(\text{Log } \bar{s}^2) \sum_{i=1}^{6} (n_i - 1) - \sum_{i=1}^{6} (n_i - 1)(\text{Log } s^2)]$$

$$C = 1 + \frac{1}{3\ (a - 1)} \left(\sum_{i=1}^{6} \frac{1}{n_i - 1} - \frac{1}{\sum_{i=1}^{6} (n - 1)} \right)$$

$$\chi_C^2 = \frac{\chi^2}{C}$$

Where: χ^2 = the uncorrected Chi-Square.

2.3026 = the constant for (Log_e 10), because common logarithms were used.

s^2 = the mean square.

$$\bar{s}^2 = \sum_{i=1}^{6} \sum_{j=1}^{n_i} x_i^2 \Big/ \sum_{i=1}^{6} (n_i - 1)$$

Σx_i^2 = the sum squares.

$(n-1)$ = the degrees of freedom for each sample or year.

C = the correction factor.

a = the number of samples or years.

To test the level of significance of differences in variances between sexes, an F-test of variance components of pooled data for males and for females was conducted, by dividing the larger value for males or for females by the smaller one.

Components of variance due to sire differences were calculated by the following formula:

$$s_S^2 = \frac{\text{Sires mean square - error mean square}}{K_o}$$

Where: s_S^2 = variance due to sire differences.

K_o = average number of progeny per sire group.

The average number of progeny per sire (K_o) was calculated according to the conventional formula:

$$K_o = \frac{1}{S - 1} \left[K_. - \frac{\sum_{i=1}^{s} K_i^2}{K_.} \right]$$

Where: K_i = number of offspring of the i^{th} sire.

$K_. = \sum_{i=1}^{s} K_i$

S = number of sires

Heritability Estimates

Estimates of heritability were calculated for each sex separately, at weaning and at a year of age, using the method of half sib correlations. Sire variance components and error variance components were calculated for each sex. The following conventional formula was used to calculate the heritability estimate:

$$h^2 = \frac{4 \; s_S^2}{s_S^2 + s_W^2}$$

Where: s_S^2 = variance due to within-year sire differences

s_W^2 = variance due to differences between offspring of the same sire in the same year.

The model used to calculate each of the variances was:

$$Y_{ij} = \mu + S_i + e_{ij}$$

Where: Y_{ij} = the observed value for an offspring of the i^{th} sire group

μ = the overall mean of the population

S_i = within-year deviation of sire-group mean from μ

e_{ij} = random error portion of individual record.

The standard errors of heritability estimates were calculated according to the formula of Osborne and Patterson (1952):

$$\text{Standard Errors} = \sqrt{\frac{2\ (s_W^2)^2 \qquad \left[s_W^2 + K_o s_S^2\right]^2}{(s_W^2 + s_S^2)^4 \quad K_o \quad (K_\circ - S)}}$$

Where: s_W^2 = variance due to differences between offspring of same sire

s_S^2 = variance due to within-year sire differences

K_o = average numbers of progeny per sire group

$K_\circ$ = total number of offspring

S = number of sires

CHAPTER IV

RESULTS AND DISCUSSIONS

Bartlett's (1937) test of homogeneity of year variances was conducted to justify pooling over years the data used in this study. Table 11 shows the results of this test which indicate the homogeneity of variances of all the traits except one, post-weaning Condition Score. These differences mean that pooling of records on this trait over the six years is not statistically justified. However, since the weaning Condition Score was poolable, according to this test of homogeneity, post-weaning Condition Score also was pooled with the realization that any conclusions concerning this trait would have to be drawn cautiously because of apparent lack of homogeneity of year variances.

Nutrition Effects

Although differences between male and female performance were expected, the different levels of feeding of the two sexes certainly increased these differences over what they would have been had males and females been fed at the same level. The reason for feeding females less than males was to provide them with enough nutrients for growth without jeopardizing their future reproductive and milking abilities as a result of excessive fat deposition. Table 12 shows sex means. Average Daily Gain of males was higher than that of females, as expected.

TABLE 11

BARTLETT'S TEST OF HOMOGENEITY OF YEAR VARIANCES

Variables	χ^2 for Variances Tested	
	s_S^2	s_W^2
At Weaning		
Body weight (actual)	7.10	9.53
Type score	1.38	3.58
Condition score	3.96	6.56
Average daily gain	5.50	7.58
Heart girth	6.10	8.61
Body length	4.21	6.08
Hip width	2.48	2.70
At Post-Weaning		
Body weight (actual)	5.8	6.95
Type score	2.66	9.78
Condition score	16.35**	12.39*
Average daily gain	10.96	2.25
Heart girth	3.28	3.88
Body length	3.62	8.08
Hip width	8.35	7.06
Lifetime average daily gain	2.79	4.07

*$P < .05$

**$P < .01$

TABLE 12

OVERALL MEANS AND STANDARD ERROR OF VARIOUS TRAITS OF BULLS AND HEIFERS

Variable	Bulls		Heifers	
	Mean	± S.E.	Mean	± S.E.
At Weaning				
Body weight (actual) (lbs)	505.70	± 3.58	443.03	± 2.85
Type score[a]	12.76	± 0.05	12.66	± 0.05
Condition score[a]	8.54	± 0.03	9.19	± 0.05
Average daily gain (lbs)	1.92	± 0.01	1.65	± 0.01
Heart girth (inches)	54.19	± 0.17	52.54	± 0.16
Body length (inches)	37.07	± 0.13	36.39	± 0.12
Hip width (inches)	13.73	± 0.06	13.75	± 0.06
At Post-Weaning				
Body weight (actual) (lbs)	726.07	± 4.55	581.48	± 3.42
Type score	12.62	± 0.05	12.52	± 0.04
Condition score	9.17	± 0.06	9.05	± 0.05
Average daily gain (lbs)	1.43	± 0.02	0.90	± 0.01
Heart girth (inches)	63.30	± 0.15	59.28	± 0.16
Body length (inches)	42.14	± 0.10	39.94	± 0.13
Hip width (inches)	16.65	± 0.06	15.75	± 0.06
Lifetime average daily gain (lbs)	1.72	± 0.01	1.35	± 0.01

[a]9-11 Good; 12-14 Choice.

Sire Effects

The results of the analyses of variance of the weaning and post-weaning data on all traits studied (Tables 13 and 14) show highly significant sire effects. These results indicate that sire differences are of great importance and are in general agreement with those of other workers.

Sex Effects

Comparisons of the overall sex means of all traits are shown in Table 12. Bulls were heavier than heifers at both weaning and post-weaning. Average Daily Gain of bulls was higher than that of heifers 1.92 and 1.65 lbs., respectively. Type Score and body dimensions values also were larger for bulls than for heifers. Type Score and Hip Width at weaning were the only two traits for which heifers had larger values than did bulls. This seems logical since heifers mature faster than bulls. Analyses of variance shown in Tables 13 and 14 indicate the level of significance of differences between the two sexes. These differences were highly significant ($P < .01$) with respect to all traits but two, Type Score at both stages and Hip Width at weaning.

In addition to mean differences between bulls and heifers, sex differences in variances can be assessed by means of an F-test. Table 15 shows results of such tests for all traits studied, indicating highly significant ($P < .01$) differences between the sexes with respect to variances due to differences between offspring of the same sire (s_W^2). However, some of the sex differences in variances

TABLE 13

ANALYSIS OF VARIANCE OF TRAITS MEASURED AT WEANING

Source of Variation	Degrees of Freedom	Mean Square						
		BW	T	C	ADG	HG	BL	HW
Sex	1	625,514.59**	0.13	67.06**	10.88**	334.78**	86.05**	0.98
Sire/Year	79	9,706.82**	2.19**	1.14**	0.07**	27.21**	15.52**	3.70**
(Sire x Sex)/ Year	79	3,992.36	1.47**	1.05**	0.04	9.56	6.62	1.44
Error	698	3,894.76	1.01	0.67	0.04	10.69	6.20	1.62
Total	857							

*$P < .05$

**$P < .01$

TABLE 14

ANALYSIS OF VARIANCE OF TRAITS MEASURED AT POST-WEANING

Source of Variation	Degrees of Freedom	Mean Square							
		BW	T	C	ADG	HG	BL	HW	LTADG
Sex	1	3,462,344.64**	1.01	7.38**	48.79**	2,574.33**	800.97**	113.02**	22.56**
Sire/Year	79	14,606.64**	1.50**	2.63**	0.15**	18.02**	9.86**	3.40**	0.05**
(Sire x Sex)/ Year	79	7,207.70	0.78	1.31	0.14**	9.62	4.28	1.17	0.03
Error	698	5,937.99	0.89	1.32	0.08	9.87	5.89	1.55	0.03
Total	857								

*P < .05

**P < .01

TABLE 15

F-TEST OF SEX DIFFERENCES IN VARIANCES[a]

Variables	s_S^2	Numerator	s_W^2	Numerator	s^2	Numerator
At Weaning						
Body weight (actual)	1.16	F[b]	1.81**	M	1.57**	M
Type score	1.72*	F	1.11**	M	1.09**	F
Condition score	1.32	F	1.76**	F	1.98**	F
Average daily gain	6.65**	F	1.83**	M	1.52**	M
Heart girth	1.18	F	1.30**	M	1.18**	M
Body length	1.63*	F	1.39**	M	1.26**	M
Hip width	2.99*	F	1.12**	M	1.22**	F
At Post-Weaning						
Body weight (actual)	1.08	F	2.05**	M	1.48**	M
Type score	1.85*	F	1.36**	M	1.47**	M
Condition score	1.91*	F	1.26**	M	1.54**	F
Average daily gain	2.49**	M	2.31**	M	1.40**	M
Heart girth	1.04	F	1.51**	F	1.42**	F
Body length	24.95**	M	1.78**	F	1.74**	F
Hip width	1.03	F	1.18**	F	1.57**	F
Lifetime average daily gain	1.23	F	1.78**	M	1.35**	M

*P < .05.

**P < .01.

TABLE 15 (continued)

[a] s_S^2 = Variance due to sire differences (within year).

s_W^2 = Variance due to differences between offspring of the same sire (within year).

s^2 = Total variance (within year).

[b] F represents female and M represents male. These letters indicate which sex yielded the larger variance component which was the numerator of the F ratio calculated.

due to sire differences (s_S^2) were not significantly (P > .05) different. All of the sex differences in total variance (s^2) were highly significant (P < .01).

Sire-Sex Interaction

The results indicate that sire-sex interactions are generally not significant and of little practical importance in all traits studies in both stages except for the traits Type and Condition measured at weaning and Average Daily Gain at post-weaning (Tables 13 and 14). These non-significant interactions are in agreement with the results obtained by Knapp and Phillips (1942); Kroger and Knox (1945); Bradley _et al_. (1966); Tanner _et al_. (1970) and Thrift _et al_. (1970) but contrary to those of Suess _et al_. (1966); and Wilson _et al_. (1967). The lack of significant sire-sex interactions in almost all the traits studied suggests that we can easily judge any sire for any trait by studying some of his offspring without paying attention to their sexes so long as sex differences are removed by appropriate adjustment. The significant interactions in the case of Type and Condition measured at weaning and Average Daily Gain measured at post-weaning probably caused either by a small number of sires or small numbers of offsprings of one sex resulting in a change reverse in rank of the two sexes. Tables 17, 18 and 19 in the Appendix show traits which have shown significant interaction effects, numbers of sires which sired calves contributing to those interactions, numbers of sires which sired calves which did not contribute to interactions, average number of calves per sire of each sexes and the overall averages of males and females with respect to these traits.

Heritability Estimates

Estimates of heritability were calculated by quadrupling paternal half-sibs correlations based on the between-sire and within-sire components of variance calculated on a pooled within-year basis. The estimates of heritability in each sex and their standard errors are shown in Table 16. These results indicate that the estimate of heritability at weaning were higher for heifer calves than for bull calves for all the traits studied except Condition Score. Several of these indicated sex differences in estimates of heritability of the same trait are undoubtedly significant at low level of probability since values obtained by adding twice the standard error to the smaller estimate and subtracting twice the standard error from the larger estimate would still be appreciably different. For the post-weaning stage, estimates of heritability were higher for heifers than for bulls for Body Weight, Type Score, Condition Score and Average Daily Gain, and higher in bulls than in heifers for body dimension traits. These results which indicate the higher heritability in heifer calves than in bull calves are in agreement with results of Guilbert and Gregory, 1952; Brown *et al.*, 1956; Synar, 1958; Carter and Kincaid, 1959; Diven *et al.*, 1960; Pahnish *et al.*, 1961; Blackwell *et al.*, 1962; Robenson *et al.*, 1963; and Pahnish *et al.*, 1964. These results suggest that heifers yield higher heritability estimates in most cases, except for body dimension

TABLE 16

ESTIMATES OF HERITABILITY* (AND THEIR STANDARD ERRORS) OF BULLS AND HEIFERS AT DIFFERENT AGES

Variables	Bulls $h^2 \pm$ S.E.	Heifers $h^2 \pm$ S.E.
At Weaning		
Body weight (actual)	.45 ± .04	.84 ± .03
Type score	.40 ± .04	.69 ± .04
Condition score	.51 ± .04	.39 ± .04
Average daily gain	.05 ± .05	.55 ± .04
Heart girth	.45 ± .04	.64 ± .04
Body length	.41 ± .04	.80 ± .04
Hip width	.47 ± .05	.66 ± .04
At Post-Weaning		
Body weight (actual)	.48 ± .04	.91 ± .03
Type score	.13 ± .01	.30 ± .05
Condition score	.27 ± .04	.56 ± .01
Average daily gain	.22 ± .14	.29 ± .04
Heart girth	.36 ± .00	.31 ± .01
Body length	.46 ± .04	.01 ± .01
Hip width	.40 ± .04	.31 ± .01
Lifetime average daily gain	.25 ± .04	.52 ± .09

*Heritabilities calculated from 434 bulls and 424 heifers sired by 85 bulls over a 6-year period.

traits at post-weaning and that heifer progeny may provide more effective genetic discrimination between sires than would bull progeny at early ages of the calves. According to Table 16, it seems that heifers, in general, yield higher heritability estimates, especially at weaning. These differences, however, were smaller at post-weaning, and even reversed for body dimension traits for which bulls yielded higher estimates of heritability than did heifers at post-weaning. Possible explanation for this is the fact that heifer calves mature physiologically faster than bull calves, and therefore, at early ages, they express genetic differences to a greater extent than do bull calves.

The estimates of heritability of Average Daily Gain and Body Weight at weaning as calculated in this study are probably greatly different from true heritability, the parameter of which they are supposedly estimates. In studies in which accurate estimation of heritability is the primary objective, adjustments to remove average effects of age at weaning are usually applied before estimation of heritability. Any confounding of sire and age of calves would affect heritability estimates calculated from non-age-adjusted data such as those used here. If such confounding exists, erroneous estimates of variance due to sire differences (s_S^2) would be obtained.

Many beef cattle selection programs are now placing increased emphasis on yearling performance variables such as Average Daily Gain from birth to a year of age. This trait is the single criterion of selection in the breeding project which yielded the data used in this study. The apparent higher heritability of this trait in heifers than in bulls as indicated in Table 16, page 55, may mean that the contribution to improvement from selection among heifer is actually appreciable, as compared to the contribution from selection among bulls, in spite of the much smaller selection differential in heifers than in bulls.

CHAPTER V

SUMMARY

The objective of this study was to assess the relative importance of sire differences, sex differences and sire by sex interaction influence on variation among individuals in various recorded variables and to estimate the heritability of these variables.

Data were obtained from 858 Angus calves sired by 85 sires over a period of 6 years (1968-1973) from the purebred Angus herd at the Plateau Experiment Station of The University of Tennessee. The traits recorded on each animal at weaning (at an average age of 231 days) and after post-weaning feeding (at an average age of 385 days) were Body Weight, Type Score, Condition Score, Average Daily Gain, Heart Girth, Body Length and Hip Width. Lifetime (to a year of age) average daily gain also was calculated. Restricted feeding of heifer calves and full feeding of bull calves were followed during the post-weaning period. Heifers were restricted to prevent the excessive fattening which can occur on a high plane of feeding from jeopardizing their future reproductive and milking abilities.

Nested within-year analyses were performed on these data. Least-square estimates of the effects of sex, sire (within year) and sire-sex (within year) interaction on the various traits were obtained. Results showed highly significant sire effects on all

the traits studied. Sex effects also were highly significant ($P < .01$) with respect to all traits but two, Type Score measured at both stages and Hip Width at weaning. Sire by sex interaction effects were non-significant in all traits except for Type and Condition Scores measured at weaning and Average Daily Gain at post-weaning. These interactions, however, were probably due to sampling because of a small number of sires or a small number of progeny per sire. Bartlett's test of homogeneity of variance was conducted in order to justify statistically the pooling of the data over the six-year period. Results of the test indicate homogeneity of variances of all traits except one, Condition Score at post-weaning. Level of significance of differences in variances between sexes was tested by a simple F-test, using variance components of pooled data for each sex. This test showed highly significant ($P < .01$) sex differences with respect to variances due to differences between offspring of the same sire (s_W^2). However, some of the sex differences in variances due to sire differences (s_S^2) were not significantly ($P > .05$) different. All of the sex differences in total variance (s^2) were highly significant ($P < .01$).

Heritability estimates were calculated for each sex separately, at weaning and at a year of age, using the method of half-sib correlations. The results indicate higher heritability estimates in heifers than in bulls which suggests that heifer progeny provide more effective genetic discrimination between sires than would bull progeny at early ages of the calves and that selection among females may be more nearly as effective as that among males than is usually believed, the higher heritability in females offsetting, to some extent, the lower intensity of selection among females as compared to that among males. In general, data from heifers yielded higher heritability estimates, especially at weaning. These differences, however, were smaller at post-weaning and even reversed in the case of body dimension traits for which post-weaning data from bulls yielded higher estimates of heritability than did post-weaning data from heifers.

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APPENDIX

APPENDIX

TABLE 17

AVERAGE NUMBER OF CALVES, MALES AND FEMALES PER SIRE, WITH THEIR AVERAGES FOR TYPE SCORE MEASURED AT WEANING

	Bull Calves		Heifer Calves	
Sire	Mean	Number of Calves	Mean	Number of Calves
1 a	11.75	4	12.00	4
2	12.75	2	11.25	2
3	11.86	9	11.11	11
4	11.91	6	11.50	5
5	12.16	3	12.00	5
6 a	12.31	8	13.00	2
7 a	12.25	10	12.45	11
8	12.18	8	12.10	5
9 a	11.83	6	12.16	3
10	12.59	6	12.58	17
11	12.26	4	12.25	4
12 a	11.83	3	12.25	2
13 a	11.50	7	12.68	8
14	12.50	3	11.37	4
15 a	11.58	6	11.72	9
16	12.50	4	12.20	5
17	11.75	5	11.75	4
18	11.50	2	11.50	1
19 a	11.75	4	11.96	14
20	12.80	5	12.75	4
21	11.71	7	11.00	3
22 a	13.00	7	13.25	4
23 a	12.91	6	13.00	10
24	12.10	5	11.00	1
25	12.60	5	11.75	2
26	14.00	4	13.08	6
27	14.00	5	13.14	7
28	13.50	5	12.66	6
29	13.62	4	13.22	9
30	13.42	7	13.37	4
31	13.20	5	13.00	1
32	12.42	7	12.00	3
33	14.00	7	13.50	5
34 a	13.70	5	14.00	6
35 a	12.80	3	13.66	3
36 a	13.00	4	14.41	6

TABLE 17 (continued)

Sire		Bull Calves Mean	Bull Calves Number of Calves	Heifer Calves Mean	Heifer Calves Number of Calves
37	a	12.87	4	13.08	6
38		14.14	7	12.00	3
39		12.50	1	13.16	3
40		14.00	3	14.00	3
41	a	12.60	5	13.00	2
42		13.12	8	10.77	9
43		13.00	2	12.35	7
44		12.27	11	12.12	4
45	a	13.05	10	13.33	3
46	a	12.30	5	12.55	9
47	a	12.50	6	12.83	6
48	a	12.83	3	12.90	5
49	a	12.37	4	12.66	3
50	a	13.00	2	14.00	1
51	a	11.40	5	12.75	2
52		13.00	4	11.66	3
53	a	12.88	9	13.60	5
54		13.66	3	13.50	1
55	a	13.08	6	13.21	7
56	a	14.00	1	15.00	1
57	a	13.10	5	13.66	3
58		12.50	2	12.11	9
59		13.00	4	12.85	7
60		13.42	7	13.08	6
61		12.87	4	12.50	2
62	a	12.20	5	12.50	3
63		13.20	5	13.07	7
64		14.00	2	13.12	4
65		13.30	5	12.41	6
66		13.74	6	13.12	8
67		13.10	5	12.77	9
68		13.62	4	12.83	6
69		12.80	5	12.50	2
70		13.66	6	12.75	2
71	a	11.75	4	13.00	3
72		13.61	9	13.41	6
73		13.00	3	11.87	4
74		13.40	5	13.00	3
75	a	13.18	8	13.40	5
76		12.71	7	12.75	4
77		12.90	5	11.80	5
78		12.75	2	12.75	4

TABLE 17 (continued)

Sire		Bull Calves		Heifer Calves	
		Mean	Number of Calves	Mean	Number of Calves
79	a	13.25	6	13.50	5
80		13.20	5	13.20	5
81		12.88	9	12.50	2
82	a	13.00	3	13.42	7
83	a	12.50	3	12.87	4
84	a	12.00	2	12.60	10
85	a	12.81	8	13.37	4

[a]Represents reversed ranking for the trait.

Bulls overall mean = 12.76; heifers overall mean = 12.66.

TABLE 18

AVERAGE NUMBER OF CALVES, MALES AND FEMALES PER SIRE, WITH THEIR AVERAGES FOR CONDITION SCORE MEASURED AT WEANING

	Bull Calves		Heifer Calves	
Sire	Mean	Number of Calves	Mean	Number of Calves
1	8.50	4	10.00	4
2	9.00	2	9.50	2
3	8.61	9	8.90	11
4 a	8.75	6	8.50	5
5	8.66	3	10.00	5
6	8.75	8	9.50	2
7	8.55	10	9.63	11
8	8.18	8	9.40	5
9	9.08	6	10.00	3
10	8.66	6	9.20	17
11	8.50	4	9.37	4
12	9.16	3	10.00	2
13	8.85	7	9.75	8
14	8.50	3	9.62	4
15	9.08	6	9.05	9
16 a	9.25	4	9.10	5
17	8.70	5	8.75	4
18 a	8.50	2	8.00	1
19 a	9.25	4	8.74	14
20	8.40	5	9.37	4
21	8.64	7	9.33	3
22	8.57	7	9.37	4
23	8.83	6	9.40	10
24	8.70	5	12.00	1
25	8.90	5	11.00	2
26	8.37	4	9.33	6
27	8.30	5	9.57	7
28	8.70	5	9.58	6
29 a	9.62	4	9.33	9
30	8.14	7	8.50	4
31	7.70	5	9.00	1
32	7.71	7	9.50	3
33	8.14	7	9.10	5
34	8.10	5	8.91	6
35	7.83	3	8.50	3
36	8.12	4	9.66	6

TABLE 18 (continued)

Sire		Bull Calves Mean	Bull Calves Number of Calves	Heifer Calves Mean	Heifer Calves Number of Calves
37		8.00	4	8.50	6
38	a	7.92	7	9.50	3
39		8.50	1	7.66	3
40		8.16	3	8.83	3
41		8.30	5	11.00	2
42		8.00	8	9.55	9
43		8.25	2	8.92	7
44		8.45	11	8.62	4
45		8.10	10	10.16	3
46		8.20	5	8.83	9
47		9.00	6	9.08	6
48		8.83	3	9.20	5
49		8.00	4	11.16	3
50		9.00	2	10.00	1
51		8.20	5	9.25	2
52		7.62	4	8.33	3
53		8.05	9	9.40	5
54	a	8.50	3	8.00	1
55		8.58	6	9.50	7
56		9.00	1	9.00	1
57		7.70	5	8.83	3
58	a	9.50	2	9.44	9
59		8.00	4	8.50	7
60		8.42	7	9.00	6
61		8.37	4	9.00	2
62		8.50	5	8.50	3
63		8.30	5	8.71	7
64		8.25	2	9.12	4
65		8.40	5	8.91	6
66		7.91	6	8.87	8
67	a	8.60	5	8.55	9
68		8.50	4	8.66	6
69		8.50	5	9.50	2
70	a	8.83	6	8.75	2
71		8.00	4	8.83	3
72		8.83	9	9.58	6
73	a	9.00	3	8.00	4
74		8.80	5	9.16	3
75		9.12	8	9.40	5
76		9.35	7	9.50	4
77	a	9.10	5	8.50	5
78		8.50	2	8.87	4

TABLE 18 (continued)

Sire	Bull Calves Mean	Bull Calves Number of Calves	Heifer Calves Mean	Heifer Calves Number of Calves
79	9.33	6	9.80	5
80	8.90	5	9.30	5
81 a	9.44	9	8.50	2
82	9.33	3	9.57	7
83	8.33	3	9.12	4
84	8.50	2	9.30	10
85	8.75	8	10.00	4

[a]Represents reversed ranking for the trait.

Bulls overall mean = 8.54; heifers overall mean = 9.19.

TABLE 19

AVERAGE NUMBER OF CALVES, MALES AND FEMALES PER SIRE, WITH THEIR AVERAGES, FOR AVERAGE DAILY GAIN MEASURED AT POST-WEANING

Sire		Bull Calves		Heifer Calves	
		ADG	Number of Calves	ADG	Number of Calves
1		1.44	4	.93	4
2		1.97	2	.72	2
3		1.78	9	.94	11
4		1.40	6	.93	5
5		1.32	3	.96	5
6		1.39	8	.83	2
7		1.50	10	1.03	11
8		1.18	8	.86	5
9		1.48	6	.88	3
10		1.47	6	.95	17
11		1.58	4	.97	4
12		1.50	3	.89	2
13		1.26	7	.95	8
14		1.67	3	.97	4
15		1.34	6	.78	9
16		1.36	4	.65	5
17		1.34	5	.97	4
18		1.38	2	.90	1
19		1.20	4	.73	14
20		1.56	5	1.05	4
21		1.31	7	.75	3
22		1.37	7	.99	4
23		1.39	6	.91	10
24		1.48	5	.67	1
25		1.62	5	.80	2
26		1.30	4	1.21	6
27		1.17	5	1.04	7
28	a	1.03	5	1.09	6
29	a	1.07	4	1.09	9
30	a	1.10	7	1.21	4
31	a	0.90	5	1.05	1
32		.95	7	.83	3
33	a	.95	7	1.16	5
34	a	1.04	5	1.10	6
35	a	.95	3	1.03	3
36	a	1.07	4	1.10	6

TABLE 19 (continued)

Sire	Bull Calves ADG	Bull Calves Number of Calves	Heifer Calves ADG	Heifer Calves Number of Calves
37 a	1.01	4	1.11	6
38	1.10	7	.93	3
39	1.15	1	1.02	3
40 a	1.21	3	1.23	3
41	1.49	5	.63	2
42	1.69	8	.77	9
43	1.73	2	.96	7
44	1.67	11	.77	4
45	1.75	10	.91	3
46	1.74	5	.91	9
47	1.81	6	.78	6
48	1.65	3	.79	5
49	1.63	4	1.00	3
50	1.88	2	.72	1
51	1.69	5	.79	2
52	1.73	4	.48	3
53	1.79	9	.78	5
54	1.80	3	.91	1
55	1.95	6	.99	7
56	1.86	1	.66	1
57	2.00	5	.69	3
58	1.67	2	.64	9
59	2.02	4	.75	7
60	1.86	7	.66	6
61	1.95	4	.72	2
62	1.77	5	.39	3
63	1.59	5	.97	7
64	1.48	2	.84	4
65	1.71	5	.79	6
66	1.70	6	.63	8
67	2.11	5	.81	9
68	1.71	4	.90	6
69	2.06	5	.74	2
70	1.68	6	.91	2
71	1.29	4	.93	3
72	1.07	9	1.17	6
73	1.34	3	.92	4
74	1.31	5	.91	3
75	1.08	8	.78	5
76	1.25	7	.92	4
77	1.52	5	.62	5
78	1.43	2	.88	4

TABLE 20

COEFFICIENTS OF SIMPLE CORRELATION BETWEEN TRAITS STUDIED

	BW	T	C	ADG	HG	BL	HW	BW	T	C	ADG	HG	BL	HW	LTADG
At Weaning															
T	0.50														
C	0.18	0.06													
ADG	0.74	0.36	0.11												
HG	0.79	0.51	0.20	0.52											
BL	0.65	0.55	0.12	0.42	0.79										
HW	0.57	0.51	0.19	0.32	0.77	0.81									
At Post-Weaning															
BW	0.84	0.35	-0.01	0.68	0.58	0.45	0.33								
T	0.34	0.44	0.13	0.26	0.37	0.39	0.34	0.30							
C	0.32	0.17	0.10	0.27	0.30	0.21	0.30	0.31	0.11						
ADG	0.33	0.10	-0.27	0.33	0.19	0.13	0.02	0.78	0.14	0.25					
HG	0.73	0.31	0.07	0.57	0.54	0.38	0.28	0.86	0.25	0.28	0.66				
BL	0.58	0.30	0.05	0.49	0.44	0.47	0.34	0.62	0.37	0.10	0.39	0.36			
HW	0.68	0.37	0.10	0.45	0.61	0.58	0.53	0.67	0.34	0.17	0.40	0.49	0.69		
LTADG	0.70	0.31	-0.10	0.78	0.49	0.39	0.27	0.92	0.27	0.35	0.83	0.78	0.56	0.56	1.00

VITA

Moyassar Yehya Al-mallah was born in Mosul, Iraq, on January 18, 1944. He graduated from Al-Sharkia High School in June 1963. The following fall he entered the Agricultural College of the University of Mosul, and on June 7, 1968, he received his Bachelor of Science Degree with a major in Animal Science. He worked with the Ministry of Agrarian Reform from July 28, 1968 to December 23, 1971.

On December 29, 1971, he arrived in Knoxville, Tennessee to begin work toward the Master of Science Degree and then the Doctor of Philosophy Degree in Animal Science with Beef Production being his field of special interest. He entered the Graduate School of The University of Tennessee in January 1972, and received the Master of Science Degree in June 1973. He started his work toward the Doctor of Philosophy Degree in June of the same year and received it in March 1975.

He is a member of the Honor Society of Agriculture (Gamma Sigma Delta).