MULTIVARIATE EVALUATION OF PHENOTYPIC RELATIONSHIPS AMONG HEIFERS' EARLY PERFORMANCE AND SUBSEQUENT PRODUCTIVITY IN HEREFORD AND ANGUS CATTLE

By

MICHAEL ADRIAN BROWN

Bachelor of Science
Oklahoma State University
Stillwater, Oklahoma
1972

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1974

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
December, 1976

Thesis
1976D
B879m
cop. 2

OKLAHOMA STATE
UNIVERSITY
LIBRARY

MULTIVARIATE EVALUATION OF PHENOTYPIC
RELATIONSHIPS AMONG HEIFERS' EARLY
PERFORMANCE AND SUBSEQUENT
PRODUCTIVITY IN HEREFORD
AND ANGUS CATTLE

Thesis Approved:

Richard R Frahm
Thesis Adviser

Rodger K. Johnson

Robert D Morrison

J Leroy Folks

Ronald W. McNew

Joe V Whiteman

Norman N Durham
Dean of the Graduate College

997226

ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to Dr. R.R. Frahm, professor of animal science, for his excellent guidance and counsel throughout the course of this study and throughout my graduate training.

Special appreciation is also extended to Dr. J.V. Whiteman, professor of animal science, and to Dr. R.K. Johnson, associate professor of animal science, for their advice and encouragement throughout my graduate program.

The author is very grateful to Dr. J.L. Folks, professor of statistics and chairman of the department of statistics, Dr. R.W. McNew, associate professor of statistics, and Dr. R.D. Morrison, professor of statistics, for their help during this study and during my graduate training.

Special appreciation is extended to Dr. D.L. Weeks for his input into this study and for his encouragement.

A special thanks goes to the author's wife, Sherry, and son, Danny, for the patience, understanding and encouragement given during both undergraduate and graduate training.

The author is deeply indebted to Melita Wyatt and Carol Taylor for expertly typing this thesis, devoting their free time to do so.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page
	103

Table Page

Table		Page

Table | Page

Table Page

CHAPTER I

INTRODUCTION

An important aspect of the cow-calf industry is productivity of the brood cows as measured by the weaning weights or preweaning gains of their calves. It would be advantageous to identify, at an early age the the production potential of cows so that those likely to be low producers can be culled from the herd.

Reliable prediction of cow productivity depends largely on the relationship between traits measurable on the cow and performance of the calves and the relationship of calf performance during early lactations and lifetime calf performance. The higher these relationships, the more accurate the lifetime production potential of replacement heifers and young cows can be predicted.

Thus far efforts to develop effective predictors of cow productivity have been difficult. Previous studies have generally indicated a low association between cow prebreeding traits and subsequent productivity. This could be due to an antagonistic relationship between cow prebreeding environment and subsequent maternal ability, an antagonistic relationship between direct genetic effects on weaning weight and maternal additive effects or both of these factors.

Cow productivity is a complex trait determined by a large number of factors, many of which may be correlated. More sophisticated statistical techniques than have been used in the past may lead to some improvement in the quest for reliable techniques for identifying poor producing cows among replacement heifer candidates or among young cows.

Simultaneous consideration of cow traits and subsequent productivity can be made using multivariate statistical methods. One approach to the problem of a low association between early cow performance and later productivity would be to consider the early cow performance traits simultaneously. Thus, it may be possible to increase the association between early cow performance and subsequent productivity or perhaps more accuractely classify cows into productivity groups based on early performance.

The intent of this research study was to investigate early identification of lifetime productivity of cows as measured by weaning traits of their calves. Thus, the objectives of this study were:

1. To find and evaluate linear combinations of cows traits from birth to yearling and calf weaning traits through the use of principal component analyses that might be useful in predicting productivity or characterizing associations between heifer growth and subsequent productivity.
2. To characterize the phenotypic dependency structure among measures of growth and performance in heifers and measures of growth in the heifers' calves through development of canonical correlations between heifers' growth and performance and growth of their calves.
3. To develop and evaluate procedures to identify, at as early an age as possible, cows that are potentially above herd average in lifetime productivity as measured by weaning weight of calves through the use of discriminant analyses

and multiple linear regression techniques.

4. To determine the extend of differences that may exist between Angus and Herefords in terms of procedures and the accuracy of predicting lifetime productivity potential.

CHAPTER II

REVIEW OF LITERATURE

Sources of Variation in Beef Cattle Performance

Phenotypic differences among beef cattle can be greatly influenced by genetics and environment. Some common sources of genetic and environmental variation are location, breed, year of birth, age of dam, sex and the interaction among these sources.

Herds of cattle may be of different breeds, located in geographically and/or climatically different regions and subject to different management schemes. The use of intraherd analyses have been recommended, where appropriate, to correct for known sources of variability specific to that herd (Dickerson, 1940; Gregory et al., 1950; Kieffer, 1959; Brown, 1960; Swiger et al., 1962; Drewry, 1964; Thompson and Marlowe, 1971). It is important to identify important sources of variation in performance and develop correction factors to adjust the performance records in order to make more accurate comparisons between individuals and groups.

Differences in age of dam at time of partuition due to differences in size, physiological maturity and maternal ability, have been shown to be an important source of variability for many of the beef traits studied. In general, two-, three-, and four-year old dams have been shown to be lower in maternal performance and thus produce calves that have reduced growth performance.

Differences in years have also been shown to be important sources of variation in beef cattle traits. Differences in years are due to differences in environmental factors such as temperature and moisture, differences in management in a given year and difference in the composition of the population in question.

Sex differences have also generally been reported to be a significant source of variation in performance traits. Heifers are generally reported to be lower in performance than bulls and steers, whereas differences between bulls and steers are more variable due to selective castration due to body size.

The interactions among year, age of dam and sex are potentially important sources of variability in beef cattle data. If large year by age of dam or year by sex interactions were operational then this would suggest that correction for age of dam or sex would have to be made using data from a given year. This is undesirable, since the estimates of correction factors would generally be based on relatively small numbers and subject to greater sampling effects. Interactions between age of dam and sex would necessitate estimation of correction factors for sex for each age of dam or correction factors for age of dam for each sex.

Knapp et al. (1942), in one of the initial studies of sources of variability in beef cattle, found significant age of dam effects on weaning weight in a Montana study of Hereford cattle. The maximum weaning weights were reported in six-year old cows. Koger et al. (1962), in a Florida study with 4,729 calves, also reported significant age of dam effects on weaning weight. Calves from younger ages of dams were lighter at weaning.

Brinks et al. (1961) reported significant sex effects for birth weight, preweaning gain and weaning weight in a study with 9,766 Hereford calves. There was little difference between bulls and steers but heifers were lower than either bulls or steers.

Many studies have studied the importance of age of dam and sex effects simultaneously and have found them to be important sources of variation in many beef cattle traits. Age of dam and sex have been found to be important sources of variation in birth weight (Koch and Clark, 1955, 5,952 Herefords from Montana; Swiger et al., 1962, 2,739 Angus and Herefords from Nebraska), weaning weight and/or preweaning gain (Rollins and Guilbert, 1954, 159 Herefords from California; Evans et al., 1955, 1,737 Herefords from Illinois; Koch and Clark, 1955; Marlowe and Gains, 1958, 6,173 Angus, Herefords and Shorthorns from Virginia; Minyard and Dinkel, 1960, 2,351 Angus and Herefords from South Dakota; Swiger, et al., 1962, 2,739 Angus and Herefords from Nebraska), weaning weight per day of age (Berg, 1961, 665 Angus from Canada) and weaning conformation (Koch and Clark, 1955). Koch and Clark (1955) found significant age of dam effects on preweaning gain and yearling weight but sex effects were considered unimportant for the traits. Marlowe and Gaines (1958) found significant age of dam effects on weaning grade but reported sex effects as unimportant.

Several studies have considered the effects of age of dam, year and sex simultaneously. Age of dam, year and sex have been found to be important sources of variation in birth weight (Swiger, 1961, 800 Herefords from Ohio; Chapman et al., 1972, 800 Polled Herefords from Mississippi; Kress and Burfening, 1972, 3,342 Herefords from Montana) weaning weights and/or preweaning gains (Burgess et al., 1954, 546 Herefords from Colorado; Clum et al., 1956, cattle from Florida; Brown, 1960, 739 Angus and Herefords from Arkansas; Swiger, 1961; Hamann et al., 1963, 1,861 Angus from Kansas; Muhmud and Cobb, 1963, 1,306 Herefords from Hawaii; Marlowe et al., 1965, 17,294 Angus and 11,663 Herefords from Virginia; Warren et al., 1965, 28,493 Angus, Hereford and Santa Gertrudis from Georgia, Cundiff et al., 1966a, 7,522 Hereford and 6,415 Angus from Oklahoma; Harwin et al., 1966, 1,627 Herefords from Colorado; Hohenboken and Brinks, 1969, 4,722 Angus from Wyoming; Sellers et al., 1970, 19,907 Angus and Herefords from Iowa; Tanner et al., 1970, 487 Angus from Oklahoma; Cardellino and Frahm, 1971, 1,226 Hereford and Angus from Oklahoma; Chapman et al., 1972; Kress and Burfening, 1972; Neville et al., 1974, 820 Herefords from Georgia; Bailey and Koh, 1974, 1,422 Herefords from Nevada), weaning conformation (Muhmud and Cobb, 1963; Marlowe et al., 1965), weaning condition (Chapman et al., 1972) and postweaning gain (Swiger, 1961). Tannery et al. (1970) found year and sex to be important sources of variation in preweaning gain, postweaning gain and yearling weight. Chapman et al. (1972) found significant year and age of dam effects for weaning grade but year was considered unimportant in explaining differences in postweaning gain or yearling weight. Kress and Burfening (1972) reported significant year and age of dam effects on cow yearling weight and significant year effects for postweaning gain, MPPA for birth weight and MPPA for weaning weight.

The interactions of year, age of dam and sex have also been studied in many research projects. Swiger (1961) found evidence of interactions between age of dam and year for weaning weight and post-weaning gain but no other possible two factor interactions were significant for these traits. There was also little evidence of any two factor interactions among year, age of dam and sex for birth weight. Cooper et al. (1965), in a Colorado study involving 6,147 Herefords, found evidence of interactions between year and age of dam and year and sex for weaning weight and weaning weight per day of age but little evidence of age of dam by sex interaction for weaning weight per day of age. Cundiff et al. (1966a), also found little evidence of an age of dam by sex interaction in Hereford weaning weights. Harwin et al. (1966), reported significant age of dam interactions with year and sex in Hereford weaning weights but reported year by sex interactions to be unimportant. Tanner et al. (1970), however, found significant year by sex interactions in Angus preweaning gain, weaning weights and yearling weight but not for postweaning gain. Bailey and Koh (1974) found significant interactions of age of dam with year and sex in one Hereford herd but not in another at a different location.

In general, year effects were important sources of variation for all traits considered. Only one study found nonsignificant year effects (Chapman et al., 1972, for postweaning gain and yearling weight) but there were only three years involved in the analyses of these traits. Age of dam was also consistently significant for the traits considered with a few exceptions. Tanner et al. (1970), reported age of dam non-significant for Angus preweaning gain, postweaning gain and yearling weight. However, the authors stated the age of dam approached significance in the case of preweaning gain and two-year old dams were not represented in the study. Kress and Burfening (1972) also reported age of dam as not significant for Hereford postweaning gain. However, the authors stated that the linear effect of age of dam was significant with heifers from younger ages of dam having higher postweaning gains. Generally in these studies, calves from younger ages of dams were lower in performance to weaning and demonstrated compensatory performance postweaning.

Sex effects were also generally considered important influences on beef cattle performance with a few exceptions. Rollins and Guilbert (1954) did not consider sex an important influence on Hereford birthweights but only 159 calves were involved in the study. Marlowe and Gaines (1958) and Chapman et al. (1972), reported that influences of sex on weaning conformation were small. No explanations were offered or apparent in either case. Generally, sex differences favored males whereas differences between bulls and steers were highly variable reflecting, perhaps, selective castration in some of the studies.

Interactions among year, age of dam and sex varied considerably among the studies. Interactions of age of dam or sex with year are possibilities with a large number of years involved in the studies. Importance of these effects should probably be ascertained for a given study. Age of dam by sex interactions were found only in two of the studies reviewed (Harwin et al., 1966; Bailey and Koh, 1974).

This literature review can be summarized as follows: (1) Year, ages of dam and sex have been shown to consistently exert an effect on preweaning traits of beef cattle. This implies that comparisons among calves across years, ages of dam and/or sex should be made using phenotypic values adjusted for these sources of variation. (2) Year, age of dam and sex effects have also been found for postweaning traits although the importance of age of dam and year effects was slightly less consistent throughout the literature. (3) Age of dam effects were consistently such that calves from younger ages of dam were not as high in performance as calves from older ages of dam. The greatest differences were generally found between two-, three-, and four-year old classes and the older ages of dam. (4) Sex effects were consistently in favor of bulls and steers as compared to heifers. Any differences between bulls and steers usually existed in preweaning traits but differences also occurred in postweaning traits. (5) Interactions among year, age of dam and sex were the least consistent of all effects in the literature. It would be advisable to estimate these effects in a given study to find their relative importance in explaining differences among traits in beef cattle.

Relationships Between Heifer Prebreeding Performance and Subsequent Productivity

A strong phenotypic association between one or more of the prebreeding traits measured on heifers and the weaning weights of their subsequent calves is imperative if potentially above average heifers are to be identified at an early age. It is the purpose of this portion of the literature review to generally establish the relationships found between heifers' prebreeding growth and the weaning weights of their calves. In addition, an abbreviated discussion will be given on dam offspring covariances, unless stated otherwise, data from reported research was adjusted for known sources of variability such as age of dam, year, and sex.

The genotypic covariance between a dam and her offspring was given by Willham (1963) as:

$$\text{Cov (Dam, Offspring)} = {}^{1}/_{2}\sigma^2_{A_0} + {}^{5}/_{4}\ \sigma_{A_0A_m} + \sigma_{D_0D_m} + {}^{1}/_{2}\ \sigma^2_{A_m}$$

where,

$\sigma^2_{A_0}$ = direct additive variance for offspring performance

$\sigma_{A_0 A_m}$ = additive covariance between direct effects for offspring performance and maternal effects

$\sigma_{D_0 D_m}$ = covariance between dominance deviations for offspring performance and maternal performance

$\sigma^2_{A_m}$ = additive variance for maternal effects.

It is apparent that if negative covariances exist between additive and/or dominance effects for direct and maternal effects then the covariance between a dam and her offspring could be negative. The covariance between additive direct and maternal effects for weaning weight has been estimated by several workers (Koch and Clark, 1955d; Hill et al., 1966; Deese and Koger, 1967; Hohenboken and Brinks, 1971; Veseley and Robison, 1971). All of these researchers found the covariance to be negative with an average value of approximately -.50.

On a phenotypic level, a negative environment covariance between maternal performance and subsequent offspring maternal performance could further complicate the relationship.

These effects could have a major influence on the relationship of heifers' early growth and subsequent productivity and should be considered when studying these relationships.

One of the initial studies concerned with the association of dam performance and offspring performance was conducted in Louisiana by Dawson et al. (1954). Weaning weight records from 111 Brahman-Angus cows and their 446 calves were studied. Weaning weights of calves were regressed on weaning weights of dams within sire of calf and within sire of dam. The resultant regression coefficients obtained were .02 and .08 for each study, respectively.

Phenotypic correlations between cow traits and calf traits were computed by Koch and Clark (1955c) from weaning weight records on 1,231 Hereford cows and their 4,234 calves and yearling weight records on 822 cows. This Montana study reported a correlation of .06 between cow and calf weaning weights. A correlation of .12 was reported between cow yearling weight and calf weaning weight. They suggested these results could be due to an unfavorable relationship between the genotype for maternal ability and the genotype for direct growth. In a companion paper Koch and Clark (1955d) presented theoretical arguments to support the conclusions of their previous study.

Rollins and Wagnon (1956) in a California study involving 91 Hereford cows and 271 calves reported relationships between cow and calf weaning weights. Approximately half of the cows and calves were on an adequate winter nutritional level and the other half were on a less than adequate level. Regression coefficients of calf weaning weight on cow weaning weight were .42 and -.06 for adequate and low nutritional levels, respectively. They concluded there was a possible association between maternal effects on calves and cow weaning weights that might bias these regressions.

In a Colorado study, Lindholm and Stonaker (1957) report a correlation of -.01 between cow weight at 18 months and calf weaning weight. Only 118 Hereford steers and their dams were used.

Brown (1958) reported on the results of a dam-offspring study involving 255 Hereford calves and their dams. Regression of dam weaning weight on each calf individually and the average of the calves resulted in coefficients of .002 and .28, respectively.

Marchello et al. (1960) in a Montana study involving records from 631 Hereford heifers and their first calf found a regression or weaning weight of first calf on 18-month weight of .18 and a correlation of .24 between cow 18-month weight and first calf weaning weight. Conclusions were drawn suggesting a low phenotypic relationship between cow 18-month weight and weaning weight of the first calf.

In a study involving records from 208 Missouri Hereford cows and their heifer calves, Sewell et al. (1963), found a regression coefficient of .04 for daughter on dam weaning weight and a correlation of .005 between the two traits.

Brinks et al. (1964), in a study involving 1,608 Herefords in Montana, reported on predicting the MPPA index. Paternal half-sib correlations were estimated among several cow traits. Phenotypic correlations reported between cow MPPA and cow weaning weight, yearling weight and 18-month weight were .09, .15 and .20, respectively. Genetic and environmental correlations between the same traits were .00, .14 and .25 and .13, .15 and .15, respectively. Phenotypic, genetic and environmental path coefficients (standardized partial regression coefficients) of cow MPPA on cow weaning weight, yearling weight and 18-month weight were also reported. These were, respectively: phenotypic -.08, .01, .31; genetic -.58, 0.04, .77 and environmental .01, -.02, .01. The authors concluded that 18-month weight was most closely associated with MPPA and there were indications of an antagonism between direct effects on preweaning growth and maternal effects as evidenced by the zero genetic correlation between cow MPPA and cow weaning weight.

In a Wisconsin study using 26 sets of identical and fraternal twin Hereford heifers and their 88 calves, Christian et al. (1965) investigated preweaning influences on weaning weight. Correlations were found between calf weaning weight and initial two-month milk production (.46), calf weaning weight and milk production from two to eight months (.48) and calf weaning weight and cow weaning weight (.07). Standardized partial regression coefficients of calf weaning weight on these same cow traits were -.10, .09 and .12, respectively. Correlations reported between cow weaning weight and calf preweaning gain to two months, initial two-month milk production and milk production from two to eight months were .07, -.10 and .20. This study suggested a negative genetic or environmental association between a dam's weaning weight and her subsequent maternal performance.

Hill et al. (1966), in a North Carolina study involving 141 Hereford cow calf pairs, estimated some of the different genetic components of weaning weight. It was found that genetic maternal effects were more important than the direct genetic effects and that an antagonistic covariance existed between direct and maternal additive effects on weaning weight.

Voght and Marlowe (1966), in a Virginia study, reported a large negative genetic correlation between preweaning gain and weaning grade. The authors interpreted this as evidence of a possible negative covariance between maternal ability and individual growth since regression of offspring on dam was used to estimate genetic parameters.

In similar studies, Deese and Koger (1967) and Vesely and Robison (1971) found evidence of negative correlations between additive direct effects and additive maternal effects. The first study involved preweaning gain and the second involved birth weight, weaning weight and weaning type score.

A review of research involving direct and maternal genetic associations prompted Cundiff and Gregory (1968) to conclude that a negative genetic or environmental correlation could exist between the weaning weight of the dam and her subsequent maternal performance.

A Nebraska study involving records of 613 cows in 115 granddam groups investigated the relationship between the early growth environment of a dam and the weaning weights of her calves (Koch, 1969). Regression of offspring weaning weight ratio on dam preweaning gain resulted in a regression coefficient of -12.4 which indicated that a negative relationship existed between dam early environment and weaning weights of her calves.

Ray et al. (1970), in an Arizona study involving performance data on 400 Hereford offspring, concluded that maternal performance is a larger influence on calf weaning weight than is the direct growth potential of the calves. They also concluded that a negative relationship between maternal performance and growth was a possibility and that bulls should be selected on different criteria than heifers.

In a New Mexico study involving 175 Hereford cows and 655 calves, Ellicot et al. (1970) reported a correlation of -.74 between means for cow weaning weight and means for cow MPPA where the means were cow age of dam means. A correlation of -.52 was reported between means for cow weaning weight and means for cow MPPA where the means were cow birth year means. A correlation of -.16 was found between cow weaning weight and MPPA. The authors concluded that a favorable preweaning environment for a cow was adversely related to her subsequent productivity.

Mangus and Brinks (1971) reported on a Colorado study involving relationships between heifer preweaning growth and subsequent productivity. Records included weaning weight MPPA and weaning weights of 610 Hereford cows that had produced 2,280 calves. Means for MPPA and cow weaning weights by both age of cows' dam and by cow birth year were calculated. The correlations between MPPA and cow weaning weight for each set of means were -.68 and -.20, respectively. The correlation of MPPA and cow weaning weight was .14 and the regression of MPPA on cow weaning weight was .03. This study suggested that cow weaning weight is not indicative of subsequent productivity and was in agreement with other studies that suggested an antagonistic relationship between early heifer growth environment and weaning weights of her calves.

Hohenboken and Brinks (1971a), in a Colorado study, reported on relationships between direct and maternal effects on weaning weight. Records on 1,386 linecross and 1,232 inbred Hereford calves were used. Intrasire phenotypic regressions of progeny weaning weight on dam weaning weight were .05 and .12 for linecrosses and inbreds, respectively. The authors suggested that the difference in regressions between the inbreds and linecrosses was due to the poorer preweaning environment of inbred cows. The estimated genetic correlation between direct and maternal effects on weaning weight was -.28. The authors concluded that maternal effects probably contributed more to the variability among weaning weights than did the direct effects and that an adverse relationship possibly existed between direct and maternal genetic effects but that its strength was not sufficient to hamper selection progress seriously.

Frey et al. (1972), in an Oklahoma study on cow type and productivity involving 220 Angus and their 990 calves, reported a regression of MPPA for weaning weight on 18-month weight of cows to be .09. The correlation between the two traits was .24. The regression of MPPA for weaning weight on first parity weaning weight was .32. Frey (1971) reported a correlation of first calf weaning weight with MPPA of .71, second calf weaning weight of .73 and average weaning weight with MPPA of .94. Thus, selection for increased cow productivity would be expected to be more effective when based on weaning weight of the first one or two calves than when based on a heifer's own growth performance.

Kress and Burfening (1972), in a Montana study involving 648 Hereford cows and their 3,342 calves, reported phenotypic correlation between heifer weaning weight and yearling weight and subsequent MPPA of .15 and .12, respectively. The correlation between a heifers' birth year effects for weaning weight and her birth year effects for MPPA was -.11. The correlation between a heifers' ages of dam effects on weaning weight and age of dam effects on MPPA was -.12. The authors indicated that the results suggested a negative relationship between a heifer's own weaning weight and her subsequent MPPA for weaning weight.

Hohenboken et al. (1973), in a Wisconsin study using monozygous and dizygous twin Hereford heifers, found phenotypic correlations between progeny weaning weight and heifer 8-month weight, heifer 15-month weight and postweaning gain of .09, .16 and .18, respectively. These results suggested that size of a heifer at eight months was a poor predictor of preweaning performance of her progeny and that size at 15 months or postweaning gain were probably better predictors of progeny preweaning performance.

Benyshek and Marlowe (1973), in a Virginia study utilizing records on 1,011 Hereford cows and their progeny, reported on the relation of mature size to progeny performance. Regressions of calf preweaning gain on mature cow size ranged from 129 to .46. Regressions of calf weaning weight on mature cow size ranged from .07 to .11.

Boston et al. (1975a), in an Oklahoma study using a large subset of the data used in this study, estimated phenotypic relationships between Angus and Hereford heifers' weaning weights and yearling weights and subsequent productivity as measured by calf weaning weight. In the Angus, correlations between a heifers' weaning weight and that of her progeny were low with the largest being .14. Angus correlations between a heifers' weaning weight and her mean progeny weaning weight and MPPA were .15 and .14, respectively. The correlations between Angus heifers' yearling weights and progeny weaning weights were slightly better with a maximum of .23. The correlations reported between Angus heifers' yearling weights and mean progeny weaning weight and MPPA were .12 and .20, respectively. In Herefords, the largest correlation between heifer weaning weight and calf weaning weight was .33. Correlations between heifer weaning weight and mean progeny weaning weight and MPPA were .20 and .24, respectively, for Herefords. The maximum correlation between heifer yearling weight and calf weaning weight was .33. Correlations between heifer yearling weight and mean progeny weaning weight and MPPA were .29 and .29, respectively, for Herefords. The authors suggested that selections of replacement heifers on the basis of their yearling weight might be more successful than selection on weaning weight. In a companion paper, Boston et al. (1975b) estimated repeatability of weaning weight to be .27 for Angus and .50 for Herefords. The authors concluded that breed difference in repeatability could exist and that the weaning weight of the first calf was generally a better indicator of cow productivity than the cows' own growth performance.

In a nutritional study, Martin et al. (1970) reported results suggesting noncreep fed calves from creep fed dams had lower weaning weights than noncreep fed calves from noncreep fed dams. Holloway and Totusek (1972) suggested similar results by reporting that calves from Angus and Hereford cows on a high plane of nutrition weaned lighter calves than their counterparts on moderate and low levels.

This review of literature indicates two things relative to cow productivity. Firstly, a low relationship between cow preweaning growth and subsequent productivity is consistently indicated in the literature. Later measures of growth in heifers were more highly associated with subsequent productivity than preweaning growth but not markedly so. Cow productivity literature also consistently suggests that an environmental and/or genetic antagonism exists between preweaning growth and subsequent productivity such that phenotypic associations between them are low. No breed differences were reported between Hereford and Angus that suggested largely different relationships among heifer growth traits and subsequent productivity.

CHAPTER III

MATERIALS AND METHODS

The data used in this study were collected from 1958 to 1975 in conjunction with the beef cattle breeding projects 670 and 1256 at the Oklahoma Agricultural Experiment Station (OAES), Stillwater. The preweaning and weaning traits of 2,039 and 836 calves from 500 and 202 Angus and Hereford cows, respectively, were used in this study. The cow traits used included preweaning, weaning and yearling traits.

Because the majority of the data is from project 1256 the procedures for project 670 will not be given.

Project 1256 was initiated at the Southwest Livestock and Forage Research Station (SWLFRS) in the early 1960's to measure direct and correlated response to selection for weaning and yearling weight. Foundation animals for the project were assembled in 1960 and foundation females were randomly allotted to lines for the 1963 breeding season. The foundation females originated from several herds in the midwestern and southwestern United States. The Angus foundation cows came from 30 sires and the Hereford foundation cows originated from 16 sires. Hereford and Angus foundation sires came from varied sources with 10 and 25 foundation sires representing each breed, respectively. These foundation sires were used in 1963, 1964, 1965 and 1966 for the Hereford sires and from 1963 through 1967 for the Angus sires. All lines were closed prior to 1966 and 1967 for the Hereford and Angus lines, respectively. Subsequent selection was done on an intraline basis. The design of the selection project is given in Table I.

TABLE I

DESIGN OF BEEF CATTLE SELECTION EXPERIMENT

Line:	5	6	7	8	9	10
Breed[a]	H	H	A	A	A	A
No. Cows	10	10	10	10	10	10
Trait Selected: Wt. at Age	205	365	205	365	CL[b]	205
Selection Criteria	I	I	I	I	-	I/P[c]
No. Bulls Selected/Year	2	2	2	2	2	5/2[c]
No. Years Bulls Used	2	2	2	2	2	2
No. Heifers Selected/Year	10	10	10	10	10	10

[a]H = Hereford, A = Angus

[b]Random mating control line

[c]Top 5 bulls selected on individual performance and two were subsequently selected on progeny performance.

In the Hereford herd, replacement breeding animals in one line were selected on the basis of heaviest individual 205-day weaning weight and the otherline was selected on the basis of heaviest weight at 365 days (bulls) or 425 days (heifers). Replacement breeding stock in two of the Angus lines was selected in the same manner as the Hereford lines, a third Angus line was used as a random mating control, and a fourth line was selected on individual and progeny 205 day weight. Each year two bulls are selected from each line to be used two successive years before being sold. Hereford bulls were used as two year olds prior to 1971 and as yearlings subsequently. Angus bulls were used as yearlings throughout the study. Heifers were bred to calve as two year olds.

Thirteen top ranking heifers based on the respective selection criteria are retained from each line and bred as yearlings. The top 10 pregnant heifers in each line selected as replacement females for 10 cows culled on the basis of serious unsoundness, open at the fall pregnany check or oldest age.

The progeny test herd at the Lake Carl Blackwell Range (LCBR) was designed to progeny test bulls from Angus lines 9 and 10. In 1969 the design of project 1256 was modified to convert line 9 to a random mating control line and after 1971 crossbred calves were produced by the Angus cows in the progeny test herd until it was dispersed in 1975.

Cattle in the selection project at SWLFRS were managed as a single herd except during the breeding season and when forage availability prohibited doing such. Every effort was made to insure as uniform of environment as practically possible for all cattle. The cattle were pastured on native range typical of central Oklahoma. In the winter the cattle grazed wheat pasture and milo stubble, as available, and were supplemented with prairie hay, alfalfa and cottonseed cake as necessary. Replacement heifers were managed on wheat pasture to gain .75 to 1.0 pound per day during their first winter. Suckling calves were pastured with their dams without creep feed and weaned at an average age of 205 days. Bull calves were placed on a 160-day feedlot performance test postweaning during the early years of the study. This was reduced to 140 days in 1974.

The Angus progeny test herd at LCBR was pastured on native pasture year around. As with the SWFLRS cattle, much care was taken to provide as uniform an environment as practically possible. The cattle were managed as one herd with the exception of the breeding season during May to June. Breeding groups were randomly allotted to separate pastures during this period. Winter supplementation consisted of prairie hay and 1 to 3 pounds of cottonseed cake depending on the condition of the cattle and the season. Replacement heifers were fed to gain .5 to 1.0 pounds per day for their first winter. All calves were raised without creep and put on 160 to 170 day feeding trials at SWLFRS. Heifers were bred to calve as two year olds and male calves were castrated at about three months of age. The major exception to this was from 1964 to 1966. During this time another study was superimposed in which a random half of the male calves of a sire were left intact (Tanner, 1969). Data collected on this herd included preweaning and postweaning traits. Due to herd expansion little selection was practiced among the cows in this herd with selection consisting of culling open, unsound, or aged cows.

Herd Designation

Performance records of cows and calves used in this study were obtained from two different breeds, of various origin, with differences in management and location existing among the cattle. Statistical analyses were made on a within herd basis as suggested by the work of

Dickerson (1940), Gregory et al. (1950), Kieffer (1959), Brown (1960), Swiger et al. (1962), Drewry (1964) and Thompson and Marlowe (1971).

Herds designation was done on the basis of breed, location and management. Thus, a herd defines a group of cattle of the same breed, raised largely at the same location and under similar management conditions.

Angus herd one consisted of Angus cattle born to project 1256 or an earlier project in the selection lines at the SWLFRS and spent their productive years as part of project 1256.

The Hereford herd consisted of cattle that were part of project 1256 or an earlier project and were born, raised and managed at the SWLFRS.

Angus herd two were Angus cattle born either at the LCBR or the SWLFRS and spent their productive lives as part of the progeny test herd of project 1256 or an earlier project. Some of the cows in this herd were born at the SWLFRS and moved to the LCBR. However, all cows born in the same year were moved at the same time. Thus, all cows born in the same year had their calves at the same location and year effects were completely confounded with location effects. This implies that removal of year would also remove location effects in this herd.

Traits Measured

Birth weights were taken on all calves within 24 hours of birth and the calves were identified at this time. Calves were weaned and weighed at an average age of 205 days and classified as to conformation and condition. Postweaning gain was measured on all calves and used to calculate yearling weights (365 days for bulls and 425 days for heifers).

Yearling conformation and condition were also obtained. The traits considered in this study were birth weight, preweaning ADG, weaning weight, weaning conformation, weaning condition, postweaning ADG, and yearling weight. The number of observations for each herd and trait involved in this study is presented in Table II

TABLE II

NUMBER OF OBSERVATIONS CLASSIFIED BY HERD AND BY TRAIT

	Angus Herd 1		Hereford Herd		Angus Herd 2	
	Cow	Calf	Cow	Calf	Cow	Calf
Birth Weight	338	1330	202	836	162	704
Preweaning ADG	338	1331	202	836	162	704
Weaning Weight	338	1331	202	836	162	709
Weaning Conformation	338	1331	202	828	162	707
Weaning Condition	--	1331	--	826	--	702
Postweaning ADG	324	--	195	--	94	--
Yearline Weight	324	--	183	--	94	--

Adjustment of Data

Phenotypic differences among animals occur due to two major causes, genetic and environmental. Differences among animals contain effects due to year of birth, age of dam, sex and other effects. However, if the known sources of variation can be adjusted for, then the phenotypic differences between animals are composed only of genetic differences and environmental differences that cannot be accounted for.

The sources of variation considered in these data were age of calf at weaning, age of dam, the year an animal was born and the sex of the animal. Age of calf effects were removed by adjusting all weaning weights to 205 days of age prior to any analysis.

The data were largelhy disproportionate and many patterns of missing cells were represented. Therefore, the data was analyzed using the General Linear Models subroutine in the Statistical Analysis System program developed by Barr and Goodnight (1976). This subroutine calculates four types of sums of squares. The third and fourth type of sums of squares were used for evaluation of the importance of sources of variation. The third type of sums of squares are partial sums of squares if there were no missing cells. If missing cells exist then these sums of squares are equivalent to the sums of squares produced by Harvey's missing cell algorithm (1960). The fourth type of sums of squares are designed to handle any missing all pattern in the data.

Analyses conducted to identify important sources of variation in the data were based on two different models. Cow traits were analyzed according to one model and calf traits according to another. In the cow data the following model was utilized.

$$Y_{ijk} = \mu + A_i + Y_j + AY_{ij} + e_{k(ij)}$$

where:

- μ = the overall mean.
- A_i = the effect of the i^{th} age of dam. (i = 2,3,4,5)
- Y_j = the effect of the j^{th} year. (j = 58,...72)
- AY_{ij} = the effect of the interaction of the i^{th} age of dam with the j^{th} year.
- $e_{k(ij)}$ = the random deviation of the k^{th} cow's phenotype from the ij^{th} age of dam-year subclass mean where $e_{k(ij)}$ was assumed to be normally distributed with a mean of 0 and variance σ^2.

The calf data were analyzed assuming the following model.

$$Y_{ijkl} = \mu + A_i + Y_j + S_k + AY_{ij} + AS_{ik} + YS_{jk} + e_{ijkl}$$

where:

- μ = overall mean of the population for a given trait
- A_i = the effect of the i^{th} age of dam (i = 2,3,4,5)
- Y_j = the effect of the j^{th} year. (j = 58,...75)
- S_k = the effect of the k^{th} sex. (k - 1,2,3)
- AY_{ij} = the interaction of the i^{th} age of dam with the j^{th} year.
- AS_{ik} = the interaction of the i^{th} age of dam with the k^{th} sex.
- YS_{jk} = the interaction of the j^{th} year with the k^{th} sex.
- $e_{l(ijk)}$ = random residual effect assumed to be normally distributed with a mean of zero and variance σ^2.

The three-factor interaction effects were considered unimportant and pooled with the variation between calves within an age of dam-year-sex subclass.

Based on the results of the preliminary analyses of variance, models for the different cow and calf traits were reduced to include only the important sources of variation. Least squares constants for these effects were then estimated using the regression subroutine in the SAS 72 program. This regression subroutine imposes the restriction that for given effects, the sum of the least squares estimates is zero. This restriction is arbitrary with regards to obtaining a solution to $X'X\beta = X'Y$ (the normal equations) but it is commonly used and has the virtue of being easily obtainable. Also, differences of linear combinations among adjusted data are invariant regardless of restrictions used to get a solution.

After least squares constants were estimated for the different effects in the cow and calf traits, transformations were performed to obtain some equivalencies. The age of dam effects were transformed to a five-year-old dam basis by adding the least squares estimate of the constant for five-year-old age of dams to the negative of the least squares estimates of the constants for the two-, three-, and four-year-old ages of dam. Year effects were transformed to additive correction factors by simply taking their negative values.

Correction factors for sex were done as multiplicative correction factors. These correction factors were estimated to convert the data to a heifer equivalency. The least squares means of heifers averaged across ages of dam and years were taken as proportions of the least squares means of steers and bulls averaged across ages of dam and years.

Several workers have indicated that multiplicative sex correction factors tend to stabilize the estimates of variances for growth traits.

After the correction factors for each trait were estimated, the data for each herd was converted to an equivalent five-year-old age of dam and heifer basis, and adjusted for year effects.

Adjustment of data in the previous manner puts the data on an equivalent basis as much as is possible by statistical control. Not all extraneous variation has been removed but most of the large and known sources have been accounted for.

Research has indicated that sires are an important source of variation for many traits. The data used in this study came from selection experiments where sires and dams were allotted at random to breeding groups and sires were not used more than two consecutive years. Therefore, there were very few full sib offspring in the data. Since this study involves studying the relations between a dam and her half-sib offspring, sire was considered a random effect. No adjustments were made for sire effects in any of the traits and sire effects were not considered in any analyses.

There has been little evidence, to date, that suggest large differences between the selection lines in any of the traits. Only two generations of selection had been practiced in the Hereford lines by 1973 (Stanforth, 1974) and slightly less than that in the Angus lines of project 1256. Thus lines were not considered an important source of variation in this data.

Multivariate Analyses

The traits considered in the multivariate analyses of the data were cow birth weight, preweaning ADG, weaning weight, weaning conformation, postweaning ADG, yearling weight and the cow's calves weaning weights. Thus, an experimental unit was considered to be a cow calf unit. The number of calves per cow was variable, ranging from one to ten with a mean of 3.9, 4.1 and 4.4 calves for the Angus herd 1, Hereford herd and Angus herd 2, respectively. Calf traits past the seventh calf were not considered because of the small numbers of cows in each herd having more than seven calves. The number of observation for each parity is given in Table III for each herd.

TABLE III

NUMBER OF OBSERVATIONS FOR EACH PARITY CLASSIFIED BY HERD

Parity	Angus Herd 1	Hereford Herd 2	Angus Herd 3
1	338	203	162
2	295	174	145
3	234	148	107
4	187	121	91
5	146	92	66
6	92	62	51
7	34	31	41

Multivariate analyses considered in this research were principal component analyses, canonical correlation analyses, discriminant analyses and multiple linear regression. Each type of analysis is discussed separately in these materials and methods.

Principal Components

Principal component analyses are generally considered a data reduction technique designed to reduce p correlated variables to a more manageable form (Morrison, 1967). Principal components are simply weighted linear combinations of the original data. Calculation of principal components is generally done using standardized response variables to insure that the weights derived are comparable.

The derivation of principal components is initiated by solving for the p characteristic roots of the correlation matrix, R, as

$$\text{determinant } (R-\lambda I) = 0$$

where:

R = correlation matrix, pxp

λ = scalar characteristic root

I = identity matrix, pxp.

If R is pxp of rank p then there exist p distinct characteristic roots. After solving for the characteristic roots, solutions for the characteristic vector associated with each characteristic root are found as solutions to:

$$(R-\lambda_i I)\underset{\sim}{a} = 0$$

where:

R = correlation matrix, pxp

λ_i= i^{th} ranked characteristic root of R (i = 1,...,p)

I = identity matrix, pxp

$\underset{\sim}{a}$ = solution vector of coefficients,

Thus, if p variables (X_1, X_2,...,X_p) are measured on an experimental unit the first principal component is given by:

$$Y_1 = a_{1i}X_1 + a_{12}X_2 + \ldots + a_{1p}X_p$$

where a_{1i} are normalized coefficients from the characteristic vector associated with the largest characteristic root of R. There are p such principal components estimable with the following properties:

1. The first principal component, calculated from the largest characteristic root of R, accounts for the maximum amount of variation in the multivariate system of original traits and is uncorrelated with all other p-1 principal components derived.
2. The second principal component, from the second largest characteristic root of R, accounts for the maximum variation remaining after the first principal component and is uncorrelated with all other principal components derived.

.
.
.

p. The p^{th} principal component, from the smallest characteristic root of R accounts for the remaining variation and is uncorrelated with all other principal components derived.

The variance of the i^{th} principal component is given by λ_i and the total variance of all possible principal components derived is

$$\sum_i \lambda_i = \text{trace (R)} = \text{rank (R)}.$$

The relative contribution of the i^{th} principal component is given by

$$\frac{\lambda_i}{\sum_i \lambda_i} = \frac{\lambda_i}{p}.$$

More detailed descriptions of principal component analyses are given by Anderson (1958) and Morrison (1967).

A possible utility of principal components in animal science is that of a data reduction technique. If, for example, 15 traits were measured on an animal, then description of response and interrelationships is extremely difficult as evidence by the fact that 105 product moment correlations could be generated. If, however, a majority of the variability could be explained by one or a few linear combinations of the data with perhaps some biological interpretation, then management of analyses would be greatly simplified. The works of Carpenter et al. (1971) and Brown et al. (1973) are two examples of the use of principal components in animal science. These workers were generally concerned with using principal components as meaures of size and/or shape in Hereford and Angus cattle.

In this research, principal component analyses were done initially to build linear combinations of the original cow and calf traits that would account for proportions of the original variation in these traits. The desired result from such an analysis is to find linear combinations of the original data that account for a large proportion of the original variation and have meaningful interpretations. In this manner a set of correlated traits could be described as a smaller set of independent linear combinations of the original traits. In addition to the above, the original phenotypic correlation structure of the data is estimated as a by-product of the principal component analyses.

Several sets of principal components were derived. In the first set, linear combinations of cow birth weight, preweaning ADG, weaning weight, weaning conformation, postweaning ADG and yearling weight were calculated.

In another set, different linear combinations of calf weaning weights were considered. More specifically, principal components were separately derived for the first two, three, four, five, six and seven parities. A third set was calculated considering the previously mentioned cow traits along with the first parity calf weaning weight. Thus, the cow prebreeding performance traits were considered separately, as were the calf weaning weights. In addition, principal components were derived including the first parity weaning weight with the cow traits and principal components were derived for the second through third, second through fourth, second through fifth, second through sixth and second through seventh parities.

Correlations of the set of the original cow traits with the principal components for calf weaning weights were computed in addition to correlations between the principal components for cow traits and principal components for calf weaning weights. In that all principal components were derived from correlation matrices, all cow and calf traits were standardized prior to performing correlation analyses.

These correlation analyses were done to ascertain any possibilities that might exist in using principal components in predicting subsequent productivity from early performance of heifers or young cows or their possible use in describing interrelationships between early performance and subsequent productivity.

Canonical Correlations

In many situations variables fall into two natural subdivisions, e.g., preweaning traits and postweaning traits. It p variables were in the first group and q variables were in the second group then there would be pq simple correlations involved in a correlation study between variables across the groups. These pq correlations would be very difficult to evaluate simultaneously.

Canonical correlation analysis circumvents this problem by building linear combinations of the original variables in each group. Let X_p be the data matrix for the first group and X_q be the data matrix for the second group. Canonical correlation analysis derives a vector of coefficients, $\underset{\sim}{a}$, for the first group and a vector, $\underset{\sim}{b}$, for the second group such that scalars $u_i = \underset{\sim}{a}'_i X_p$ and $v_j = \underset{\sim}{b}'j\ X_q$ are formed for each individual in each group, respectively. These new scalars are subject to the following constraints:

1. Corr $(u_i, u_j) = 0,\ i \neq j$
2. Corr $(v_i, v_j) = 0,\ i \neq j \quad i, j=1,2,\ldots,p$
3. Co-r $(u_i, v_j) = 0,\ i \neq j$
4. u_1 and v_1 are the pair of linear combinations of the original data of the two groups most high correlated among all linear combination meeting the above conditions.

5. u_2 and v_2 are the pair of linear combinations of the original data of the two groups with the second highest correlation among all linear combinations of the original data meeting the above conditions.

6. Etc.

There are p or q canonical correlations possible between two groups of data depending on which is the smaller number.

Canonical correlations can be derived using either the covariance matrix or the correlation matrix. The correlation matrix is generally used when the variables are of differing units or differing relative magnitudes. The correlation matrix $\underset{p+qxp+q}{R}$ is constructed and partitioned into submatrices as follows:

$$R = \left[\begin{array}{c|c} R_{11} & R_{12} \\ \hline R_{21} & R_{22} \end{array}\right]$$

where:

R_{11} is the pxp correlation matrix among variables in the first group.

R_{22} is the qxq correlation matrix among variables in the second group.

$R_{12}=R_{21}'$ is the pxq correlation matrix between variables in the first group and variables in the second group.

The canonical correlations between variables in the first group and variables in the second group are found as the square roots of the characteristic vectors, λ_i, of the matrix

$$(R_{11}^{-1} R_{12} R_{22}^{-1} R_{21}).$$

The coefficients $\underset{\sim}{a}_i$ and $\underset{\sim}{b}_i$ associated with each characteristic roots are the scaled characteristic vectors corresponding to each characteristic root. More specifically, $\underset{\sim}{a}_i$ is found as a solution to

$$(R_{11}^{-1} R_{12} R_{22}^{-1} R_{21} - \lambda_i I)\underset{\sim}{a} = 0$$

and $\underset{\sim}{b}_i$ is found as a solution to

$$(R_{22}^{-1} R_{21} R_{11}^{-1} R_{12} - \lambda_i I)\underset{\sim}{b} = 0.$$

Detailed discussions of canonical correlation analyses are given by Anderson (1958) and Morrison (1967).

The interpretation of canonical correlations is based on the sign and relative magnitudes of the coefficients $\underset{\sim}{a}_i$ and $\underset{\sim}{b}_i$. Canonical correlations can never be negative. Thus, negative relationships are reflected by negative signs on the coefficients. Also, one variable may be more important than another and this is reflected in the relative magnitudes on the coefficients. Explanation of interpretation can best be done by example.

Suppose a researcher was interested in the relationship between preweaning and postweaning growth in cattle. Group one (X_1) variables might be birthweight, weaning weight and weaning grade and group two (X_2) variables might be postweaning gain and yearling grade. Further suppose that a canonical correlation of .50 was estimated and the values of the coefficient vectors were $\underset{\sim}{a}' = (.1 = .5 = .2)$ and $\underset{\sim}{b}' = (1.0 \ .2)$ for the two groups, respectively. This correlation suggests high values of $U = \underset{\sim}{a}' X_1$ are associated with high values of $V = \underset{\sim}{b}' X_2$. Thus, we would want to make U large if V is large, in agreement with the canonical correlations. This then implies, in the context of our example, that high birth weights, and low weaning weights and grades are associated with high postweaning gains and yearling grades. More simply, we might conclude that cattle with poor preweaning growth show compensatory gain and grade.

The primary utility of canonical correlations in animal science would be to derive linear combinations of easily measured traits that are more highly correlated than the bivariate correlations with another set of traits that are not so easily measured. Young (1975) used canonical correlation analyses to evaluate the relationships between a gilt's prebreeding traits and subsequent reproductive performance. Whereas the product moment correlations between prebreeding traits and reproductive traits were generally less than .10, canonical correlations of .38, .32 and .18 were found. This suggests a substantial improvement in association between the groups of traits as compared to the bivariate correlations.

One aspect of canonical correlation analyses not often emphasized is the fact that the first canonical correlation is the maximum possible correlation among linear combinations of traits in one group and traits in another. Thus, we can estimate the upper bound that can be expected in terms of correlations between the two groups of traits.

Canonical correlation analyses were done in this research to find combinations of cow traits most highly correlated with linear combinations of the calf traits among all such linear combinations of traits. The desired results from these analyses were to find meaningful linear combinations of cow traits more highly correlated with linear combinations of the calf traits than are the bivariate data. Thus, the number of relationships between variables to consider could be decreased and the strength of the relationships increased.

The primary canonical correlation analysis was done between cow birth weight, weaning weight, weaning conformation and postweaning ADG and subsequent calf weaning weights. In another set of analyses cow yearling weight was substituted for postweaning ADG. Analyses between the cow prebreeding traits and subsequent calf weaning weights were performed sequentially for the first two, three, four, five, six and seven parities, respectively. This was done because there were a variable number of calves per cow and the sequential order of relationships was of interest. Canonical correlations between cow birth weight, weaning weight, weaning conformation, postweaning ADG and first parity weaning weight and subsequent productivity were also derived. Also cow yearling weight was substituted for postweaning ADG and the analyses rerun. As in previous canonical correlations, the analyses were conducted sequentially for the second two, three, four, five, six and seven parities. The first weaning weight of a cow's calf was grouped with the "cow traits" to see if the canonical correlation between the cow traits and calf weaning weights would be increased over the previous canonical correlations.

These canonical correlation analyses should indicate the maximum association that might be expected between the early performance of heifers or young cows and their subsequent productivity as measured by the weaning weights of their calves. In addition, these canonical correlation analyses should be useful in describing interrelationships between the heifer or young cow traits and their subsequent productivity at these maximum levels of association.

Discriminant Functions and Regression

The linear discriminant function was originally introduced by R. A. Fisher in 1936 as a means to classify an observation into one of several populations (Morrison, 1967). It has since evolved into a seemingly complex algorithm.

The basic idea of discriminant functions is to develop coefficients that would enable calculation of linear combinations of original data that would facilitate assignment of an observation to one population or another. For example, it would be extremely beneficial if some linear combination of prebreeding traits could serve to classify a cow into the ranks of an above average producing group or below average producing group with some reliability.

Basically, a linear discriminant function maps multivariate means into univariate space in such a manner that the generalized squared distance between group sample means given by:

$$D_M^2 = (\underset{\sim}{\bar{X}}_i - \bar{X}_j)' \; V^{-1} \; (\underset{\sim}{\bar{X}}_i - \bar{X}_j)$$

is maximized relative to the original variation where:

$\underset{\sim}{\bar{X}}_i$ = sample mean vector from group i

$\underset{\sim}{\bar{X}}_j$ = sample mean vector from group j

V^{-1} = inverse of variance-covariance matrix.

The linear discriminant function for group j is given by a scalar constant (K) and coefficient vector ($\underset{\sim}{C}$) where

$$K_j = -{}^{1}/_{2} \; \underset{\sim}{\bar{X}}'_j \; V^{-1} \; \underset{\sim}{\bar{X}}_j$$

$$\underset{\sim}{C}_j = V^{-1} \; \underset{\sim}{\bar{X}}_j$$

and we would classify an observation into population j if

$K_j + C_j'X_j \; K_i + C_i'X_i \quad i \neq j$. Alternately, and perhaps more obviously, an observation X would be classified into population j if the generalized squared distance (D_I^2) of that observation from the j^{th} sample mean was smallest as compared to generalized squared distance from the other groups where:

$$D_I^2 = (X-\overline{X}_j)' \, V^{-1} \, (X-\overline{X}_j).$$

Another method by which classification is done is through the use of posterior probabilities of group membership given by:

$$\text{EXP} \; {}^1/_2 \, D_i^2 \, (y) \quad / \sum_{j=1}^{n} \text{EXP} \; {}^1/_2 \, D_j^2 \, (y)$$

where:

D_i^2 is the generalized squared distance of an observation (y) from the i^{th} group. $i=1,2,\ldots,n$.

In the case where a pooled variance-covariance matrix is used then the generalized squared distance is an given previously. When there is sufficient evidence of heterogeneity of covariance matrices among groups, the within covariance matrices are used to calculate the generalized squared distance of an observation (y) from the i^{th} group as:

$$D_i^2(y) = (X-\overline{X}_i)' \, V_i^{-1} \, (X-\overline{X})_i + \ln|V_i|$$

where V_i is the covariance matrix of the i^{th} group.

Discriminant analyses were done by Gaskins, et al. (1975) to classify Hereford cattle into medium or large body type categories at three different times in the postweaning feeding period using weight and size measures in addition to sonoray measures of fat and muscle thickness. The proportions of correct classifications were high with an average of

97.1% correct for bulls, 95.7% correct for steers and 85.5% correct for heifers.

Discriminant analyses were done in this study to discriminate between classes of cows based on their productivity as measured by the weaning weights of their calves. This procedure reduces a multivariate set of variables from two or more populations into a new univariate variable. Thus, discrimination between populations can be made by assigning an observation to the population whose univariate mean is closest to the univariate observation.

Several types of discriminant functions were considered. The first set of discriminant functions used cow birth weight, weaning weight, weaning conformation and postweaning ADG to discriminate between four productivity groups of cows based on the sum of the weaning weights of their calves. The cows were initially assigned to a productivity group based on their relative position in a herd with regards to the total pounds of calf produced. The top 25 percent of the herd was assigned to group 1, the next 25 percent to group 2, the third 25 percent to group 3 and the lower 25 percent to group 4. Analyses were performed with groupings based on the sum of the 205 day weights for the first two, three, four, five, six and seven calves and based on Most Probable Producing Ability (MPPA). This last quantity is calculated according to the formula set forth by Lush (1945, 1948):

$$MPPA = HA + [\frac{nr}{1+(n-1)\ r} \quad (\overline{WWT205} - HA)]$$

where:

HA = mean weaning weight for a herd

n = number of calf weaning weight records for a cow n=1,...,10.

r = repeatability of calf weaning weight

$\overline{WWT205}$ = the mean weaning weight of the calves of a cow.

The herd averages used in these estimates were 426, 445 and 434 for Angus herd 1, Hereford and Angus herd 2, respectively. The estimates of repeatability used were .27 for Angus and .50 for Herefords (Boston et al. (1975a).

Not all cows remained in a particular productivity group for all analyses since the criterion of initial classification changed for each analysis, in addition to the fact that many cows were deleted from the later analyses involving the sum of several calves weights since only three or four of their own calves' records were available. However, for the most part, the composition of a group was fairly stable across the analyses.

Similar discriminant analyses were performed using cow birth weight, weaning weight, weaning conformation, postweaning ADG and first parity weaning weight to discriminate between productivity groups of cows where the productivity groups were formed as in the first set of discriminant analyses. The obvious difference between the two sets of analyses was the inclusion of the first calf's weaning weight of the cows into the vector of "cow traits." This was done to ascertain if the information on the cows' first calf would help better differentiate between productivity groups.

Because all variables involved are probably from a normal distribution or at least one that is asymptotically normal, the equivalent of the above discriminant analyses may be done via multiple linear regression.

The following model was fit to the data:

$$\sum_{j=1}^{n_k} y_i = \beta_0 + \beta_1(\text{CBWT})_i + \beta_2(\text{CWWT})_i + \beta_3(\text{CWGD})_i + \beta_4(\text{CPWADG})_i + e_{ij}$$

where:

$\sum_{j=1}^{n_k} y_i$ = sum of the n_k calf weaning weights (SWWT205) for the i^{th} cow in the herd where

n_k = 2,3,4,5,6,7 for analysis 1,2,3,4,5,6, respectively

β_0 = the intercept of the regression line

β_1 = the partial regression of SWWT205 on cow birth weight

β_2 = the partial regression of SWWT205 on cow weaning weight

β_3 = the partial regression of SWWT205 on cow weaning conformation grade

β_4 = the partial regression of SWWT205 on cow postweaning ADG

e_{ij} = residual effect unaccounted for by regression assumed to be normally distributed with a mean of zero and variance σ^2.

A similar series of models was employed using the additional independent variable of first parity weaning weight with reasons being as previously described. The dependent variables were then the sums of calf weaning weights beginning with second parity.

These discriminant and regression analyses should indicate the relative success that might be expected in classifying heifers or young cows into relative productivity groups based on their performance early in life. The regression analyses will find the linear combination of heifer or young cow traits most highly correlated with a linear combination of subsequent calf weaning weights where the weights given the calf weaning weights are predetermined. Thus, these analyses should indicate how successfully subsequent performance of heifers or young cows can be identified from traits measured early in life.

Thus, the relationships between early cow performance and subsequent productivity were studied using four different multivariate techniques, namely, principal component analyses, canonical correlation analyses, multiple linear regression analyses and discriminant analyses. In addition, these analyses were done to ascertain if changes in the relationship between early cow performance and subsequent productivity occurred as the number of calves considered increased.

CHAPTER IV

RESULTS AND DISCUSSION

Effects of Age of Dam, Sex and Year

Univariate Analyses of variance were done to ascertain the relative importance of age of dam, year of birth and the interaction of the effects in explaining differences among cow birth weights, preweaning average daily gains, weaning weights, weaning conformations, postweaning average daily gains and yearling weights. Analyses of variance were also done to partition differences among calf birth weights, preweaning average daily gains, weaning weights, weaning conformations and weaning condition scores. The effects considered in the model to analyze calf data were age of dam, year of birth, sex and the two factor interactions among these effects. The analyses were done separately by Angus herd 1, Hereford herd and Angus herd 2. The F-value for testing the significance of effects in the model are presented in Table IV and V for the cow traits and calf traits, respectively. The complete analyses of variance are presented in Table LXI through Table LXVI of the Appendix for the cow and calf data, respectively.

Age of dam effects were found to be important sources of variation for cow and calf birth weight, preweaning ADG, weaning weight and weaning conformation and calf weaning condition in all three herds. Age of dam effects were also significant for cow postweaning ADG and

TABLE IV

F-VALUES ASSOCIATED WITH ANALYSES OF VARIANCE FOR COW TRAITS

Source	Birth Wt.			Birth-Wn. ADG			Weaning Wt.			Weaning Conformation			Postweaning ADG			Yearling Wt.		
	HERD			HERD			HERD			HERD			HERD			HERD		
	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2
Age of dam	9.3**	7.6**	4.9**	34.0**	16.6**	5.8**	37.3**	19.3**	6.5**	22.5**	9.1**	2.3^{+}	8.4**	5.3**	.6	5.9**	6.7**	.8
Year of birth	4.4**	3.5**	2.9*	12.6**	4.1**	4.6**	13.6**	3.8**	2.7*	7.1**	13.6**	6.1**	104.2**	31.5**	52.2**	45.0*	22.8**	20.4**
Age of dam x Year of birth	1.1	1.2	.8	1.2	1.5^{+}	1.5	1.3	1.4^{+}	1.4	1.5*	3.4**	.3	1.6*	1.2	.2	1.0	.7	.9

+ $p < .10$

* $p < .05$

** $p < .01$

TABLE V

F-VALUES ASSOCIATED WITH ANALYSIS OF VARIANCE FOR CALF TRAITS

Source	Birth Wt. HERD			Birth-Wn. ADG HERD			Weaning Wt. HERD			Weaning Conformation HERD			Weaning Condition HERD		
	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2
Age of dam	16.8**	47.1**	18.8**	33.5**	65.2**	13.4**	37.8**	78.6**	17.9**	3.7*	48.4**	4.6**	25.5**	40.5**	3.6*
Year of birth	5.1**	5.3**	13.6**	24.1**	8.6**	3.8**	22.9**	8.7**	4.4**	4.1**	17.4**	3.3**	47.5**	26.4**	2.7**
Sex	38.2**	36.7**	13.0**	56.8**	36.5**	17.6**	67.2**	46.4**	20.0**	.3	.2	3.3*	12.4**	6.0*	5.0**
Age x year	1.8**	1.6*	1.7*	2.8**	2.1**	1.2	3.0**	2.2**	1.3	.4	1.8**	2.5**	2.3**	2.3**	1.6^{+}
Age x sex	.4	.9	.6	.2	2.3^{+}	.8	.3	2.2^{+}	.5	.6	.3	.4	1.9	.4	1.2
Year x sex	1.0	.9	1.2	2.0*	1.7^{+}	1.5^{+}	2.0*	1.7*	1.5^{+}	.6	.8	1.3	2.0*	1.6^{+}	3.0**

\+ $p < .10$

* $p < .05$

** $p < .01$

yearling weight in Angus herd 1 and Hereford herd but not in Angus herd 2.

These results are in general agreement with other workers who found significant age of dam effects on various traits. Koch and Clark (1955a) and Swiger (1961) found significant age of dam effects on birth weight in Hereford cattle. Important age of dam effects were also reported for birth to weaning gain in Hereford and Angus cattle (Rollins and Guilbert, 1954; Koch and Clark, 1955a; Marlowe and Gaines, 1958; Berg, 1961; Muhmud and Cobb, 1963; Marlowe et al., 1965). Many researchers have found significant age of dam effects on weaning weight in both the Hereford and Angus breeds (Knapp et al., 1942; Burgess et al., 1954; Rollings and Guilbert, 1954; Evans et al., 1955; Koch and Clark, 1955a; Clum et al., 1956; Brown, 1960; Minyard and Dinkel, 1960; Swiger, 1961; Koger et al., 1962; Hamann et al., 1963; Muhmud and Cobb, 1963; Warren et al., 1965; Cundiff et al., 1966a; Harwin et al., 1966; Sellers et al., 1970; Tanner et al., 1970; Cardellino and Frahm, 1971; Bailey and Koh, 1974; Neville et al., 1974). Koch and Clark (1955a), Marlowe and Gaines (1958), Marlowe et al. (1965) and Muhmud and Cobb (1963) all found significant age of dam effects on weaning conformation. No reports were found in the literature relative to the effects of age of dam on weaning condition score. Age of dam effects were also considered important in differences in Hereford postweaning gain by Swiger (1961). However, Tanner et al. (1970) reported age of dam to have a neglible effect on postweaning gain in Hereford and Angus cattle. Koch and Clark (1955a) found significant age of dam effects on yearling weight in Hereford, Angus and Shorthorn cattle, but

Tanner et al. (1970) reported age of dam effects as nonsignificant for this trait in Herefords and Angus.

Year effects were significant in all herds for all calf traits studied, as well as for cow birth weight, preweaning ADG, weaning weight and weaning conformation. Year effects were also large for cow postweaning ADG and yearling weight in the Angus herds and Hereford herd.

Year effects on cattle traits have been studied extensively by other workers. Gregory et al. (1950) and Swiger (1961) both found significant year effects on Hereford birth weight. Large differences among years were found by Gregory et al. (1950); Muhmud and Cobb (1963); Marlowe et al. (1965); Tanner et al. (1971) for preweaning gain in Hereford and Angus cattle. In one of the most extensively studied traits, significant year effects were found for weaning weight by Burgess et al. (1954); Clum et al. (1956); Brown (1960); Swiger (1961); Muhmud and Cobb (1963); Warren et al. (1965); Cundiff et al. (1966a); Harwin et al. (1966); Hohenboken and Brinks (1969); Sellers et al. (1970); Tanner et al. (1970), Cardellino and Frahm (1971); Boston (1973); Neville et al. (1974); and Bailey and Koh (1974). Significant year effects on weaning conformation were found by Muhmud and Cobb (1963) and Marlowe et al. (1965). No reports were found in the literature that had studied year differences in weaning condition score. Swiger (1960) found important year effects on postweaning gain and yearling weight in Herefords and Tanner (1970) found significant year effects for yearling weight in Angus.

Generally there were significant differences among sexes. Bulls and steers exceeded heifers in birth weight, preweaning ADG, and weaning weight in all three herds. Heifers had higher weaning condition scores than bulls in all three herds. Sex effects on weaning conformation were generally small with the exception of the Angus herd 2 where bull and steers graded slightly higher than heifers at weaning.

Results in the literature are in general agreement with these findings. Gregory et al. (1950); Koch and Clark (1955a); Koch et al. (1959); Brinks et al. (1961); Swiger (1961); Swiger et al. (1962); and Wilson (1973) found significant sex differences in birthweight. Sex differences in preweaning gain were also reported in the literature (Marlowe and Gaines 1958; Koch et al., 1959; Berg 1961; Brinks et al., 1961; Swiger et al., 1962; Muhmud and Cobb 1963; Marlowe et al., 1965; Tanner et al., 1970). Many studies have examined differences between sexes in weaning weight and have found these differences to be generally large but variable due to the confounding of sex effect with selective castration (Burgess et al., 1954; Rollins and Guilbert 1954; Evans et al., 1955; Koch and Clark 1955a; Clum et al., 1956; Brown 1960; Minyard and Dinkel 1960; Brinks et al., 1961; Swiger 1961; Koger et al., 1962; Swiger et al., 1962; Hamann et al., 1963; Muhmud and Cobb 1963; Marlowe et al., 1965; Cundiff et al., 1966a; Harwin et al., 1966; Tanner et al., 1970; Bailey and Koh 1974; Neville et al., 1974). Significant sex effects were found for weaning conformation by Koch and Clark (1955a), Muhmud and Cobb (1963), Marlowe et al. (1965). No reports were found in the literature relative to sex differences in weaning condition score.

The interactions of year with age of dam and sex can be considered as random variation associated with different traits in beef cattle but are most often considered fixed effects. If these fixed interactions were large and frequent then this would necessitate the calculation of age of dam and/or sex correction factors within each year. In data sets involving a large number of years and a large number of animals, interactions with year can many times be detected. This is due mainly to two factors. The first and most obvious is the power of the statistical test for significance due to the large numbers involved. Secondly, with a large number of year involved, it is not uncommon for differences among some of the ages of dam or differences between sexes to vary slightly over the years.

In these data small unimportant interactions between age of dam and year were detected for cow preweaning ADG and weaning weight in the Hereford herd and cow weaning conformation in the Angus herd 1 and Hereford herd. Small year by age dam interactions were found for cow postweaning ADG in the Angus herd 1. Unimportant interactions between age of dam and year were also detected in calf birth weight for all three herds. In addition small year by age of dam interactions were found for calf preweaning ADG, weaning weight and weaning condition score for the Angus herd 1 and Hereford herd and for calf weaning conformation for the Hereford herd and Angus herd 2. None of these interactions were of large magnitude and this source of variability was considered to be unimportant.

The interaction of year with sex was generally unimportant in these data. Small year by sex interactions were detected for calf preweaning ADG, weaning weight and weaning condition score in the Angus herds and Hereford herd. None of these interactions were of sufficient magnitude to cause concern and were considered negligible in subsequent analyses.

The interaction of age of dam with sex is of particular interest in that if it were large it would necessitate calculation of age of dam correction factors for each sex and sex correction factors for each age of dam. In these data the only evidence of an interaction of age of dam with sex was for calf preweaning ADG and weaning weight in the Hereford herd. It was not of sufficient magnitude, however, to be considered important in further analyses.

Swiger (1961) found that interactions between year, age of dam and sex were small and not significant for Hereford birth weights. Wilson (1973) also found the interaction age of dam with sex to be unimportant in birthweight. Cooper et al. (1965) found evidence of interactions of year with age of dam and sex in Hereford preweaning gains but little evidence of an age of dam by sex interactions. Tanner (1970) also found evidence of a year by sex interaction in Angus preweaning gains. Evidence suggesting existence of interactions involving year and age of dam have also been found for weaning weight (Swiger 1961; Cooper et al., 1965; Harwin et al., 1966; Hohenboken and Brinks 1969; Bailey and Koh 1974). Year by sex interactions in weaning weight were found by Cooper et al. (1965) and by Tanner et al. (1970). However, Swiger (1961) and Harwin et al. (1966) found little evidence of year by sex interactions in Hereford weaning weights. Age of dam by sex interactions were found for Hereford weaning weights by Harwin et al., (1966) and Bailey and Koh (1974). Swiger (1961) and Cundiff et al. (1966a) did not find evidence of an age of dam by sex interaction in Hereford weaning weights.

It appears that age of dam, year and sex are generally important sources of variation effecting beef cattle performance. Interactions between age of dam, year and sex are much less consistent in the literature. The importance of these interactions with year is probably a function of specific year involved and/or the source of the data. Thus general statements about interactions with year probably cannot be made and the relative importance of interactions with year should be ascertained for a specific research project. In these data, none of the interactions with years were of sufficient magnitude to justify their consideration in subsequent correction of the data.

After preliminary analyses of variance, the linear models corresponding to cow and calf traits were reduced to include only those effects found to be important sources of variation. Where appropriate, least squares constants were estimated for age of dam effects and year effects for cow birth weight, preweaning ADG, weaning weight, weaning conformation, postweaning ADG and yearling weight. Age of dam constants were subsequently converted to correction factors to adjust to a five-year old age of dam basis. Estimates of the constants for cow traits are given in Tables VI-IX for the Angus herd 1, Hereford herd and Angus herd 2.

Least squares estimates of the effects of age of dam, year of birth and sex were derived for calf birth weight, preweaning ADG, weaning weight, weaning conformation and weaning condition score. Age of dam constants were converted to correction factors to adjust records to a five year old cow basis. Sex effects were converted to multiplicative correction factors by taking the ratio of the least squares mean for heifers to the least squares mean for bulls or steers to adjust the data to a heifer basis. The least squares constants of age of dam and year effects for calf traits for each of the three herds

TABLE VI

LEAST SQUARES AGE OF DAM CONSTANTS ($\hat{\beta}$) AND STANDARD ERRORS FOR COW TRAITS IN POUNDS

		Birth Wt.		Birth-Wn. ADG		Weaning Wt.		Weaning Conformation		Postweaning ADG		Yearling Wt.	
Age of Dam[a]	Herd	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.
2	Angus1	- 6.6	.79	-.237	.0152	-55.3	3.35	-.80	.079	.093	.0175	22.5	5.76
	Hereford	- 8.3	1.80	-.261	.0334	-61.8	7.33	-.95	.168	.152	.0344	21.5	9.38
	Angus2	-10.3	2.55	-.270	.0482	-65.5	10.96	.00	.000	.000	.0000	0.0	0.00
3	Angus1	- 1.7	1.09	-.127	.0210	-27.8	4.64	-.55	.110	.032	.0189	20.6	6.24
	Hereford	- 3.1	1.58	-.109	.0293	-25.3	6.44	-.16	.150	.069	.0304	33.7	8.29
	Angus2	- 4.9	2.38	-.095	.0450	-24.2	10.22	.00	.000	.000	.0000	0.0	0.00
4	Angus1	- 1.1	1.16	-.049	.0224	-11.2	4.95	-.20	.117	.025	.0198	17.0	6.51
	Hereford	2.3	1.51	-.037	.0281	- 5.2	6.16	-.20	.145	.065	.0287	29.6	7.82
	Angus2	2.0	2.19	-.085	.0414	-15.3	9.41	.00	.000	.000	.0000	0.0	0.00

[a]age of dam 5=0.

TABLE VII

LEAST SQUARES YEAR CONSTANTS ($\hat{\beta}$) AND STANDARD ERRORS IN POUNDS FOR COW TRAITS IN ANGUS HERD 1

Year of Birth	Birth Wt.		Birth-Wn. ADG		Weaning Wt.		Weaning Conformation		Postweaning ADG		Yearling Wt.	
	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.
60	- .8	4.59	-.234	.0884	-48.9	19.54	-1.56	.461	.076	.0764	- 42.8	25.14
62	-7.8	1.87	-.142	.0360	-37.1	7.95	.08	.187	.000	.0000	0.0	.00
63	-1.3	1.61	-.067	.0309	-14.9	6.82	.05	.161	.063	.0268	- 4.0	8.83
64	-2.2	1.22	-.042	.0234	-10.9	5.18	.15	.122	.093	.0204	5.3	6.72
65	3.6	1.31	.036	.0251	11.0	5.55	.00	.131	-.310	.0222	- 61.0	7.30
66	2.4	1.29	.041	.0247	10.9	5.47	.00	.129	-.439	.0216	- 88.0	7.11
67	.3	1.15	.022	.0221	5.0	4.89	.22	.115	.020	.0194	7.4	6.38
68	6.2	1.18	.096	.0226	25.8	5.00	-.20	.118	-.264	.0198	- 33.6	6.51
69	-1.7	1.17	-.077	.0225	-17.5	4.97	-.51	.117	.045	.0197	- 15.7	6.48
70	-2.9	1.42	.003	.0274	- 2.2	6.05	.47	.143	.569	.0239	212.0	7.85
71	1.8	1.30	.205	.0249	43.9	5.51	.78	.130	.298	.0218	110.5	7.16
72	2.4	1.30	.158	.0249	34.8	5.51	.51	.130	.152	.0219	.9	7.20

TABLE VIII

LEAST SQUARES YEAR CONSTANTS ($\hat{\beta}$) AND STANDARD ERRORS IN POUNDS FOR COW TRAITS IN THE HEREFORD HERD

Year of Birth	Birth Wt.		Birth-Wn. ADG		Weaning Wt.		Weaning Conformation		Postweaning ADG		Yearling Wt.	
	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.
58	1.4	4.26	-.075	.0790	-14.1	17.33	-2.80	.394	.000	.0000	0.0	0.00
59	2.1	3.35	-.205	.0621	-40.1	13.61	.41	.310	-.062	.0597	- 58.1	16.28
60	-3.8	3.36	.004	.0623	- 3.1	13.66	.59	.311	.053	.0599	6.9	16.32
61	.7	2.83	-.026	.0525	- 4.8	11.52	.00	.000	.221	.0504	-42.3	13.75
62	-6.4	2.04	.043	.0378	2.3	8.29	.83	.189	.000	.0000	0.0	0.00
63	-8.1	1.78	.058	.0330	3.8	7.24	- .24	.165	-.014	.0318	.3	8.67
64	1.6	2.13	-.011	.0394	- .6	8.65	.15	.197	.235	.0379	49.6	10.33
65	-3.3	2.12	.037	.0394	4.6	8.64	- .17	.197	-.334	.0380	- 67.8	10.37
66	3.2	1.76	-.074	.0327	-12.0	7.16	- .21	.164	-.425	.0315	-108.6	8.58
67	1.7	1.68	-.094	.0312	-17.5	6.84	- .18	.156	.071	.0300	- 3.8	8.18
68	5.1	1.84	.084	.0341	22.6	7.49	.44	.175	-.266	.0328	- 35.8	8.95
69	-1.1	1.75	-.039	.0325	- 9.0	7.13	- .51	.163	-.208	.0313	- 57.0	8.52
70	.1	2.15	.006	.0399	1.4	8.75	.13	.198	.492	.0384	109.4	10.47
71	4.1	2.39	.217	.0443	48.4	9.72	1.27	.221	.340	.0426	124.2	11.61
72	2.7	2.06	.076	.0382	18.2	8.38	.29	.191	-.102	.0391	- 1.6	10.68

TABLE IX

LEAST SQUARES YEAR CONSTANTS ($\hat{\beta}$) AND STANDARD ERRORS IN POUNDS FOR COW TRAITS IN ANGUS HERD 2

Year of Birth	Birth Wt.		Birth-Wn. ADG		Weaning Wt.		Weaning Conformation		Postweaning ADG		Yearling Wt.	
	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.
58	-1.2	2.25	.009	.0425	.6	9.65	-2.20	.083	.000	.0000	0.0	0.00
59	-1.5	1.77	-.026	.0334	- 6.9	7.60	.43	.274	-.174	.0477	- 5.9	14.34
61	3.4	2.04	.002	.0385	3.7	8.75	.43	.213	.090	.0416	53.8	12.52
63	4.7	1.76	-.226	.0333	-41.5	7.58	- .42	.156	-.062	.0465	13.1	13.99
65	-3.2	1.71	.092	.0323	15.7	7.34	.59	.203	.886	.1312	84.8	39.50
66	- .3	1.68	.077	.0318	15.5	7.24	.95	.198	.000	.0000	0.0	0.00
67	-1.9	1.37	.072	.0259	12.9	5.89	.22	.194	-.741	.0461	-119.6	13.87

are presented in Tables X-XIV along with the multiplicative sex correction factors.

Thus, correction factors were estimated for the traits used in the analyses to put the cow data on a five year old age of dam basis with year effects minimized. The calf data were adjusted to a five year old age of dam equivalent and to a heifer basis. Year effects were also removed by statistical control in the calf data.

Age of dam correction factors for cow birth weight, preweaning ADG and weaning weight were very comparable between the Angus herds 1 and 2. However, in the Angus herd 2, age of dam effects were not significant sources of variation for weaning conformation, postweaning ADG or yearling weight, whereas age of dam was a significant source of variation in the Angus herd 1 for these traits. From the signs on the coefficients for postweaning gain and yearling weight in the Angus herd 1, it appears that these cows demonstrated compensatory gain postweaning and increased feed consumption and/or gain enough to increase yearling weight.

Age of dam correction factors for calf birth weight, preweaning ADG, weaning weight, weaning conformation and weaning condition score were reasonably similar between the two Angus herds. However, there was larger difference between 2 year old dams and 5 year old dams in the Angus herd 2 than Angus herd 1 for birth weight and weaning weight. Hereford herd age of dam correction factors for cow birth weight, preweaning ADG, weaning weight, weaning conformation, postweaning ADG and yearling weight were reasonably similar to those of the Angus herds. Age of dam correction factors for calf birth weight, preweaning ADG, weaning conformation and weaning condition score in the Herefords were

TABLE X

LEAST SQUARES AGE OF DAM CONSTANTS ($\hat{\beta}$) AND STANDARD ERRORS FOR CALF TRAITS IN POUNDS

		Birth Wt.		Birth-Wn. ADG		Weaning Wt.		Weaning Conformation		Weaning Condition	
Age of Dam[a]	Herd	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.
2	Angus1	- 6.7	.63	-.254	.0154	-58.8	3.41	- .86	.144	-.67	.050
	Hereford	-10.9	.82	-.316	.0214	-75.8	4.66	-1.03	.079	-.85	.073
	Angus2	-13.1	1.00	-.280	.0241	-68.1	5.26	- .51	.110	-.60	.106
3	Angus1	- 3.3	.60	-.160	.0148	-36.0	3.26	- .60	.138	-.42	.048
	Hereford	- 4.8	.79	-.178	.0207	-41.5	4.50	- .68	.076	-.58	.070
	Angus2	- 5.0	.93	-.142	.0223	-35.0	4.89	- .52	.102	-.54	.098
4	Angus1	- 1.3	.62	-.081	.0153	-17.9	3.38	- .36	.162	-.24	.050
	Hereford	- 1.9	.82	-.065	.0215	-15.3	4.67	- .19	.079	-.16	.072
	Angus2	- 2.5	.93	-.096	.0224	-22.7	4.91	- .21	.102	-.24	.098

[a]age of dam 5=0.

TABLE XI

LEAST SQUARES YEAR CONSTANTS ($\hat{\beta}$) AND STANDARD ERRORS IN POUNDS FOR CALF TRAITS IN ANGUS HERD 1

Year of Birth	Birth Wt.		Birth-Wn. ADG		Weaning Wt.		Weaning Conformation		Weaning Condition	
	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.
62	-4.0	5.18	.072	.1276	10.9	28.15	.51	1.187	1.02	.415
63	-1.6	7.28	-.038	.1794	- 9.7	39.55	1.25	1.668	- .37	.583
64	- .5	2.68	-.037	.0660	- 8.2	14.55	- .05	.614	.00	.214
65	1.0	1.54	-.035	.0379	- 6.1	8.37	- .18	.353	- .59	.123
66	1.6	1.23	-.046	.0303	- 7.9	6.68	- .50	.282	- .75	.098
67	1.5	1.10	.010	.0270	3.6	5.96	- .14	.251	- .38	.088
68	4.9	1.07	.049	.0264	14.9	5.82	- .47	.246	- .53	.086
69	-2.5	1.00	-.132	.0246	-29.6	5.42	- .58	.229	- .53	.080
70	-2.1	.96	-.104	.0236	-23.3	5.20	- .22	.219	- .10	.077
71	- .4	.93	.137	.0230	27.7	5.08	.71	.214	.92	.075
72	2.3	.94	.143	.0231	31.6	5.10	.62	.215	.35	.075
73	.7	.93	.037	.0230	8.3	5.08	.22	.214	- .24	.075
74	-1.6	.94	.076	.0231	14.1	5.10	.36	.215	.69	.075
75	.6	.99	-.132	.0245	-26.3	5.40	.52	.228	.51	.0796

TABLE XII

LEAST SQUARES YEAR CONSTANTS ($\hat{\beta}$) AND STANDARD ERRORS IN POUNDS FOR CALF TRAITS IN THE HEREFORD HERD

Year of Birth	Birth Wt.		Birth-Wn. ADG		Weaning Wt.		Weaning Conformation		Weaning Condition	
	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.
60	-3.6	7.72	.194	.2019	36.2	43.94	.00	.00	.00	.00
61	-5.0	2.80	.127	.0733	21.0	15.95	.00	.00	.00	.00
62	2.3	2.64	.077	.0691	18.1	15.05	.16	.247	.22	.226
63	-2.1	1.83	-.058	.0479	-14.2	10.44	-1.21	.168	- .66	.154
64	.3	1.83	-.099	.0479	-19.9	10.44	- .65	.168	- .76	.154
65	-1.0	1.24	-.022	.0324	- 5.6	7.05	- .49	.108	- .58	.099
66	3.9	1.24	-.057	.0325	- 7.5	7.07	- .20	.107	- .50	.098
67	2.5	1.19	-.136	.0311	-25.2	6.77	- .34	.102	- .45	.093
68	5.8	1.14	.072	.0298	20.7	6.48	.04	.097	- .20	.089
69	- .5	1.09	-.112	.0284	-23.6	6.18	- .61	.091	- .39	.083
70	-3.5	1.01	-.124	.0263	-29.2	5.73	- .04	.082	- .04	.075
71	- .4	1.03	.142	.0269	28.5	5.86	.86	.085	1.13	.077
72	3.1	1.08	.057	.0282	14.9	6.15	.43	.090	.65	.082
73	.4	1.16	-.039	.0303	- 7.5	6.59	.58	.098	- .03	.090
74	-1.7	1.11	.061	.0291	10.6	6.35	.60	.093	.72	.086
75	- .3	1.15	-.082	.0469	-17.3	6.57	.87	.111	.88	.102

TABLE XIII

LEAST SQUARES YEAR CONSTANTS ($\hat{\beta}$) AND STANDARD ERRORS IN POUNDS FOR CALF TRAITS IN ANGUS HERD 2

Year of Birth	Birth Wt.		Birth-Wn. ADG		Weaning Wt.		Weaning Conformation		Weaning Condition	
	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.	$\hat{\beta}$	S.E.
60	-1.3	2.42	-.106	.0584	-25.1	12.82	-.91	.280	-1.56	.283
61	1.5	1.69	.128	.0408	21.4	8.73	.30	.187	.33	.180
62	2.0	1.50	.030	.0362	9.3	7.94	.35	.166	.38	.160
63	1.5	1.23	-.138	.0297	-22.4	6.30	-.65	.132	- .32	.131
64	-3.4	1.17	-.111	.0282	-25.3	6.19	-.63	.130	- .46	.124
65	-3.5	1.03	.075	.0249	12.0	5.46	.24	.114	.21	.110
66	.8	1.00	.048	.0242	11.2	5.31	.18	.111	.27	.107
67	-3.5	.95	.057	.0229	8.1	5.03	.23	.105	.09	.101
68	2.1	.92	.045	.0221	11.3	4.85	.19	.101	.00	.000
69	-3.4	.84	-.063	.0203	-16.4	4.46	-.04	.093	.22	.097
70	-2.3	.93	.000	.0223	- 1.6	4.89	.30	.102	.19	.090
71	9.4	1.04	.036	.0251	17.4	5.53	.40	.116	.67	.111

TABLE XIV

MULTIPLICATIVE SEX CORRECTION FACTORS
FOR CALF TRAITS

Sex	Birth Wt. HERD			Birth-Wn. ADG HERD			Weaning Wt. HERD			Weaning Conformation HERD			Weaning Condition HERD		
	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2	Angus1	Hereford	Angus2
Bull	.94	.94	.93	.92	.93	.91	.92	.93	.91	1.00	1.00	.99	1.01	1.01	1.02
Heifer	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Steer	—	—	.93	—	—	.94	—	—	.95	—	—	.99	—	—	1.00

also reasonable similar to Angus calf herds 1 and 2. However, younger ages of dam in Herefords tended to produce lighter calves at 205 days than did the same ages of dam in the Angus as was found by Cardellino and Frahm (1971).

Sex least squares constant were estimated for each calf traits within each herd where appropriate. Multiplicative correction factors developed from these estimates were used to adjust records within each herd to a heifer equivalent basis. Correction of data for sex effects by multiplicative correction factors tends to equalize the variances of each sex (Koch et al., 1959; Minyard and Dinkel 1960; Brinks et al., 1961; Cundiff et al., 1966b). The multiplicative sex correction factors were very comparable across the three herds (Table XIV).

A cow's productivity was measured by weaning weight of her calf. Thus, calf traits other than weaning weight were not considered in any of the multivariate analyses to look for associations between cow traits and subsequent productivity.

Product-Moment Correlations

Product-moment correlations among cow and calf traits were a necessary first step in evaluation relationships between early cow performance and subsequent productivity. Multivariate analyses depend on these correlations.

Correlations among cow birth weight, preweaning ADG, weaning weight, weaning conformation, postweaning ADG and yearling weight are presented in Table XV for each herd. Generally, birthweight was moderately positively associated with weaning weight and yearling weight and positively associated with preweaning and postweaning daily gain

TABLE XV

CORRELATIONS AMONG COW TRAITS FOR THE THREE HERDS

	Herd	Birth-Wn. ADG	Weaning Wt.	Weaning Conformation	Postweaning ADG	Yearling Wt.
Birth Wt.	Angus 1	.19**	.41**	.01	.15**	.45**
	Hereford	.14+	.37**	.00	.18*	.46**
	Angus 2	.37**	.56**	.12	.17+	.47**
Birth-Wn. ADG	Angus 1		.97**	.38**	-.14*	.68**
	Hereford		.97**	.38**	-.32**	.54**
	Angus 2		.98**	.30**	-.11	.63**
Weaning Wt.	Angus 1			.36**	-.09	.73**
	Hereford			.35**	-.26**	.62**
	Angus 2			.30**	-.07	.67**
Weaning Conformation	Angus 1				-.29**	.06
	Hereford				-.24**	.05
	Angus 2				-.07	.22*
Postweaning ADG	Angus 1					.60**
	Hereford					.60**
	Angus 2					.67**

+ $p < .10$

* $p < .05$

** $p < .01$

but to a lesser degree than with the weights. Birthweight and weaning conformation appeared to be essentially independent traits. Preweaning daily gain had a strong positive association with weaning weight as would be expected. Preweaning ADG was moderately positively associated with both weaning conformation and yearling weight but negatively associated with postweaning ADG which suggests that below average early growth was compensated for during the postweaning period. Weaning weight was positively associated with weaning conformation and to a larger extent with yearling weight. Like preweaning daily gain, weaning weight was negatively associated with postweaning daily gain. Weaning conformation was negatively associated with postweaning daily gain but was apparently uncorrelated with yearling weight. As might be expected, postweaning daily gain and yearling weight were positively associated. These correlations are in general agreement with the many estimates reported in the literature.

Table XVI presents the correlations among the different parity weaning weights of calves from the Angus herd 1, Hereford herd and Angus herd 2. The first parity may contain some calves from three year-old-dams, the second parity may contain calves from four year-old-dams, etc. However, the average age of dam for each parity group (Table XVII) suggests that essentially each parity group represents the age of dam group associated with the parity, e.g., first parity is equivalent to calves from cows calving first as two-year-olds. Because of age of dam adjustments, comparisons involving parities do not involve ages of dam. The correlations among half-sib weaning weights provide estimates of repeatabilities for weaning weight. The pattern of these correlations suggested two conclusions. First

TABLE XVI

CORRELATIONS AMONG HALF-SIB 205-DAY WEIGHTS IN THE THREE HERDS

	Herd	Parity2	Parity3	Parity4	Parity5	Parity6	Parity7
Parity 1	Angus 1	.40**	.35**	.27**	.35**	.30**	-.02
	Hereford	.55**	.55**	.50**	.48**	.43**	.45*
	Angus 2	.19*	.23*	.28**	.45**	.32*	.22
Parity 2	Angus 1		.38**	.25**	.27**	.21+	.09
	Hereford		.53**	.44**	.42**	.39**	.47*
	Angus 2		.36**	.34**	.31*	.29+	.46**
Parity 3	Angus 1			.33**	.30**	.22*	.08
	Hereford			.49**	.42**	.40**	.19
	Angus 2			.32**	.34*	.30*	.36*
Parity 4	Angus 1				.42**	.44**	.05
	Hereford				.47**	.49**	.29
	Angus 2				.41**	.25	.44*
Parity 5	Angus 1					.23*	.26
	Hereford					.55**	.62**
	Angus 2					.12	.41*
Parity 6	Angus 1						.28
	Hereford						.53*
	Angus 2						.25

+ $p < .10$

* $p < .05$

** $p < .01$

TABLE XVII

AVERAGE AGES OF DAMS IN MONTHS FOR THE DIFFERENT PARITY GROUPINGS FOR EACH HERD

Parity	Angus herd 1	Hereford herd	Angus herd 2
1	26.2	26.6	26.8
2	39.1	39.7	41.0
3	51.8	52.4	53.1
4	63.9	65.6	65.7
5	76.8	77.7	78.1
6	87.2	89.2	89.9
7	96.1	99.3	101.9

correlations tended to decrease as the time interval between the parities involved decreased particularly in Angus herd 1. Second, correlations among parity weaning weights were larger for Herefords than for Angus. These two results were also noted by Boston et al. (1975a) in a repeatability study using a large subset of this data. They concluded that a possible breed difference in repeatability could exist and that early cow performance records are a poor predictor of productivity for more than 4 or 5 years removed. Koger and Knox (1947), Gregory et al. (1950), Koch and Clark (1955b) and Cunningham and Henderson (1965b) also reported decreases in correlations among half-sib traits as the records were further removed in time. Repeatabilities of Hereford weaning weights reported in the literature using adjacent records using correlations among half-sibs or regression of later of earlier records were .50 (Koger and Knox, 1947), .49, .43, .33 (Gregory et al., 1950), .51 (Botkin and Whately 1953), .66, .39, .47 (Koch and Clark 1955b) .35 and .68 (McCormick et al., 1956) and .51 (Boston et al., 1975a) Angus estimates of adjacent records found in the literature were .47 (preweaning daily gain) (Cunningham and Henderson 1955b) and .28 (weaning weight) (Boston et al., 1975a).

Table XVIII presents correlations between cow prebreeding traits and the weaning weights of their calves for the Angus herd 1, Hereford herd and Angus herd 2. It is the correlations among the cow prebreeding traits and the subsequent weaning weights that largely determine success or failure of predicting subsequent performance. Cow birth weight was lowly positively associated with calf weaning weight the first seven parities. The correlation between birth weight and subsequent productivity was slightly higher in the Angus herd 2 than the other two herds. The association between cow preweaning ADG and subsequent productivity was slightly better in these herds but appear to decrease or become perhaps negative after the fifth parity calf. The correlations between cow weaning weight and subsequent productivity reflect those correlations of cow preweaning ADG with subsequent productivity. The correlations were generally low and tended to become lower and/or negative past the fifth parity. Cow weaning conformation and subsequent productivity were generally lowly and negatively associated. This suggested that calves from cows with high weaning conformation were lighter at weaning. Cow postweaning daily gain was generally lowly and positively associated with subsequent productivity whereas cow yearling

TABLE XVIII

CORRELATIONS AMONG COW TRAITS AND PROGENY WEANING WEIGHTS FOR THE THREE HERDS

Calf Weaning Wt.	Herd	Cow Traits: Birth Wt.	Birth-Wn. ADG	Weaning Wt.	Weaning Conformation	Postweaning ADG	Yearling Wt.
Parity 1	Angus 1	.07	.17**	.18**	-.03	.09	.21**
	Hereford	.12	.08	.11	.02	.13	.19**
	Angus 2	.25	.23**	.26**	.08	.15+	.28**
Parity 2	Angus 1	.12	.11+	.13*	.02	.12*	.17**
	Hereford	.14	.17*	.20*	.11	.17*	.28**
	Angus 2	.19*	.12	.15	-.04	.30**	.21*
Parity 3	Angus 1	.02	.19**	.18*	-.06	.07	.19**
	Hereford	.12	.10	.12	-.02	.03	.09
	Angus 2	.18	.23*	.24*	-.02	.26*	.40**
Parity 4	Angus 1	.03	.10	.10	.00	.16*	.19*
	Hereford	.11	.16	.17	-.05	.20*	.21*
	Angus 2	.19	.15	.17	-.21	.27*	.23*
Parity 5	Angus 1	.13	.14	.16+	.02	-.06	.06
	Hereford	.07	.04	.04	-.14	.06	.06
	Angus 2	.27	.06	.10	.06	.20	.26*
Parity 6	Angus 1	.22	-.06	-.01	-.11	.15	.11
	Hereford	.00	.10	.10	-.05	.04	.02
	Angus 2	.18	.02	.05	-.18	.34*	.21
Parity 7	Angus 1	.05	-.22	-.19	-.19	-.14	-.16
	Hereford	.06	.08	.08	.01	.26	.31
	Angus 2	.32	-.15	-.09	-.22	.24	-.06

+ $p < .10$

* $p < .05$

** $p < .01$

weight was more strongly associated with subsequent productivity than any other trait previously considered. Thus, these product moment correlations suggested that the best single predictor of productivity would be yearling weight.

Other studies have found similar associations between cow traits and subsequent productivity. Koch and Clark (1955c) reported the phenotypic correlations between calf weaning and cow weaning and yearling weight to be .06 and .12, respectively. Lindholm and Stonaker (1957) found a correlation of -.01 between cow 18-month weight and calf weaning weight. Marchello et al. (1960) reported a correlation of .24 between cow 18 month weight and weaning weight of her first calf. Sewell et al. (1963) found a correlation of .005 between daughter and dam weaning weights. Brinks et al. (1964) reported on the correlation between MPPA for weaning weight and cow birth weight, preweaning gain, weaning weight, postweaning gain, yearling weight, yearling to 18 month gain and 18 month weight. These correlations were .07, .07, .09, .10, .15, .12 and .20 for MPPA with each cow trait, respectively. Christian et al. (1965) estimated a correlation of dam weaning weight with calf preweaning daily gain of .07. Mangus and Brinks (1971) found a correlation of .14 between cow MPPA for weaning weight and actual cow weaning weight. Frey et al. (1972) reported a correlation of .24 between cow 18 month weight and MPPA for weaning weight. Kress and Burfening (1972) found correlations between MPPA for weaning weight and cow birth weight, weaning weight, postweaning gain and yearling weight of .08, .15, -.01 and .12, respectively. Boston et al. (1975b) reported correlations between cow weaning weight and yearling weight and different measures of progeny weaning weights in Hereford and

Angus cows. For the Angus, correlations reported between cow weaning weight and each of the first seven parity calves were .13, .07, .07, .14, .12 and .03, respectively. The same correlations for the Herefords were .19, .26, .13, .19, .29, .33 and .17, respectively. Correlations reported between Angus cow yearling weight and each of the first seven parity calves were .15, .12, .12, .22, .16, .23 and .01, respectively. For the Herefords, these correlations were .30, .33, .12, .28, .17, .35 and .19, respectively. Correlations reported between dam weaning weight and mean progeny weaning weight and MPPA for weaning weight were .15 and .14 and .20 and .24 for the Angus and Herefords, respectively. The correlations of dam yearling weight with mean progeny weaning weight and MPPA for weaning weight reported were .19 and .20 and .29 and .29 for Angus and Herefords, respectively. The authors concluded that selection for productivity might be most effective based on cow yearling weight compared to other growth traits measured on the cow prebreeding.

Thus, these data indicated the associations between cow prebreeding traits and progeny weaning traits were low. This agrees with the results of many similar studies. These studies are also in general agreement that later heifer weights are more indicative of future productivity that are earlier weights.

Multivariate Analyses

It would be highly useful to efficient beef production if effective techniques could be developed for accurately predicting the production potential of replacement heifers. The preceding discussion concerning correlations between specific cow traits and her subsequent productivity indicated that judgements based upon any one of these cow traits would be of somewhat limited value. Since most of the traits measured on the cow are intercorrelated, the possibility exists that some combination of these traits may be more effective in predicting future productivity. The main thrust of this study deals with the evaluation of linear combinations of cow traits and calf weaning weights as to their usefulness in terms of predicting productivity from early cow performance. Also these linear combinations will be evaluated in terms of their description of intrarelationships of cow traits as they are associated with the calf weaning weights and *vice versa*. Four types of multivariate methods were employed: principal component analyses, canonical correlation analyses, multiple linear regression and discriminant analyses.

Principal Components

In animal science research a large number of measurements are generally taken on each animal. Simultaneous evaluation of interrelationships among all of these measurements is often extremely difficult. Multivariate methods of analyses can be utilized as a possible solution to this problem. Principal component analysis is a data reduction technique that can reduce a set of correlated variables to a smaller set of new uncorrelated variables. In essence, it finds linear combinations of original traits that account for a certain proportion of the variation in the multivariate set of data. More specifically, if there are p original correlated variables, then there are p linearly independent linear combinations of the data that can be derived assuming the correlation matrix of these variables is of rank p . The first linear combination of the original data derived accounts for the largest possible proportion of the variation in the original variables. This first new variable is called the first principal component. The second linear combination of original data (second principal component) accounts for the next largest possible proportion of original variation among all possible linear combinations uncorrelated with the first principal component. The third principal component accounts for the third largest proportion of original variation and is uncorrelated with the first two, etc. Principal components can be very useful when several original variables may be reduced to fewer new variables that have acceptable interpretations. This may aid in interpretation in two ways. Firstly, analyses using principal components analyze a system of the traits simultaneously. Secondly, fewer variables are involved in the analyses and interpretations can be easier providing the individual principal component has clear biological interpretations. Some problems can exist with principal component analyses. It is possible for a linear combination of traits to be derived that has no useful interpretation or the original variation may be spread nearly equally among all pincipal components. Thus, to account for a majority of the original variation, nearly as many principal components as there are original traits would be required. This situation would likely be of very limited value in interpretation.

Principal component analyses have been employed on a limited basis animal science research and were utilized by Wright (1932), Carpenter et al. (1971), Brown et al. (1973) and Young (1975) with various levels of success.

The objective of this portion of the study was to evaluate the potential of principal components as a method to study various measures of growth and subsequent productivity in Hereford and Angus cows.

Table XIX presents the first four principal components associated with cow birth weight, preweaning ADG, weaning weight, weaning conformation grade, postweaning ADG and yearling weight. Interpretation of principal components is based on the sign and relative magnitude of the coefficients. If a principal component is interpreted as a weighted average of an animal's performance then it is clear that the signs and magnitudes of the coefficients determine the numeric value of the new calculated variable (principal component).

The first principal component for cow traits accounted for 49%, 46%, and 50% of the variation among the original cow traits in the Angus herd 1, Hereford herd and Angus herd 2, respectively. This principal component was interpreted as a general measure of growth through yearling primarily due to preweaning influences. Essentially this component contrasts heifers with high preweaning performance and therefore a heavy yearling weight with heifers that are below average in weaning traits and yearling weight.

The second principal component for cow traits accounted for 27%, 29% and 24% of the variation in the original heifer performance traits in the Angus herd 1, Hereford herd and Angus herd 2. The interpretation of this principal component was as a measure of compensatory postweaning growth and yearling weight after poor preweaning performance. Basically, this component contrasts heifers heavy at birth with below average preweaning gain, weaning weight and weaning conformation and above average postweaning gain and yearling weight with heifers that have opposite performance in these traits.

TABLE XIX

COEFFICIENTS OF PRINCIPAL COMPONENTS FOR COW TRAITS FROM WITHIN EACH HERD

	Principal component[a]											
	1			2			3			4		
	Herd			Herd			Herd			Herd		
Cow Trait	Angus 1	Hereford	Angus 2	Angus 1	Hereford	Angus 2	Angus 1	Hereford	Angus 2	Angus 1	Hereford	Angus 2
Birth Wt.	.30	.28	.38	.24	.34	.09	.88	-.62	-.31	.20	.61	.85
Birth-Wn. ADG	.53	.55	.50	-.23	-.22	-.29	-.21	.03	-.12	-.30	-.33	-.37
Weaning Wt.	.56	.59	.54	-.15	-.12	-.24	.01	-.12	-.18	-.23	-.16	-.14
Weaning Conformation	.22	.26	.22	-.50	-.35	-.27	-.12	.59	.90	.83	.68	.26
Postweaning ADG	.08	-.03	.14	.70	.69	.79	-.35	.45	.20	.37	.01	-.08
Yearling Wt.	.51	.45	.49	.36	.47	.39	-.21	.22	.09	.03	-.15	-.22
% Total Variation	48.6	45.6	50.5	27.3	29.4	23.9	13.2	13.0	14.4	10.7	11.9	10.8

[a]The entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield principal components 1, 2, 3 or 4.

Interpretations of the third and fourth principal components are not as immediate as the first two and their interpretation depends on which herd they were derived from. The third principal component from the Hereford herd and Angus herd 2 and the fourth principal component from the Angus herd 1 have essentially the same interpretation. This component contrasts heifers below average in weaning weight due to below average birth weight and/or preweaning gain and above average in weaning conformation, postweaning gain and yearling weight with heifers having an opposite type of growth performance.

Since the first two principal components for cow triats accounted for 75% of the variation in the original heifer traits and they were both consistent and easily interpreted across all herds, it seems reasonable to use these two new variables in place of six original cow traits. Not all variation is accounted for but this is compensated for by increased ease of interpretation.

Table XX gives coefficients for the first two principal components derived for various combinations of calf weaning weights. These were derived sequentially for the first two, three, four, five, six and seven weaning weights. Sequential relationships were examined only to seven calves because the number of cows having more than seven calves was low.

The first principal component for the different parity weaning weights accounted for a large proportion of the variation in the calf weaning weights for the Angus herd 1, Hereford herd and Angus herd 2, respectively. It can be interpreted as a measure of productivity as measured by weaning weight. Generally, it contrasts sets of half-sib calves that are above average in weaning weight with sets of half-sib

TABLE XX

COEFFICIENTS OF PRINCIPAL COMPONENTS FOR CALF WEANING WEIGHTS FOR VARIOUS COMBINATIONS OF PARITY GROUPS FOR THE THREE HERDS

	Calf Weaning Weight Principal Component #1[a]																	
Parity	Angus 1 Parity						Hereford Parity						Angus 2 Parity					
	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7
1	.71	.58	.51	.46	.43	.41	.71	.58	.52	.47	.43	.40	.71	.50	.43	.41	.40	.33
2	.71	.59	.51	.44	.39	.38	.71	.57	.50	.45	.40	.38	.71	.60	.51	.42	.40	.39
3		.57	.52	.46	.41	.40		.57	.51	.46	.41	.40		.62	.52	.43	.42	.38
4			.45	.43	.43	.42			.47	.44	.41	.42			.53	.46	.43	.40
5				.45	.41	.41				.42	.40	.41				.50	.44	.40
6					.37	.38					.39	.38					.35	.31
7						.18						.18						.42
% Tot. Var.	69.8	58.4	49.9	46.6	43.0	37.6	77.5	69.5	63.2	58.8	56.2	53.8	59.7	50.9	46.7	46.1	41.9	41.7

TABLE XX (continued)

Parity	Angus 1						Hereford						Angus 2					
	Calf Weaning Weight Principal Component #2[a]																	
	Parity						Parity						Parity					
	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7
1	-.71	-.59	-.35	-.30	-.29	-.35	-.71	-.01	-.12	-.16	-.28	.20	-.71	.86	.84	-.66	-.38	.68
2	.71	-.18	-.44	-.53	-.51	-.30	.71	-.70	-.54	-.48	-.44	.19	.71	-.44	-.46	-.54	.34	-.44
3		.79	.08	-.22	-.32	-.25		.71	-.12	-.36	-.41	.55		-.26	-.29	.40	.27	-.23
4			.82	.59	.48	.04			.82	.36	.13	.26			.65	.07	-.14	.02
5				.49	.10	.16				.70	.46	-.33				-.32	-.55	.44
6					.56	.35					.58	-.26					.59	-.15
7						.76						-.61						-.27
% Tot. Var.	30.2	21.6	19.5	17.1	15.7	16.2	22.5	15.8	14.3	12.7	12.6	13.8	40.3	27.7	20.8	17.7	15.4	13.4

[a] That entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield principal component 1 or 2 for each respective set of weaning weights.

calves that are above average in weaning weight with sets of half-sib calves below average in weaning weight. It appears that, in general the first principal component for calf weaning weight accounts for a larger proportion of original variation in Herefords than in Angus. This is may be due to the higher correlations between half-sib weaning weights as noted earlier in the results of this research. There are no apparent changes in interpretation of the first principal component as the number of calves in the analyses increases.

The second principal component for calf weaning weight accounted for between 13% and 40% of the variation in original traits across the herds and parity groupings. The second principal component for the first two, three and four parities in the Angus herd 1 and Hereford herd generally contrast sets of half-sibs below average in weaning weight until the last calf with sets of half-sibs above average until the last calf. In Angus herd 2, this second principal component for the first two parities contrasted two half-sibs with the first calf below average and the second calf above average with two half-sibs that were above and below average in weaning weight, respectively. The second principal component in Angus herd 2 for the first three and four priaties generally contrasted sets of half-sibs having the first calf above average in weaning weight and the remainder at or below average with sets of half-sibs having the first calf below average and the remainder average or above average in weaning weight. The second principal component for the first seven parity calves has no consistent interpretation across herds but generally describes below average production during some stage whether it be prior to five years of age, subsequent to five years or in both stages of production.

As plainly evidenced, useful interpretations of principal components are not always immediate. In this case the first principal component for calf weaning weight was the most useful one as it did account for about 50% of the variability in most cases. This suggested that the first principal component may be used without too great a loss of information in place of the two to seven half-sib calf weaning weights. This is further enhanced by the consistency of the coefficients across the three herds in addition to the immediate interpretation of this first principal component for calf weaning weight.

Principal components were derived for calf preweaning ADG as a measure of productivity in a manner similar to calf weaning weights. It was found that these analyses using calf preweaning ADG were essentially a repetition of those using calf weaning weights because of the high correlation between weaning weight and preweaning ADG (.98) and similar correlations of these traits with others. Because of this strong similarity, subsequent analyses were done using only calf weaning weight and only the analyses involving weaning weight are reported.

Principal components were also derived for cow traits including cow birth weight, preweaning ADG, weaning weight, weaning conformation, postweaning ADG, yearling weight and weaning weight of first calf. The coefficients for these principal components are presented in Table XXI along with the proportion of variation accounted for by these principal components. This was done in this manner to ascertain if additional information on the first calf weaning weight might be helpful in evaluation of heifer performance and subsequent productivity.

The first two principal components were very comparable to the first two principal components of cow traits that did not include first

TABLE XXI

COEFFICIENTS FOR PRINCIPAL COMPONENTS FOR COW TRAITS INCLUDING FIRST PARITY CALF WEANING WEIGHT WITHIN EACH HERD

	Principal Component[a]											
	1			2			3			4		
	Herd			Herd			Herd			Herd		
Trait	Angus 1	Hereford	Angus 2	Angus 1	Hereford	Angus 2	Angus 1	Hereford	Angus 2	Angus 1	Hereford	Angus 2
Birth Wt.	.30	.29	.37	.22	.32	.08	-.32	-.17	-.25	.82	.60	-.17
Birth-Wn. ADG	.52	.54	.49	-.24	-.25	-.32	.06	-.03	.00	-.19	-.33	-.18
Weaning Wt.	.56	.58	.52	-.17	-.15	-.27	-.02	-.07	-.06	.02	-.16	-.20
Weaning Conformation	.20	.25	.21	-.51	-.35	-.28	-.09	.17	.63	-.19	.69	.65
Postweaning ADG	.09	-.02	.15	.68	.68	.77	-.10	-.07	.26	-.40	.03	.02
Yearling Wt.	.50	.46	.48	.34	.43	.36	-.09	-.13	.22	-.23	-.14	-.10
Weaning Wt. of First Calf	.16	.13	.24	.14	.21	.15	.93	.95	-.65	.21	-.06	.68
% Total Variation	42.4	39.6	45.2	23.6	25.8	20.7	13.7	13.3	12.6	11.2	11.1	12.1

[a]The entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield principal components 1, 2, 3 or 4.

calf weaning weight. Essentially the first principal component was a measure of growth through yearling due mainly to preweaning influence and a measure of productivity of first parity. This component contrasted heifers above average in birth weight, preweaning ADG, weaning weight, weaning conformation, yearling weight and first parity weaning weight with those heifers below average in these traits. This principal component accounted for 42%, 40%, and 45% of the total variation in original traits for the Angus herd 1, Hereford herd and Angus herd 2, respectively. This was slightly less than the variation accounted for by the first principal component for cow traits that did not include first parity weaning weight.

The second principal component for cow traits including first parity weaning weight contrasted heifers below average in preweaning gain, weaning weight and weaning conformation and above average in birth weight, postweaning gain, yearling weight and first parity calf weaning weight with heifers above average in weaning traits and below average in birth weight, postweaning traits and first parity weaning weight. This component accounted for 24%, 26% and 21% of the original variation in the Angus herd 1, Hereford herd and Angus herd 2, respectively. This is slightly less than the variation accounted for by the second principal component for cow traits that did not include the first parity weaning weight.

The interpretation of the third principal component for cow traits that include first parity weaning weight was perhaps less obvious than the first two principal components. In the Angus herd 1 and Hereford herd this third principal component can be interpreted as, essentially, a measure of prenatal growth and weaning weight of first calf although weaning conformation in the Herefords appears to be of some importance. The third principal component in the Angus herd 2 can be interpreted as a measure of prenatal growth, weaning conformation, postweaning growth and weaning weight of first calf. The third principal component in the Angus herd 1 contrasted heifers below average in birth weight and above average in first calf weaning weight with heifers above average in birth weight and below average in first calf weaning weight. This third principal component in the Hereford herd contrasts heifers below average in birth weight and above average in weaning conformation and first parity weaning weight with heifers above average in birth weight and below average in weaning conformation and first parity weaning weight. In the Angus herd 2, this third principal component contrasts heifers below average in birth weight and first parity weaning weight and above average in weaning conformation, postweaning ADG and yearling weight with heifers above average in birth weight and first parity weaning weight and below average in weaning conformation and postweaning traits. This third principal component in the Angus herd 1 and Hereford herd gave the first parity weaning weight more weight than any other principal component.

The coefficients to the principal components for various combinations of calf weaning weight parity groups, excluding first parity, are given in Table XXII. The interpretations of these coefficients are very similar to those given for parity groupings that included the first parity weaning weight. Because of this strong similarity, interpretations will not be repeated.

Principal component analyses may be a useful technique in studies of this type. It appears from the results of these analyses that it

TABLE XXII

COEFFICIENTS OF PRINCIPAL COMPONENTS FOR CALF WEANING WEIGHTS FOR VARIOUS COMBINATIONS OF PARITY GROUPS FOR THE THREE HERDS

Calf Weaning Wt. Principal Component #1

Parity	Angus 1					Hereford					Angus 2				
	Parity					Parity					Parity				
	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7
2	.71	.57	.47	.41	.39	.71	.58	.50	.43	.41	.71	.59	.49	.47	.43
3	.71	.62	.51	.45	.42	.71	.60	.51	.45	.38	.71	.58	.49	.47	.41
4		.54	.51	.51	.47		.56	.50	.46	.40		.57	.51	.48	.43
5			.51	.45	.45			.48	.45	.44			.51	.45	.40
6				.42	.42				.45	.43				.37	.31
7					.25					.39					.46
% Tot. Var.	68.8	54.8	49.3	44.6	36.6	76.4	65.6	59.6	56.8	54.0	67.8	55.8	51.0	44.6	44.6

Calf Weaning Wt. Principal Component #2

Parity	Angus 1					Hereford					Angus 2				
	Parity					Parity					Parity				
	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7
2	-.71	-.61	.63	.58	-.38	-.71	-.59	-.52	.53	.21	-.71	-.22	.54	-.11	-.12
3	.71	-.12	.38	.45	-.39	.71	-.17	-.42	.51	.60	.71	-.50	.48	.11	.18
4		.78	-.48	-.37	-.13		.79	.30	-.06	.33		.80	-.47	-.27	-.22
5			-.48	-.04	.10			.68	-.43	-.28			-.51	-.57	-.51
6				-.56	.31				-.53	-.19				.76	.79
7					.77					-.61					-.15
% Tot. Var.	31.2	25.1	20.7	18.1	17.6	23.6	18.6	15.7	14.5	15.6	32.2	22.7	18.3	18.1	15.3

[a] The entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield principal component 1 or 2..

could be possible to reduce the number of variables in the cow traits from six original variables to two or three new variables and still account for a major portion of the variation. If the first parity weaning weight is not to be included (perhaps unavailable), it is recommended that only the first two principal components be used. In the case where the first parity weaning weight is included with the cow traits, the first three principal components could be used to account for a comparable portion of the variation even though the interpretation of the third principal component is more difficult and less consistent than the first two principal components. In terms of the principal components for calf weaning weights it appears that the first principal component was the only one with a useful and consistent interpretation. While it does not account for all of the variation in the original calf weaning weights it does account for between 38% to 78% of the total variation. Also this principal component was very repeatable across herds which suggests possibilities of general use.

Correlations among cow traits, principal components for cow traits and principal components for calf weaning weights were calculated for the Angus herd 1, Hereford herd and Angus herd 2 to ascertain the association between these different measures of growth and productivity.

Correlations among cow traits and principal components for calf weaning weights are presented in Table XXIII. The first principal component for calf weaning weight was measure of productivity in terms of weaning weights and contrasted sets of half-sibs above average in weaning weights with sets of half-sibs below average in weaning weight. Cow birth weight was consistently positively associated with

TABLE XXIII

CORRELATIONS AMONG COW TRAITS AND PRINCIPAL COMPONENTS FOR CALF WEANING WEIGHTS FOR VARIOUS COMBINATIONS OF PARITY GROUPS FOR THE THREE HERDS

	Calf Weaning Weight Principal Component #1																	
Cow Trait	Angus 1						Hereford						Angus 2					
	Parity						Parity						Parity					
	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7
Birth Wt.	.12*	.09	.04	.08	.20^{+}	.15	.14^{+}	.17*	.19*	.18^{+}	.07	.15	.30**	.25*	.26*	.37**	.37**	.30^{+}
Birth-Wn. ADG	.17**	.22**	.16*	.18*	.08	.27	.19*	.17*	.18^{+}	.22*	.20	.11	.24**	.24*	.27*	.19	.09	-.09
Weaning Wt.	.18**	.23**	.16*	.18*	.12	.28^{+}	.21**	.20*	.21*	.24*	.20	.13	.28**	.27**	.29**	.24^{+}	.15	-.04
Weaning Conformation	-.01	-.05	-.05	-.08	-.09	.02	.08	.03	.02	-.02	.05	.10	.03	.02	-.06	-.11	-.19	-.26^{+}
Postweaning ADG	.14*	.14*	.13*	.10	.14	.06	.14^{+}	.12	.21*	.13	.07	.22	.28**	.31**	.44**	.43**	.43**	.32^{+}
Yearling Wt.	.24	.27**	.22**	.19*	.20^{+}	.29^{+}	.26**	.23**	.29**	.26*	.16	.23	.32**	.39**	.49**	.37*	.37*	.04

TABLE XXIII (continued)

Cow Trait	Angus 1 Parity 1-2	1-3	1-4	1-5	1-6	1-7	Hereford Parity 1-2	1-3	1-4	1-5	1-6	1-7	Angus 2 Parity 1-2	1-3	1-4	1-5	1-6	1-7
	Calf Weaning Weight Principal Component #2																	
Birth Wt.	.05	-.06	-.04	.03	.08	.09	.03	-.03	-.06	-.10	.03	-.04	-.07	.12	.02	.00	.01	.01
Birth-Wn. ADG	-.04	.01	.00	.08	-.03	-.18	.01	-.07	.01	-.11	-.08	.08	-.11	.11	.10	-.07	-.07	.22
Weaning Wt.	-.03	.00	-.01	.08	-.01	-.16	.02	-.07	.00	-.13	-.07	.07	-.11	.13	.09	-.06	-.06	.21
Weaning Conformation	.06	-.03	.03	.07	.07	-.06	.08	-.09	-.11	-.22*	-.28*	.22	-.10	.14	.10	-.27*	-.27+	.50**
Postweaning ADG	-.01	-.07	.09	-.04	.06	-.12	.12	-.17+	.00	-.09	-.01	-.17	.13	-.03	.03	.10	.24	-.30+
Yearling WT.	.04	-.04	.04	.01	.04	-.14	.10	-.21*	-.08	-.22*	-.10	-.21	-.05	.11	.14	-.04	.06	.02

+ $p < .10$

* $p < .05$

** $p < .01$

the first principal component for calf weaning weight. Cow preweaning ADG and weaning weight were generally positively associated with the first principal component for calf weaning weight. The magnitudes of these correlations were similar to the correlations of cow birth weight with the first principal component for calf weaning weight with the exception of the Angus herd 1. In this herd cow birth weight was lowly associated with the first principal component for calf weaning weight. Cow weaning weight and preweaning ADG were more strongly associated with subsequent productivity than cow birth weight in this herd. The correlation between cow weaning conformation and the first principal component for calf weaning weight were all low. There was some indication that weaning conformation was lowly and negatively associated with subsequent productivity in the Angus but the evidence is inconclusive. Cow postweaning ADG was consistently positively associated with the first principal component for calf weaning weight. The magnitude of this correlation was about the same as that of cow preweaning ADG or weaning weight with the first principal component for calf weaning weights. Cow yearling weight was also consistently positively associated with subsequent productivity. This correlation may be the strongest as compared to the other cow traits mentioned previously.

Correlations between cow traits and the second principal components for calf weaning weights were all low and few were significantly different from zero. Those that were significant had no obviously useful interpretation.

Thus, analyses suggest that yearling weight was the best single trait predictor of productivity as measured by the first principal component for calf weaning weight.

The next set of analyses performed was to ascertain if linear combinations of cow traits that accounted for a major portion of the variation in the original cow traits (first four principal components for cow traits) might describe the association between cow early performance traits and subsequent productivity.

Correlations among the first four principal components for the cow traits and the first two principal components for calf weaning weights are given in Table XXIV. The first principal component for the cow traits was interpreted as a measure of growth through yearling, primarily due to preweaning influences. The second principal component for cow traits was interpreted as a measure of compensatory growth postweaning after poor preweaning growth.

The correlations between the first principal component for the cow traits and first principal component for calf weaning weights were generally positive and significantly different from zero in all three herds. This indicates that heifers heavier than average at birth, weaning and 425 days of age with above average preweaning gain and weaning conformation and average postweaning gain tend to have better than average productivity as measured by the weaning weights of their calves. The correlations of the second principal component for cow traits and the first principal component for calf weaning weights were all positive and many were significantly different from zero. This indicates that heifers above average in birth weight, below average in preweaning ADG, weaning weight and conformation and above average in postweaning ADG and yearling weight tend to have calves heavier at weaning. The correlations of the third and fourth principal components for cow traits with the first principal component for calf

TABLE XXIV

CORRELATIONS AMONG PRINCIPAL COMPONENTS FOR COW TRAITS AND PRINCIPAL COMPONENTS FOR CALF WEANING WEIGHTS FOR VARIOUS COMBINATIONS OF PARITY GROUPS FOR THE THREE HERDS

	Calf Weaning Wt. Principal Component #1																	
Cow Trait	Angus 1						Hereford						Angus 2					
Principal Comp.	Parity						Parity						Parity					
	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7
1	.21**	.25**	.19*	.19*	.16	.33^{+}	.22**	.19*	.19*	.20^{+}	.11	.15	.30**	.36**	.38**	.34**	.21	-.12
2	.14*	.13*	.12^{+}	.10	.18^{+}	.05	.15^{+}	.15^{+}	.21*	.15	.04	.17	.20^{+}	.20^{+}	.31*	.33**	.37**	.33^{+}
3	-.01	-.06	-.07	-.02	.09	-.01	.04	.00	.04	-.02	.06	.15	-.05	-.06	-.16	-.19	-.24	-.26
4	-.03	-.11	-.11	-.13	-.04	-.09	.01	.01	-.02	-.06	-.08	.05	.06	-.05	-.10	-.03	.01	.06

	Calf Weaning Wt. Principal Component #2																	
Cow Trait	Angus 1						Hereford						Angus 2					
Principal Comp.	Parity						Parity						Parity					
	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7
1	-.03	-.03	.00	.06	.04	-.06	.06	-.18*	-.16^{+}	-.33**	-.14	-.10	-.13	.16	.13	-.12	-.09	.25
2	-.02	-.06	.07	-.06	.03	-.11	.10	-.14	-.04	-.13	.03	-.25	.15	-.08	-.02	.18	.28^{+}	-.39*
3	.05	-.04	-.08	.00	.04	.20	.10	-.17*	-.04	-.18	-.28^{+}	-.02	.05	.02	.03	-.23^{+}	-.23	.44**
4	.09	-.08	.00	.01	.12	.08	.05	-.04	-.15	-.13	-.17	.22	.03	.01	-.13	.05	.00	-.03

+ $p < .10$

* $p < .05$

** $p < .01$

weaning weights were genrally low and not significantly different from zero. Correlations between the first four principal components for cow traits and the second principal component for calf weaning weights were also low and generally not significantly different from zero. The first two principal components for cow traits were the most promising predictors of productivity as measured by the first principal component for calf weaning weights.

Correlations among the principal components for cow traits that included the first parity weaning weight and principal components for calf weaning weights excluding the first parity weaning weight were calculated and are presented in Table XXV. The first principal component for cow traits can be interpreted as a measure of growth through a yearling due to preweaning influences and productivity for first calf. The second principal component for cow traits can be interpreted generally as a measure of postweaning compensatory growth after poor weaning performance and productivity for the first parity calf. The third principal component gave considerable weight to the weaning weight of the first calf, positively in the Angus herd 1 and Hereford herd and negatively in the Angus herd 2. Correlations between the first principal component for cow traits and the first principal component for calf weaning weight were generally positive and significantly different from zero. This suggests that heifers with above average birth weight, weaning traits, yearling weight and first parity weaning weight tend to produce calves heavier than average at weaning past the first parity. Correlations between the second principal component for cow traits and the first principal component for calf weaning weight were all positive and many were significantly different from zero.

TABLE XXV

CORRELATIONS AMONG PRINCIPAL COMPONENTS FOR COW TRAITS (INCLUDING WEANING WEIGHT OF FIRST CALF) AND PRINCIPAL COMPONENTS FOR DIFFERENT PARITY GROUPS OF CALF WEANING WEIGHTS FOR THE THREE HERDS

Calf Weaning Wt. Principal Component #1

Cow Trait Principal Comp.	Angus 1 Parity					Hereford Parity					Angus 2 Parity				
	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7
1	.24**	.16*	.18*	.16	.31+	.22*	.21*	.18	.11	.17	.29*	.34**	.34**	.24	-.10
2	.14*	.15+	.11	.19+	.06	.24**	.31*	.24*	.13	.18	.22+	.31*	.38**	.41**	.39*
3	.39**	.36**	.35**	.32**	.36*	.53**	.61**	.58**	.62**	.69**	-.09	-.21+	-.39**	-.38**	-.43*
4	.06	.03	.08	.20+	.16	-.09	-.06	-.09	-.05	.11	-.01	-.05	.03	-.03	-.07

Calf Weaning Wt. Principal Component #2

Cow Trait Principal Comp.	Angus 1 Parity					Hereford Parity					Angus 2 Parity				
	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7
1	.02	.06	-.09	-.07	-.07	-.18*	-.16	-.30**	.06	-.14	.28*	-.16	.04	-.06	-.12
2	-.02	.08	.05	-.03	-.12	-.13	-.06	-.16	-.02	-.32	-.03	.09	.07	.20	.22
3	.01	.01	-.07	.00	-.11	.05	-.13	-.11	.15	-.02	-.10	-.20	.10	-.09	-.24
4	-.08	-.10	-.02	.01	.09	-.18	-.03	-.17	.27+	.02	-.03	-.04	-.13	-.07	-.05

+ $p < .10$

* $p < .05$

** $p < .01$

This suggests that heifers above average in birth weight, postweaning ADG, yearling weight and first parity weaning weight and below average in preweaning ADG, weaning weight and weaning conformation tend to be above average in productivity as measured by the first principal component for calf weaning weights excluding the first parity. Correlations between the third principal component for cow traits and the first principal component for calf weaning weights excluding first parity were generally favorable and significantly different from zero. These correlations appeared to be slightly larger than other correlations derived with cow and calf principal components. This was probably due in part to the large weight given first parity weaning weight in the cow traits and its correlation with subsequent weaning weights. Correlations between the fourth principal component for cow traits and the first principal component for calf weaning weights were low and not significantly different from zero. Likewise, correlations between the first four principal components for cow traits and the second principal components for calf weaning weights were generally small and not significantly different from zero.

The analyses suggest that the third principal component for cow traits that include the first parity weaning weight was most strongly associated (as compared to the other cow principal components) with subsequent productivity as measured by the first principal component for calf weaning weights. The associations with the third principal component are not too surprising in that this principal component gives much weight to the first parity weaning weight. Many studies have indicated that selection of heifers based on weaning weight of the first parity calf would result in some progress (Koger and

Knox 1947; Gregory et al., 1950; Koch 1951; Botkin and Whatley 1953; Dawson et al., 1954; Rollins and Guilbert 1954; McCormick et al., 1956; Whatley 1960; Lueke et al., 1963; Minyard and Dinkel 1965; Drewy and Hazel 1966; Frey et al., 1972; Boston et al., 1975a).

The correlations between the first two principal components for cow traits and the first principal component for calf weaning weights were encouraging. It was surprising that addition of first parity weaning weight into the cow traits made little difference between correlations among the first two principal components for cow traits and principal components for calf weaning weights. The correlations between cow preweaning gain, weaning weight and yearling weight and the first principal component for calf weaning weights were very similar to the correlations between the first component for cow traits and the first principal component for calf weaning weights. Practically, the best prebreeding indicator of productivity as measured by the first principal component for calf weaning weights appears to be heifer yearling weight. Also, if information on the first calf is available, then the best indicator of productivity as measured by the first principal component for calf weaning weights (excluding first parity) appears to be the third principal component for cow traits that includes the first parity weaning weight.

The results of these analyses clearly indicate the difficulty of predicting subsequent productivity from prebreeding performance of heifers. They also indicate that the weaning weight of the first calf is probable needed to predict future productivity with acceptable accuracy. These conclusions agree with other studies concerned with predicting cow productivity (Marchell et al., 1960; Ellicot et al., 1970; Frey et al., 1972; Boston et al., 1975b).

Despite other problems, principal component analysis appear promising in terms of a data reduction technique. Also, as implied by these analyses, principal components may be useful in describing simultaneous interrelationships among traits. In this study it was possible to describe how cow traits were simultaneously associated with subsequent productivity and approximately how strong the association was. Judging from the results of this study further use of principal component analyses in animal science research should be encouraged.

Canonical Correlations

In many research situations variables measured on an animal will fall into two distinct categories. The example pertaining to this research places early heifer performance traits into one category and the subsequent weaning weights of her calves into a second category. It is often desirable to ascertain if a dependency exists between linear combinations of variables in one group and linear combinations of variables in the second group. Previously reported were correlations among certain linear combinations of traits in each group. These linear combinations were subject to the restriction that they account for the maximum original variability in the traits. Canonical correlation analysis develops linear combinations of traits in each group subject to other restrictions. One of these restrictions is that the correlation for the first set of canonical variates, u_1 (a linear combination of traits in the first group) and v_1 (a linear combination of traits in the second group), be maximum among all sets of u_i

uncorrelated with u_1 and v_j uncorrelated with v_1. The second set of canonical variates have the second highest correlation subject to the same restriction of independence as u_1 and v_1. This procedure has the obvious advantage of finding a "weighted average" of traits in the first group that have the highest possible correlation with a "weighted average" of traits in the second group. This, in effect, sets the upper limit to the association between traits in first group and traits in the second group. In this study it essentially sets the upper limit as to how successfully subsequent productivity can be predicted from early cow performance.

Canonical correlation analyses generate two results of interest. For each group of variables, coefficients for each variable in a group are generated. In addition, correlations between the linear combinations of traits in each group are derived. The key to interpretation of these analyses is the magnitude and sign of the coefficients. Suppose, for example, a linear combination of cow weaning weight and yearling weight (u) was positively associated with a linear combination of the first two parity weaning weights (v). Further suppose that the coefficient for heifer weaning weight is negative, the coefficient for heifer yearling weight is positive and the coefficients for the two calf weaning weights are both positive. Since u and v are positively associated, large values of u are associated with large values of v. The new variable, u, for a heifer will be large when her weaning weight is below average and her yearling weight is above average and v will be large when both calves are above average in weaning weight.

Canonical correlation analyses were performed to evaluate the associations between linear combineations of early cow performance traits and linear combination of calf weaning weights. The objectives were to ascertain if interpretable linear combinations of cow traits and calf weaning weights might be found such that the correlation between the two linear combinations is maximized. Hopefully, then, these linear combinations might be useful in predicting productivity from early cow performance.

Table XXVI gives the first canonical correlations between cow birth weight, weaning weight, weaning conformation and postweaning ADG and different parity groupings of calf weaning weights. Separate analyses were performed for the first, two, three, four, five, six and seven parity calves. Analysis did not go beyond seven calves because the number of cows with calves past the seventh parity was low. Preweaning ADG was not included with the cow traits because of its high association with weaning weight. Since yearling weight is a function of weaning weight and postweaning ADG, separate analyses were subsequently performed deleting postweaning ADG and including yearling weight.

In the Angus herd 1, the first canonical variate for cow traits generally contrasts heifers below average in birth weight and weaning conformation and above average in weaning weight and postweaning ADG with heifers opposite in those traits. The first canonical variate for calf weaning weights generally contrasts sets of half-sibs above average in weaning weight with sets of half-sibs below average in weaning weight through the first four parity weaning weights. For the analyses considering the first seven parity weaning weights in the Angus herd 1 interpretations changed slightly. The first canonical variate for cow traits contrasts heifers below average in birth weight and above average in weaning weight, conformation and postweaning ADG

TABLE XXVI

FIRST CANONICAL CORRELATIONS AND COEFFICIENTS BETWEEN COW TRAITS AND CALF WEANING WEIGHTS FOR THE THREE HERDS

	Angus 1						Hereford						Angus 2					
Canonical Corr #1:	.24*	.28+	.29	.30	.35	.43	.31*	.32+	.38+	.40	.41	.50	.42*	.47+	.51	.52	.55	.58
Cow Trait (u)[a]																		
Birth Wt.	.01	-.30	-.29	-.41	-.98	-.57	.05	-.02	-.16	-.15	-.13	-.17	.26	.13	.11	.01	.11	-.92
Weaning Wt.	.92	1.00	1.00	.94	.96	.87	.71	.65	.81	.74	.72	.59	.54	.66	.65	.74	.54	1.00
Weaning Conf.	-.24	-.49	-.40	-.30	-.13	.25	.26	.34	.06	.24	.24	.30	-.09	-.15	-.35	-.41	-.47	.09
Postweaning ADG	.51	.34	.46	.68	.28	.66	.79	.85	.91	.90	.90	.99	.70	.71	.71	.69	.74	.27
Calf Wean. Wt. (v)[a]																		
Parity 1	.72	.33	.47	.48	.44	.17	.11	.23	.01	.11	.13	-.05	.59	.42	.25	.30	.10	.33
Parity 2	.47	.04	.07	.11	-.13	.15	.93	1.00	.71	.78	.79	.40	.70	.45	.32	.32	.24	.37
Parity 3		.67	.55	.50	.49	.28		-.38	-.46	-.41	-.40	-.12		.53	.40	.43	.28	.52
Parity 4			.25	.47	.57	.38			.71	.71	.73	.69			.47	.54	.49	.36
Parity 5				-.38	-.28	-.02				-.43	-.39	-.71				-.23	-.09	-.25
Parity 6					-.88	-.25					-.11	-.33					.42	-.22
Parity 7						-.76						.87						-1.00

[a] Entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield u or v.

with heifers opposite in those traits. The first canonical variate for calf weaning weights contrasts sets of half-sibs above average through the fourth parity and below average from the fifth to the seventh parity with sets of half-sibs below average through the fourth parity and above average from the fifth through seventh parity. In Angus herd 1, these analyses suggest that heifers below average in birth weight and weaning conformation and above average in weaning weight and postweaning ADG tend to produce heavier than average calves at weaning through the first four calves. It also suggests that heifers below average in birth weight and above average in weaning weight, conformation and postweaning ADG tend to produce calves with above average weaning weights through the fourth aprity and with below average weaning weights from the fifth to the seventh parity.

The first canonical variate for cow traits in the Hereford herd generally contrasted heifers below average in birth weight and above average in weaning weight, conformation and postweaning ADG with heifers above average in birth weight and below average in weaning weight, conformation and postweaning ADG. The first canonical variate for calf weaning weights generally contrast sets of half-sibs that are average or above for the first, second, fourth, and seventh parity and below average on the third, fifth and sixth parity with sets of half-sibs with opposite patterns. These analyses in the Hereford herd indicate that heifers with an above average weaning weight (due primarily to above average preweaning ADG), weaning conformation and postweaning ADG tend to produce calves average or above in weaning weight for the first two parities above average for the fourth and seventh parity and below average for the third, fifth and sixth parity.

The first canonical variates through the first six parities in the Angus herd 2 contrast heifers above average in birth weight, weaning weight and postweaning ADG and below average in weaning conformation with heifers that are opposite in those traits. The positive weight given to birth weight in this herd is probably due to the slightly higher correlations between heifer birth weight and subsequent productivity as shown in Table XXVI. The first canonical variates for calf weaning weights through the fourth parity contrast sets of half-sibs that are above average in weaning weight with sets of half-sibs that are below average. The first canonical variates for the first five and six parities contrast sets of half-sibs with half-sibs having opposite patterns. The first canonical variate for the first seven parities weaning weights in the Angus herd 2 contrasted sets of half-sibs above average for the first four parities and below average for the last three parities with sets of half-sibs below average for the first four parities and above average for the last three. The results of these analyses in the Angus herd 2 indicated that heifers above average in birth weight, weaning weight and postweaning ADG and below average in weaning conformation tend to have above average calves through the fourth parity and above average on the sixth parity. The results also indicate that heifers below average in birth weight and above average in weaning weight and postweaning ADG tend to have calves above average for the first four parities and below average subsequently through the seventh.

Table XXVII gives the results on the second canonical correlations for the Angus herd 1, Hereford herd and Angus herd 2. Most of these second canonical correlations in this analysis were low and none were

TABLE XXVII

SECOND CANONICAL CORRELATIONS AND COEFFICIENTS FOR COW TRAITS AND CALF WEANING WEIGHTS FOR THE THREE HERDS

	Angus 1						Hereford						Angus 2					
Canonical Corr #2:	.11	.16	.19	.23	.26	.30	.08	.13	.17	.22	.22	.22	.16	.16	.25	.31	.32	.55
Cow Trait (u)[a]																		
Birth Wt.	.74	.74	.49	-.22	.39	.87	.64	.58	.15	.11	.16	.13	-.28	-.37	.20	.82	-.59	.31
Weaning Wt.	-.65	-.27	-.42	-.62	.34	-.35	-.18	.45	-.47	-.50	-.54	-.63	-.36	-.28	.16	-.52	1.00	.30
Weaning Conf.	.80	.63	.75	.55	-.18	.30	-.70	-.67	1.00	1.00	1.00	1.00	-.43	-.46	.87	.76	.18	-.50
Postweaning ADG	.45	.56	.75	.78	.72	.53	.09	-.37	.11	-.08	-.09	-.09	.60	.59	-.05	.12	-.13	.70
Calf Wean. Wt. (v)[a]																		
Parity 1	-.82	.01	-.19	-.17	.25	-.23	1.00	.03	.20	.27	.29	.26	-.83	-.89	.80	.25	.79	.02
Parity 2	.98	1.00	.80	.26	.41	.48	-.75	-.36	.90	.57	.57	.41	.74	.65	.10	.20	.06	.18
Parity 3		-.61	-.75	-.45	.11	-.36		1.00	-.50	-.14	-.12	-.07		.12	.24	-.10	.63	.17
Parity 4			.60	.74	.25	-.15			-.84	-.63	-.63	-.66			-.86	-.68	.04	.42
Parity 5				-.85	-.24	.10				-.75	-.70	-.71				.91	-.70	-.03
Parity 6					.55	.99					-.10	-.14					-.77	.48
Parity 7						-.37						.18						.20

[a] Entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield u or v.

significantly different from zero. In addition, interpretations of the majority of the analyses were even more difficult than the first. The second canonical correlation involving cow traits and the first seven parities in Angus herd 2 was of interest, however. The signs and magnitudes of the coefficients for the second canonical variable for cow traits were very similar to those of the first five first canonical variables for cow traits in Angus herd 2. Consequently, most of the signs on the coefficients for the second canonical variate for calf traits were positive as they were on the first five first canonical variates for calf weaning weights. Also, the first and second canonical correlations were not largely different (.58 vs. .55) although neither was significantly different from zero because of the low numbers involved.

The canonical correlation analyses were repeated substituting heifer yearling weight for heifer postweaning ADG and are reported in Table XXVIII and Table XXIX . The results of these analyses were very comparable to the previous analyses. One difference however, was that heifer weaning weight was given less weight in the cow canonical variates. Also, more weight was placed on yearling weight than was placed on postweaning ADG. Another difference was that the cow canonical variates in the Herefords had a negative weight given to heifer weaning weight. This probably indicates that more importance is being placed on yearling weight due to postweaning ADG than on yearling weight due to a heavy weaning weight.

The results of these analyses suggest that selection of Angus heifers based on the first canonical variate might be moderately successful in terms of picking heifers that would be above average in

TABLE XXVIII

FIRST CANONICAL CORRELATIONS AND COEFFICIENTS BETWEEN COW TRAITS AND CALF WEANING WEIGHTS FOR THE THREE HERDS

	Angus 1						Hereford						Angus 2					
Canonical Corr #1:	.24+	.28+	.29	.32	.36	.39	.29*	.32+	.33	.36	.39	.55	.36	.46	.48	.48	.49	.63
Cow Trait (u)[a]																		
Birth Wt.	-.03	-.32	-.33	-.52	-.97	-.77	.08	-.05	-.08	-.09	.00	-.14	.45	.16	.18	.18	.29	-.78
Weaning Wt.	.38	.69	.50	-.42	.39	.51	-.05	-.31	-.17	-.26	-.43	-.67	.12	.04	.08	.07	-.14	.54
Weaning Conf.	-.25	-.48	-.39	-.08	-.08	.11	.31	.43	.29	.51	.50	.44	-.11	-.20	-.37	-.36	-.45	.07
Yearling Wt.	.72	.52	.70	1.00	.66	.61	.93	1.00	1.00	1.00	1.00	1.00	.62	.91	.86	.87	.92	.73
Calf Wean. Wt. (v)[a]																		
Parity 1	.78	.54	.49	.45	.47	.32	.16	.34	.23	.34	.39	.08	.76	.43	.31	.31	.13	.24
Parity 2	.39	-.01	.00	.06	-.12	.00	.91	1.00	.91	.94	.90	.30	.51	.17	.10	.10	.04	.29
Parity 3		.68	.57	.37	.47	.41		-.57	-.59	-.50	-.46	-.06		.72	.62	.62	.49	.61
Parity 4			.26	.66	.65	.45			.32	.32	.38	.39			.36	.35	.33	.29
Parity 5				-.74	-.44	-.11				-.55	-.33	-.66				.01	.13	-.02
Parity 6					-.79	-.52					-.48	-.65					.35	-.11
Parity 7						-.54						1.00						-1.00

[a] Entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield u or v.

TABLE XXIX

SECOND CANONICAL CORRELATIONS AND COEFFICIENTS FOR COW TRAITS AND CALF WEANING WEIGHTS FOR THE THREE HERDS

	Angus 1						Hereford						Angus 2					
Canonical Corr #2	.10	.15	.18	.25	.29	.29	.08	.15	.19	.22	.22	.22	.10	.17	.25	.33	.33	.48
Cow Trait (u)[a]																		
Birth Wt.	.86	.81	.49	.10	.26	.18	.54	.57	-.12	-.07	-.04	.10	-.21	-.87	.00	.61	.72	.67
Weaning Wt.	-.90	-.76	-1.00	1.00	-1.00	-1.00	-.43	1.00	-1.00	-.81	-.86	.98	.67	-.38	-.09	-.94	-1.00	-.46
Weaning Conf.	.76	.61	.79	-.61	.41	.12	-.68	-.51	.91	.92	.90	-.73	.81	-.37	.97	.84	.72	-.52
Yearling Wt.	.41	.66	1.00	-.70	1.00	1.00	-.26	-.57	.42	.02	.03	-.06	-.49	.79	.21	.40	.40	.71
Calf Wean. Wt. (v)[a]																		
Parity 1	-.76	.08	-.13	.29	.12	.15	1.00	-.17	.36	.27	.29	-.22	.68	-.82	.65	.05	-.15	-.03
Parity 2	1.00	1.00	.72	-.09	.29	.26	-.78	-.07	.44	.22	.18	.12	-.88	-.31	.06	.05	.02	-.04
Parity 3		-.62	-.77	.55	-.13	-.11		1.00	-.65	-.24	-.23	.17		.77	.31	-.03	-.18	.22
Parity 4			.66	-.48	.44	.50			-.86	-.75	-.75	.75			-.98	-.82	-.77	.27
Parity 5				.70	-.71	-.79				-.50	-.44	.33				.98	1.00	.25
Parity 6					.63	.56					-.09	.14					.21	.50
Parity 7						.06						-.21						.30

[a] Entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield u or v.

productivity through the fourth parity. There was also some indication in the Angus that the first canonical variate for cow traits derived from the analyses involving the first four parity calves might be the best for predicting future productivity from heifer prebreeding traits. Thus, it might be recommended to select Angus heifers that are above average in weaning weight and either postweaning ADG or yearling weight and below average in weaning conformation. The results from the analyses of the Hereford data do not appear to be very useful in terms of predicting productivity because of the alternating signs on the coefficients for the calf weaning weight canonical variate. These analyses do set the upper limit to the correlations that can be obtained between linear combinations of cow prebreeding traits and linear combinations of subsequent calf weaning weights. Consequently, it is evident that at best, only moderate success can be expected in terms of predicting productivity from prebreeding traits.

Canonical correlation analyses were also performed including the weaning weight of the first calf in with the cow traits. The results of the first canonical correlations are presented in Table XXX for the Angus herd 1, Hereford herd and Angus herd 2. Correlations between linear combinations of cow traits including first parity weaning weight and subsequent calf weaning weights were done sequentially for the second and third parity, second through fourth parity, second through fifth parity, second through sixth parity and second through seventh parity.

Inclusion of the first parity weaning weight in the cow traits nearly doubled the strength of the canonical correlations as compared to the canonical correlations that did not include first parity weaning

TABLE XXX

FIRST CANONICAL CORRELATIONS AND COEFFICIENTS FOR COW TRAITS (INCLUDING FIRST PARITY WEANING WEIGHT) AND SUBSEQUENT CALF WEANING WEIGHTS IN THE THREE HERDS

	Angus 1					Hereford					Angus 2				
Canonical Corr #1:	.47**	.49**	.52*	.55	.57	.64**	.67**	.69**	.69**	.71**	.45	.51	.56+	.63	.63
Cow Trait (u)[a]															
Birth Wt.	-.01	-.03	.09	.29	.18	.04	.01	.02	.01	-.04	.02	.07	.27	.32	.79
Weaning Wt.	.12	.01	.23	.03	.12	.13	.17	.18	.20	-.01	-.06	.02	-.33	-.43	-.68
Weaning Conf.	-.07	-.02	-.05	-.06	.04	.02	-.04	-.10	-.11	.01	-.27	-.47	-.17	-.24	-.24
Yearling Wt.	.20	.32	-.01	.00	.08	.04	.07	.02	-.01	.31	.89	.69	.62	.56	-.02
Wean. Wt. First Calf	.90	.89	.92	.92	.90	.95	.94	.96	.96	.91	.35	.46	.67	.72	.64
Calf Wean. Wt. (v)[a]															
Parity 2	.64	.57	.50	.46	.44	.61	.48	.39	.37	.30	.28	.14	.08	-.03	-.21
Parity 3	.57	.44	.37	.27	.28	.54	.37	.34	.34	.37	.87	.58	.35	.14	-.28
Parity 4		.32	.11	-.07	-.07		.38	.30	.27	.34		.57	.25	.17	-.06
Parity 5			.42	.40	.46			.25	.21	-.06			.64	.61	.48
Parity 6				.41	.41				.11	-.10				.52	.47
Parity 7					-.38					.48					.71

[a] Entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield u or v.

weight in with the cow traits. The first canonical variate generally contrasts heifers above average in weaning weight, postweaning gain and first parity calf weaning weight and average or below in weaning conformation with heifers opposite in those traits. The first canonical variate for calf weaning weights was not as consistent over all herds. However, the signs of the coefficients were generally favorable. The first canonical variate in Angus herd 1 generally contrasts sets of half-sibs above average through the sixth parity and below average on the seventh with sets of half-sibs with an opposite pattern. In the Hereford herd, the first canonical variate contrasts sets of half-sibs above average through the fourth parity, average or above on the fifth and sixth parity and above average on the seventh parity with sets of half-sibs having opposite patterns. The first canonical variate in the Angus herd 2 contrasts sets of half-sibs average or above for the second through the seventh parity with sets of half-sibs of opposite pattern. These analyses indicate that heifers above average in weaning weight, postweaning gain and first calf weaning weight tend to be above average in subsequent production. The canonical correlation appears to be stronger in the Herefords than in the Angus. This was probably due to the higher and more consistent correlations among half-sib weaning weights in the Herefords (Table XVI)indicated a higher repeatibility of calf weaning weight for Herefords as was shown by Boston et al. (1975a).

Table XXXI gives the results for the second canonical correlations among cow traits including first calf weaning weights and the calf weaning weights from the second through the seventh parities. These analyses were difficult to interpret and do not appear promising in terms of predicting productivity from early cow performance.

TABLE XXXI

SECOND CANONICAL CORRELATIONS AND COEFFICIENTS FOR COW TRAITS (INCLUDING FIRST PARITY WEANING WEIGHT) AND SUBSEQUENT CALF WEANING WEIGHTS IN THE THREE HERDS

	Angus 1					Hereford					Angus 2				
Canonical Corr #2	.19	.19	.25	.33	.40	.24[+]	.27	.34	.34	.42	.11	.18	.41	.42	.56
Cow Trait (u)[a]															
Birth Wt.	-.78	-.66	-.54	-1.00	-.84	-.25	-.39	-.25	-.20	-.20	-.72	-.08	.54	.53	-.81
Weaning Wt.	.89	.86	.17	.90	.75	.42	.60	.56	.53	.35	1.00	.28	-.93	-.98	1.00
Weaning Conf.	-.79	-.84	.15	-.06	.30	.59	.24	.53	.53	.52	-.07	.84	.63	.62	-.14
Postweaning ADG	-.23	-.39	1.00	.26	.54	.93	1.00	.89	.90	.96	-.36	.43	-.41	-.44	.53
Wean. Wt. First Calf	-.18	-.11	-.11	.05	-.28	-.30	-.39	-.32	-.32	-.42	.12	-.29	.57	.53	.04
Calf Wean. Wt. (v)[a]															
Parity 2	-.86	-.71	.15	.00	-.07	.99	.57	.78	.80	.27	-.92	.51	-.16	-.21	.41
Parity 3	.93	1.00	.09	.59	.20	-1.00	-1.00	-.73	-.71	-.47	.84	.61	-.39	-.45	.56
Parity 4		-.32	.86	.62	.49		.57	.57	.61	.50		-.90	-.58	-.62	.54
Parity 5			-.96	-.19	-.23			-.77	-.70	-.94			1.00	1.00	-.13
Parity 6				-.88	-.60				-.17	-.40				.09	.08
Parity 7					-.61					.80					-.94

[a] Entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield u or v.

Yearling weight was substituted for postweaning ADG in the cow traits including first calf weaning weight. The results of these analyses were presented in Tables XXXII and XXXIII . Basically, these analyses were very comparable to those done using cow postweaning ADG. Consequently, the results from these will not be discussed separately.

These canonical correlation analyses illustrate some of the inherent problems in multivariate analyses. There are only two types of constraints imposed in canonical correlation analyses. The first constraint states that the first canonical variates (u_1 and v_1), which are linear combinations of traits in each group, have the highest possible correlations. Also, the second canonical variates (u_2 and v_2) have the second highest possible correlation, the third set of canonical variates have the third highest possible correlation, etc. In turn, these correlations are derived under the constraints that u_i and u_j, v_i and v_j, and u_i and v_j are all uncorrelated for $i \neq j$. In effect, then, this procedure derives coefficients for the original traits only to satisfy the above contraints and, consequently, the resultant analyses may not always have a useful interpretation.

These results do indicate that, in the Angus, selection of heifers above average in weaning weight and postweaning ADG and below average in weaning conformation tend to be above average in productivity through at least the fourth parity. This seems reasonable in that high values of first canonical variate for heifer prebreeding traits generally describe heifers superior in growth ability at all ages measured but slightly below average in conformation at weaning. These analyses also indicate that, in all herds, selection of heifers with above average weaning weight, postweaning ADG and first calf weaning weight and

TABLE XXXII

FIRST CANONICAL CORRELATIONS AND COEFFICIENTS FOR COW TRAITS (INCLUDING FIRST PARITY WEANING WEIGHT) AND SUBSEQUENT CALF WEANING WEIGHT IN THE THREE HERDS

	Angus 1					Hereford					Angus 2				
Canonical Corr #1:	.47**	.50**	.52*	.55	.59	.64**	.68**	.69**	.70**	.72*	.46+	.54+	.56+	.64	.65
Cow Trait (u)[a]															
Birth Wt.	-.01	-.03	.06	.27	.11	.02	-.03	-.03	-.04	-.07	.00	.02	.18	.23	-.51
Weaning Wt.	.28	.26	.23	.04	.23	.19	.28	.25	.25	.27	.55	.50	.26	.07	.30
Weaning Conf.	-.06	-.02	-.03	-.04	.10	.03	-.02	-.07	-.07	.00	-.22	-.42	-.26	-.29	.29
Postweaning ADG	.17	.25	.09	.07	.25	.12	.21	.16	.16	.30	.69	.60	.51	.49	-.35
Wean. Wt. First Calf	.89	.88	.91	.92	.85	.94	.90	.93	.93	.88	.34	.41	.60	.665	-.64
Calf Wean. Wt. (v)[a]															
Parity 2	.65	.58	.51	.47	.45	.63	.50	.43	.42	.30	.55	.30	.24	.10	.05
Parity 3	.56	.43	.36	.27	.27	.51	.31	.29	.29	.33	.66	.41	.29	.09	.08
Parity 4		.32	.14	-.04	-.01		.43	.35	.33	.39		.61	.44	.30	-.13
Parity 5			.38	.37	.41			.21	.18	-.07			.41	.44	-.44
Parity 6				.40	.39				.09	-.05				.55	-.54
Parity 7					-.46					.44					-.42

[a] Entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield u or v.

TABLE XXXIII

SECOND CANONICAL CORRELATIONS AND COEFFICIENTS FOR COW TRAITS (INCLUDING FIRST PARITY WEANING WEIGHT) AND SUBSEQUENT CALF WEANING WEIGHT IN THE THREE HERDS

	Angus 1					Hereford					Angus 2				
Canonical Corr #2:	.18	.19	.30	.33	.37	.26*	.26	.33	.35	.51	.13	.23	.38	.38	.62
Cow Trait (u)[a]															
Birth Wt.	-.82	-.71	-.55	-1.00	-.92	-.26	-.27	-.18	-.07	-.17	.95	-.33	.44	.44	-.46
Weaning Wt.	1.00	1.00	-.98	.42	.50	-.57	-.57	-.39	-.54	-.81	-.16	-.25	-.78	-.78	.15
Weaning Conf.	-.78	-.84	.16	-.03	.20	.61	.61	.72	.65	.53	-.18	.64	.79	.76	-.10
Yearling Wt.	-.16	-.43	1.00	.57	.47	1.00	1.00	1.00	1.00	1.00	-.68	.88	-.31	-.36	.92
Wean. Wt. First Calf	-.22	-.16	-.06	.06	.13	-.23	-.23	-.18	-.17	-.37	.44	-.36	.36	.35	.35
Calf Wean. Wt. (v)[a]															
Parity 2	-.87	-.73	.12	.02	-.07	1.00	1.00	1.00	1.00	.18	1.00	-.05	-.02	-.04	.20
Parity 3	.92	1.00	.20	.60	.38	-1.00	-1.00	-.62	-.55	-.25	-.63	.87	-.53	-.58	.57
Parity 4		-.29	.83	.70	.50		.00	.22	.35	.25		-.84	-.70	-.70	.34
Parity 5			-.95	-.32	-.15			-.72	-.43	-.74			.93	.89	.37
Parity 6				-.81	-.69				-.52	-.69				.07	.25
Parity 7					-.51					1.00					-.83

[a] Entries in each column are coefficients for the respective traits. Thus, the sum of the standardized traits weighted by their respective coefficients yield u or v.

average weaning conformation tend to be above average in subsequent productivity. This again makes sense in that high values of this first canonical variate generally describe heifers superior in growth at all ages measured and an indication of superior productivity as measured by the weaning weight of their first calf.

The canonical correlation analyses suggest some general useful results. Firstly, it is suggested that there is a low association between the cow prebreeding traits reported in this study and their subsequent calf weaning weights. In that the first canonical correlation is an estimate of the maximum correlation that exists between these two sets of traits, this suggests that identification, based on prebreeding records, of cows superior in production would be only moderately successful. If an antagonism exists between early heifer performance and subsequent productivity as indicated by other workers, then this could explain this low association. These analyses also suggest that, at this maximum level of association, cow prebreeding traits indicative of early productivity are not especially indicative of productivity at later ages. This, in turn, suggests that the association between heifer prebreeding traits and subsequent productivity is lower than are the canonical correlations. Further research is needed into the aspect of different patterns of heifer prebreeding performance resulting in different patterns of productivity.

Discriminant Functions

Linear discriminant analysis is a multivariate method used to classify individuals into populations using a linear combination of variables observed on the individuals. For example, it may be desired to classify heifers into calf calving difficulty categories based on prebreeding pelvic measurements and growth traits. If growth measurements were available on a group of heifers in addition to calving difficulty scores for their first calf, then a linear discriminant function could be computed for future classification of other heifers into calving difficulty categories. The success of such classification procedures is dependent upon how well the discriminant function is able to differentiate among individuals in the population. The procedure develops coefficients for the variables measured on an individual such that the generalized squared distances are maximized between sample means of the various subpopulations In other words, observations are mapped from multivariate space into one-space in such a manner that the distances between the new "mapped" sample means are maximized relative to the variation in the original traits.

It was of interest in this study to ascertain if heifers could be classified into populations of productivity as measured by calf weaning weights using heifer growth and performance early in life. The Angus herd 1, Hereford and Angus herd 2 were each divided into quartiles based on the total pounds of calves weaned. These divisions were done on the basis of the first two, three, four, five, six and seven calves. Thus, six separate analyses were performed; one for each of the six different parity groupings for each herd. Heifer traits used to differentiate between productivity quartiles were birth weight, weaning weight, weaning conformation and postweaning ADG. Preweaning ADG and yearling weight were not included due to their high correlation with weaning weight and postweaning ADG, respectively. Inclusion of highly correlated traits may result in matrix singularities during the solution for finding the discriminant functions. In another set of analyses quartiles of productivity were formed by the division of the three herds into quartiles based on productivity from the second through third, fourth, fifth, sixth and seventh parity. Thus, five separate analyses were performed using the five parity groupings for each herd. In this set of analyses heifer birth weight, weaning weight, weaning conformation, postweaning ADG and first parity weaning weight were used to differentiate among the different quartiles of productivity as measured by total pounds of calf weaned.

Quartiles of productivity were chosen to be of interest in that a breeder may wish to keep the top 25 percent of his heifers, sell the second 25 percent as replacement heifers and sell the rest as feeders or for slaughter. Alternately, he may want to cull the bottom 25 percent of his heifers based on their prebreeding growth, calve out the remainder and save the top 25 percent to 50 percent based on early growth and first calf weaning weight. There are many useful alternatives to this method if successful discrimination between the qurtiles can be made. Subsequently, first quartile will refer to the top 25 percent of a herd, second quartile to the next 25 percent, third quartile to the next lower 25 percent and fourth quartile to the bottom 25 percent of the herd.

Linear discriminant functions developed from heifer prebreeding traits to classify heifers into quartiles of productivity are presented in Table XXXlV for the Angus herd 1, Hereford herd and Angus herd 2, respectively. When the pooled variance-covariance matrix is used, these linear discriminant functions can be used in a manner analogous to multiple linear regression. Four new variables were generated for

TABLE XXXIV

LINEAR DISCRIMINANT FUNCTIONS DEVELOPED FROM HEIFER TRAITS TO CLASSIFY EACH PARITY GROUP INTO QUARTILES OF PRODUCTIVITY AS MEASURED BY TOTAL POUNDS OF CALF WEANED

Parity	Trait	Angus Herd 1				Hereford Herd				Angus Herd 2			
		Quartile				Quartile				Quartile			
		1	2	3	4	1	2	3	4	1	2	3	4
	Constant	-366.86	-360.94	-356.75	-356.08	-342.88	-340.71	-332.59	-332.60	-	-	-	-
	Birth Wt.	.39	.40	.38	.39	.31	.27	.30	.31	-	-	-	-
1-2	Weaning Wt.	.40	.37	.37	.37	.50	.49	.49	.48	-	-	-	-
	Weaning Conf.	33.78	34.10	34.10	34.16	26.93	27.28	26.73	26.91	-	-	-	-
	Postweaning ADG	118.38	117.96	117.96	115.07	108.63	106.61	105.36	106.24	-	-	-	-
	Constant	-378.48	-371.20	-366.46	-371.12	-347.74	-333.90	-342.23	-338.20	-	-	-	-
	Birth Wt.	.35	.34	.39	.38	.39	.34	.37	.38	-	-	-	-
1-3	Weaning Wt.	.42	.39	.39	.39	.53	.51	.52	.50	-	-	-	-
	Weaning Conf.	35.11	35.51	35.19	35.71	26.46	26.71	26.71	26.68	-	-	-	-
	Postweaning ADG	115.93	116.88	115.48	114.51	104.06	101.03	101.03	101.95	-	-	-	-
	Constant	-429.78	-425.74	-425.74	-423.44	-343.81	-326.17	-333.64	-329.17	-237.99	-214.71	-210.25	-209.27
	Birth Wt.	.58	.57	.63	.59	.26	.23	.23	.27	- .06	.01	.01	- .06
1-4	Weaning Wt.	.52	.50	.50	.49	.56	.54	.54	.53	.42	.40	.37	.38
	Weaning Conf.	36.89	37.49	37.27	37.57	24.66	24.66	24.91	24.95	11.24	10.71	11.24	11.56
	Postweaning ADG	145.44	145.58	145.09	143.10	111.12	106.19	107.45	105.56	129.50	120.37	120.87	117.34
	Constant	-	-	-	-	-315.78	-311.71	-302.78	-306.28	-218.08	-203.09	-197.15	-199.44
	Birth Wt.	-	-	-	-	.50	.37	.45	.44	.08	.14	.14	- .05
1-5	Weaning Wt.	-	-	-	-	.48	.49	.47	.47	.32	.31	.30	.31
	Weaning Conf.	-	-	-	-	22.85	23.17	22.84	23.16	12.96	12.26	12.51	13.29
	Postweaning ADG	-	-	-	-	95.06	94.50	90.11	93.14	112.18	106.90	104.05	104.68

TABLE XXXIV (continued)

Parity	Trait	Angus Herd 1 Quartile 1	2	3	4	Hereford Herd Quartile 1	2	3	4	Angus Herd 2 Quartile 1	2	3	4
	Constant	-472.90	-463.91	-467.52	-458.96	-364.03	-365.25	-349.30	-366.35	-306.30	-289.36	-287.32	-279.25
	Birth Wt.	1.18	1.19	1.19	1.13	.50	.62	.59	.61	.81	.68	.81	.62
1-6	Weaning Wt.	.65	.62	.63	.63	.56	.55	.55	.54	.43	.42	.42	.41
	Weaning Conf.	35.19	35.48	35.30	35.13	26.96	26.86	26.10	27.35	15.84	15.84	15.45	16.21
	Postweaning ADG	162.07	158.38	158.49	157.69	114.48	112.03	109.82	111.68	157.47	153.76	151.15	146.60
	Constant	-602.97	-556.26	-557.55	-565.17	-384.55	-377.55	-359.21	-381,12	-430.76	-416.43	-402.68	-402.18
	Birth Wt.	1.40	1.44	1.43	1.42	1.94	1.92	1.86	2.01	1.71	1.73	1.72	1.74
1-7	Weaning Wt.	.77	.67	.67	.62	.35	.35	.35	.35	.61	.57	.57	.58
	Weaning Conf.	54.11	53.81	53.92	54.13	29.98	29.58	28.67	29.90	21.67	21.91	21.23	22.24
	Postweaning ADG	64.02	62.00	59.22	60.83	78.53	77.67	77.14	73.73	208.23	203.61	201.13	199.05

each observation, each new variable corresponding to a particular quartile. These four new variables were generated by multiplying the coefficient vector (d_i) for each quartile times the observation vector (χ) and adding the appropriate constant (c_i) ($c_i + \chi' d_i$). Classification into a quartile is done by assigning the observation into the quartile with the largest new discriminant variable. When a pooled variance-covariance matrix is not used because of heterogeneity of the within quartile covariance matrices, posterior probabilities of group membership would be used for classification. Four posterior probabilities are computed for each observation in these analyses and a heifer is assigned to the quartile with the highest posterior probability of group membership.

Interpretation of the four discriminant vectors developed for each herd and parity grouping is difficult due, in part, to the fact that the discriminant vectors were developed from the variance-covariance matrix. Thus, the coefficients were developed as weighting factors for original traits and thus are not easily comparable in terms of relative importance. Also, the constants associated with each vector are not the same because the group means change and this must be considered in the interpretation of the vectors. In three of the herd-parity groups, heterogeneity of variance-covariance matrices was detected and linear discriminant functions were not developed. Heterogeneity of variance-covariance matrices can be due to a single difference among the variances and covariances or it can be due to the cumulative effects of several differences. It is difficult to exactly pinpoint where these differences exist and it was considered more useful to look for patterns of differences.

In Angus herd 1, for the analysis involving the first through fifth parity calves (Appendix Table LXVI), it appeared that the associations between heifer birth weight and heifer weaning weight and weaning conformation and postweaning ADG were different among the four quartiles of productivity. The only possible pattern suggested was that the covariances between birth weight and weaning weight and between birth weight and postweaning ADG and the variation among heifer weaning weights were larger for the more productive heifers. In the Angus herd 2, for the analysis involving the first and second parities (Appendix Table LXVIII) it appeared that associations between birth weight and weaning conformation were smaller for the more productive heifers with the exception of the fourth quartile. In this same herd for the analysis involving the first three calves (Appendix Table LXIX), it appeared that the associations between birth weight and weaning weight and weaning conformation were lower in the second quartile as compared to the other quartiles. Also in the Angus herd 2, in the analyses involving the first five parity calves (Table LXX), it appears that the covariances between birth weight and weaning conformation were higher in the middle two quartiles, the covariance between birth weight and postweaning ADG was higher in the second quartile, the variances of weaning weight and conformation were higher in the first and third quartile and the covariances of weaning weight with weaning conformation and postweaning ADG appeared larger in the first and third quartile.

Coefficients for the linear discriminant functions were reasonably comparable across the three herds as best could be determined. It is very difficult to evaluate patterns of differences because the constants involved in the discriminant function change and relative magnitudes of the coefficients also change. The same also applies to the comparing of different analyses within herds. As the relative magnitudes of the coefficients change across the different parity grouping, the constants for each discriminant function also change due to the change in the group means. Also, in cases where the within covariance matrices were used, there are no functions to compare. Thus, the best way to evaluate these discriminant functions is to evaluate them on the basis of successful classification into the different productivity groups.

Table XXXV presents classification results for the six parity grouping analyses for the Angus herd 1, Hereford herd and Angus herd 2. The numbers in the table are the proportion of heifers actually in a given quartile of productivity that were correctly classified by the discriminant function into that quartile of productivity. For example, there were 69 heifers in the Angus herd 1 in the upper 25 percent. Thirty-three of these heifers or 47.8 percent were classified into the first quartile of productivity by the discriminant function. Proportions of correct classifications are given in blocks down the diagonal. The actual numbers of heifers classified are given in Table XXXVI.

There was some evidence that proportions of correct classifications were different among the quartiles in some of the herd-parity group classes. In Angus herd 1 the proportions correctly classified differed among the quartiles for the analyses involving the first two calves ($P < .01$), the first three calves ($P < .10$), the first four calves ($P < .10$), the first six calves ($P < .05$) and the first seven calves ($P < .10$). In general, it appeared that the proportions of correct classifications were higher for the first and fourth quartiles than in the

TABLE XXXV

PERCENTAGE OF HEIFERS FROM EACH QUARTILE OF PRODUCTIVITY AS MEASURED BY TOTAL POUNDS OF CALF WEANED CLASSIFIED INTO QUARTILES BY DISCRIMINANT FUNCTIONS FOR EACH PARITY GROUP

		Classified Into Quartile[a]:																							
From Quartile[a]	Herd	1						2						3						4					
		Parity						Parity						Parity						Parity					
		1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7
	Angus 1	47.8	48.2	50.0	51.5	52.4	87.5	24.6	18.5	22.7	12.1	19.0	0.0	14.5	13.0	11.4	18.2	4.8	12.5	13.0	20.4	15.9	18.2	23.8	0.0
1	Hereford	42.1	45.2	58.3	47.1	40.0	50.0	15.8	25.8	20.8	11.8	30.0	16.7	21.0	9.7	4.2	17.6	10.0	16.7	21.0	19.4	16.7	23.5	20.0	16.7
	Angus 2	59.1	58.8	62.5	57.1	54.6	50.0	18.2	11.8	18.8	14.3	27.3	12.5	13.6	23.5	12.5	14.3	9.1	25.0	9.1	5.6	6.2	14.3	9.1	12.5
	Angus 1	29.2	24.6	24.4	26.3	21.7	11.1	26.4	26.3	24.4	29.0	21.7	33.3	9.7	22.8	20.0	26.3	8.7	33.3	34.7	26.3	31.1	18.4	47.8	22.2
2	Hereford	25.7	19.4	7.4	15.8	8.3	40.0	37.1	41.9	33.3	42.1	25.0	0.0	20.0	22.6	22.2	26.3	41.7	40.0	17.1	16.1	37.0	15.8	25.0	20.0
	Angus 2	9.1	0.0	6.2	23.1	8.3	33.3	63.6	82.4	50.0	46.2	41.7	22.2	4.6	11.8	18.8	15.4	25.0	33.3	22.7	5.6	25.0	15.4	25.0	11.1
	Angus 1	21.4	17.2	29.6	14.7	36.4	25.0	27.1	27.6	13.6	17.6	36.4	25.0	11.4	31.0	27.3	52.9	18.2	37.5	40.0	24.1	29.6	14.7	9.1	12.5
3	Hereford	24.3	28.1	28.0	10.5	25.0	0.0	29.7	37.5	20.0	15.8	16.7	16.7	27.0	12.5	20.0	47.4	50.0	66.7	18.9	21.9	32.0	26.3	8.3	16.7
	Angus 2	13.6	17.6	18.8	14.3	20.0	11.1	13.6	17.6	25.0	35.7	20.0	33.3	59.1	41.2	31.2	28.6	40.0	44.4	13.6	23.5	25.0	21.4	20.0	11.1
	Angus 1	26.8	25.0	19.6	16.7	30.4	25.0	14.1	21.4	23.9	22.2	21.7	25.0	11.3	14.3	21.7	22.2	4.4	25.0	47.9	39.3	34.8	38.9	43.5	25.0
4	Hereford	26.3	21.2	11.5	15.8	23.1	16.7	26.3	27.3	30.8	26.3	7.7	0.0	21.0	18.2	23.1	10.5	23.1	16.7	26.3	33.3	34.6	47.4	46.2	66.7
	Angus 2	13.6	5.6	6.2	14.3	9.1	11.1	22.7	38.9	12.5	14.3	0.0	22.2	13.6	0.0	18.8	7.1	18.2	11.1	50.0	55.6	62.5	64.3	72.7	55.6

[a] Quartile 1 = upper 25%, 2 = upper middle 25%, 3 = lower middle 25%, 4 = lower 25%

TABLE XXXVI

NUMBER OF HEIFERS FROM EACH QUARTILE OF PRODUCTIVITY AS MEASURED BY TOTAL POUNDS OF CALF WEANED CLASSIFIED INTO QUARTILES BY DISCRIMINANT FUNCTIONS FOR EACH PARITY GROUP

Classified Into Quartile[a]:

From Quartile[a]	Herd	1						2					
		Parity						Parity					
		1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7
	Angus 1	33	26	22	17	11	7	17	10	10	4	4	0
1	Hereford	16	14	14	8	4	3	6	8	5	2	3	1
	Angus 2	13	10	10	8	6	4	4	2	3	2	3	1
	Angus 1	21	14	11	10	5	1	19	15	11	11	5	3
2	Hereford	9	6	2	3	1	2	13	13	9	8	3	0
	Angus 2	2	0	1	3	1	3	14	14	8	6	5	2
	Angus 1	15	10	13	5	8	2	19	16	6	6	8	2
3	Hereford	9	9	7	2	3	0	11	12	5	3	2	1
	Angus 2	3	3	3	2	2	1	3	3	4	5	2	3
	Angus 1	19	14	9	6	7	2	10	12	11	8	5	2
4	Hereford	10	7	3	3	3	1	10	9	8	5	1	0
	Angus 2	3	1	1	2	1	1	5	7	2	2	0	2

From Quartile[a]	Herd	3						4					
		Parity						Parity					
		1-2	1-3	1-4	1-5	1-6	1-7	1-2	1-3	1-4	1-5	1-6	1-7
	Angus 1	10	7	5	6	1	1	9	11	7	6	5	0
1	Hereford	8	3	1	3	1	1	8	6	4	4	2	1
	Angus 2	3	4	2	2	1	2	2	1	1	2	1	1
	Angus 1	7	13	9	10	2	3	25	15	14	7	11	2
2	Hereford	7	7	6	5	5	2	6	5	10	3	3	1
	Angus 2	1	2	3	2	3	3	5	1	4	2	3	1
	Angus 1	8	18	12	18	4	3	28	14	13	5	2	1
3	Hereford	10	4	5	9	6	4	7	7	8	5	1	1
	Angus 2	13	7	5	4	4	4	3	4	4	3	2	1
	Angus 1	8	8	10	8	1	2	34	22	16	14	10	2
4	Hereford	8	6	6	2	3	1	10	11	9	9	6	4
	Angus 2	3	0	3	1	2	1	11	10	10	9	8	5

[a] Quartile 1 = upper 25%, 2 = upper middle 25%, 3 = lower middle 25%, 4 = lower 25%.

second and third. This implies that we can identify the upper or lower 25 percent more successfully than the middle two quartiles in the Angus herd 1. In the Hereford herd, there was evidence that the proportions of correct classifcations differ among the quartiles for the analyses involving the first three ($P < .05$), four ($P < .05$) and seven ($P < .10$) parities. It appears that in the first three and four parities classification into the third quartile was not as successful. In the analyses involving the first seven parities, there appeared to be less successful classification into the second quartile. Thus, evidence in these two herds generally suggests that classification into the upper or lower quartiles using discriminant functions may be more successful than classification into the middle quartiles. This seems reasonable in that extremes should be easier to identify. However, in the Angus herd 2, this was not the case. There was little evidence in this herd suggesting any differences in the proportion correctly classified among any of the quartiles.

Another interpretation of these analyses is the overall proportion of the heifers that were correctly classified into the proper quartile based on the prebreeding traits of the heifers. These results are presented in Table XXXVII along with chi-square tests for differences among herds. In addition, proportion of correct classification was regressed on parity grouping within each herd. This was done to ascertain if the proportions were changing linearly as the number of calves in the analysis increased. A weighted least squares analysis may have been more appropriate in that the proportions within a herd have different variances. However, simple linear regression was chosen as a simplistic approach to generally indicate linear patterns in the proportions.

TABLE XXXVII

PERCENTAGE CORRECT CLASSIFICATION FOR EACH PARITY GROUP INTO THE PROPER QUARTILE FOR PRODUCTIVITY

Parity	1-2	1-3	1-4	1-5	1-6	1-7	$\bar{y}$	$\hat{\beta}$
Angus 1	33.3 (282)[a]	36.0 (225)	34.1 (179)	42.6 (141)	33.7 (89)	45.5 (33)	37.5	1.79
Hereford	33.1 (148)	33.1 (127)	36.3 (102)	45.9 (74)	38.3 (47)	47.8 (23)	39.1	2.82*
Angus 2	58.0 (88)	59.4 (69)	51.6 (64)	49.1 (55)	52.3 (44)	42.8 (35)	52.2	-2.85*
χ^2	19.03**	14.79**	5.86+	.51	4.28	.14		

[a] Numbers in parentheses are numbers in the analyses
+ P < .10
* P < .05
**P < .01

There appeared to be little difference in the proportions of correct classification between the Angus herd 1 and Hereford herd in any of the parity groupings. However, it appeared that Angus herd 2 had higher proportions of correct classification than the other two herds for the first three parities. As evidenced by the regression coefficients, Angus herd 1 and Hereford herd increased in proportion of correct classifications, where Angus herd 2 decreased as the number of calves considered increased. Thus, differences among the herds were not significant when five, six or seven calves were considered in the analyses.

The proportions of correct classification in Angus herd 1 and Hereford herd were low. However, these proportions involve correct classification into all quartiles. In the Angus herd 1, correct classification into the middle quartiles was less successful than the upper or lower quartiles. Thus, consideration of the first and fourth quartiles only more nearly equalizes the proportions in the two Angus herds. Over all herds and parity groupings, however, it appeared that the most consistent success could be attained in identifying the upper 25 percent of the herd.

Another way to consider the classification of heifers into productivity groups is to consider the proportions of heifers that were above the median and were classified into the first and second quartiles and the proportion of heifers that were below the median and were classified into the third and fourth quartiles. This allows cross-classification between the first and second quartile and between the third and fourth quartile. Thus a correct classification was considered to be classification into the third or fourth quartile if a heifer was below median. The proportions of correct classifications under this definition are reported in Table XXXVIII for each herd and parity grouping.

These proportions were considerably higher than the proportions reported previously. There some evidence of a difference among the herds in the analysis considering the first two calves and in the analysis considering the first six calves. Also there was a trend for proportions in the Angus herds to decrease as more calves were considered and for the proportions in Herefords to increase. Generally, about

60 percent of the above and below median heifers were correctly identified in terms of their lifetime productivity.

TABLE XXXVIII

PERCENTAGE CLASSIFICATION OF HEIFERS OF ABOVE MEDIAN PRODUCTIVITY INTO THE FIRST TWO QUARTILES AND HEIFERS OF BELOW MEDIAN PRODUCTIVITY INTO THE LAST TWO QUARTILES[a]

Parity	1-2	1-3	1-4	1-5	1-6	1-7	$\bar{y}$	$\hat{\beta}$
Angus	59.6 (282)[b]	56.4 (225)	58.7 (179)	61.7 (141)	47.2 (89)	57.6 (33)	56.9	-.99
Hereford	53.4 (148)	54.3 (127)	56.9 (102)	62.2 (74)	57.4 (47)	69.6 (23)	59.0	2.73*
Angus 2	71.6 (88)	68.1 (69)	68.8 (64)	65.4 (55)	70.5 (44)	60.0 (35)	67.4	-1.55
χ^2	7.64*	3.8	2.59	.25	6.54*	.88		

[a] Productivity based on total pounds of calf weaned.
[b] Numbers in parentheses are numbers in the analyses.
* P < .05.

A breeder may wish to cull the lower 25% of his heifers before breeding and select replacement heifers based on their first calf. Table XXXIX presents the proportion of above average heifers that would be culled if the lower quartile as classified by the discriminant function were culled. There was little evidence of differences among the herds with the exception of the Angus herd 2 in the analysis considering the first three calves. Also, there is little evidence in a linear change in these proportions as the number of calves considered in the analyses increases. Consequently, about 20% of the above median heifers would be expected to be culled if culling was based on the lower quartile as classified by the discriminant function.

TABLE XXXIX

PERCENTAGE OF ABOVE MEDIAN HEIFERS CLASSIFIED INTO LOWER QUARTILE AS CLASSIFIED BY DISCRIMINANT FUNCTION[a]

Parity	1-2	1-3	1-4	1-5	1-6	1-7	$\bar{y}$	$\hat{\beta}$
Angus 1	24.1 (141)[b]	23.4 (111)	23.6 (89)	18.3 (71)	36.4 (44)	11.8 (17)	22.9	-.79
Hereford	19.2 (73)	17.7 (62)	27.5 (51)	19.4 (36)	22.7 (22)	18.2 (11)	20.8	.05
Angus 2	15.9 (44)	5.9 (34)	15.6 (32)	14.8 (27)	17.4 (23)	11.8 (17)	13.6	.38
χ^2	1.62	5.29[+]	1.55	.24	3.11	.30		

[a] Discriminant function developed from heifer traits.

[b] Numbers in parentheses are the numbers of above median heifers.

[+] $P < .10$

Linear discriminant analyses were also done in the three herds to try to discriminate among quartiles of productivity as measured by MPPA. The linear discriminant functions for the Angus herd 1, Hereford herd and Angus herd 2 are given in Table XL. Heifer birth weight, weaning weight, weaning conformation and postweaning ADG were used to build these functions.

The proportions of heifers from a particular quartile that were classified into the four quartiles of MPPA productivity by the discriminant function are given in Table XLI and the actual numbers are given in Table XLII. Differences among quartiles in percent correct classification were found in the Angus herd 1 ($P < .01$) and Hereford herd ($P < .01$) but not in the Angus herd 2. It appears that classification into the first quartile was more successful in the Angus herd 1 as compared to the other quartiles, particulary the second. In the Hereford herd, it appears that correct classification was substantially lower in the third quartile than the other quartiles. The percentage of total correct classifications into all quartiles is given in Table XLIII. In the Angus 34.0% and 43.6% of the total number were correctly classified and in the Herefords 34.7% of the total were correctly classified. Herd differences were not significant. These results were reasonably comparable to the proportions of correct classifications averaged over the six parity groupings reported previously. The proportions of heifers classified into the first and second quartile if above median in MPPA or classified into the third and fourth quartiles if below median are given in Table XLIV. These classification were considered "acceptable" under certain circumstances. In the Angus 60.2% and 62.8% of the total were classified into an acceptable quartile and

TABLE XL

LINEAR DISCRIMINANT FUNCTIONS DEVELOPED FROM HEIFER TRAITS FOR CLASSIFICATION INTO QUARTILES OF PRODUCTIVITY AS MEASURED BY MPPA

Trait	Angus 1				Hereford				Angus 2			
Constant	-338.11	-335.64	-331.74	-331.68	-332.63	-316.92	-319.16	-326.09	-178.69	-162.05	-162.70	-160.66
Birth Wt.	.59	.59	.58	.58	.69	.64	.66	.69	.30	.28	.23	.22
Weaning Wt.	.32	.30	.29	.30	.42	.40	.40	.40	.34	.33	.32	.32
Weaning Conformation	31.31	31.65	31.74	31.65	26.51	26.12	26.21	26.63	8.99	8.41	9.08	9.24
Postweaning ADG	115.84	115.80	115.33	114.57	98.56	96.40	95.96	96.15	64.38	60.13	61.12	57.88

TABLE XLI

PERCENTAGE OF HEIFERS FROM EACH QUARTILE OF PRODUCTIVITY AS MEASURED BY MPPA CLASSIFIED INTO QUARTILES BY DISCRIMINANT FUNCTIONS

		Classified Into Quartile:			
From Quartile:	Herd	1	2	3	4
	Angus 1	51.4	12.2	17.6	18.9
1	Hereford	52.5	25.0	7.5	15.0
	Angus 2	55.6	7.4	18.5	18.5
	Angus 1	36.9	17.9	32.1	13.1
2	Hereford	19.5	48.8	12.2	19.5
	Angus 2	14.3	42.9	19.0	23.8
	Angus 1	25.3	16.1	35.6	23.0
3	Hereford	26.7	44.4	6.7	22.2
	Angus 2	14.3	14.3	23.8	47.6
	Angus 1	25.3	10.1	31.6	32.9
4	Hereford	29.8	25.5	10.6	34.0
	Angus 2	12.0	28.0	12.0	48.0

TABLE XLII

NUMBER OF HEIFERS FROM EACH QUARTILE OF PRODUCTIVITY AS MEASURED BY MPPA CLASSIFIED INTO QUARTILES BY DISCRIMINANT FUNCTIONS

		Classified Into Quartile:			
From Quartile	Herd	1	2	3	4
	Angus 1	38	9	13	14
1	Hereford	21	10	3	6
	Angus 2	15	2	5	5
	Angus 1	31	15	27	11
2	Hereford	8	20	5	8
	Angus 2	3	9	4	5
	Angus 1	22	14	31	20
3	Hereford	12	20	3	10
	Angus 2	3	3	5	10
	Angus 1	20	8	25	26
4	Hereford	14	12	5	16
	Angus 2	3	7	3	12

TABLE XLIII

PERCENTAGE CORRECT CLASSIFICATIONS INTO MPPA QUARTILES OF PRODUCTIVITY

Herd			
Angus 1	Hereford	Angus 2	χ^2
34.0 (324)[a]	34.7 (173)	43.6 (94)	3.08[NS]

[a] numbers in parentheses are numbers in the analyses.

TABLE XLIV

PERCENTAGE OF HEIFERS ABOVE MEDIAN IN MPPA CLASSIFIED INTO THE FIRST AND SECOND QUARTILE AND HEIFERS BELOW MEDIAN IN MPPA CLASSIFIED INTO THE THIRD AND FOURTH QUARTILE

Herd			
Angus 1	Hereford	Angus 2	χ^2
60.2 (324)[a]	53.8 (173)	62.8 (94)	2.68[NS]

[a] Numbers in parentheses are numbers in the analyses.

53.8% of the Herefords were similarly classified. Herd differences were not significant. Again, these results were reasonably comparable to the similar interpretations of the classifications into quartiles based on the sum of the calf weaning weights. Table XLV gives results of the proportion of heifers above median in MPPA that were classified into the fourth quartile. As mentioned previously, this interpretation should indicate what proportion of above average producing heifers might be culled if culling the lower quartile as classified by the discriminant function. In the Angus herds 15.8% and 20.8% of the above median heifers were classified into the fourth quartile and 17.3% of the above median heifers were classified similarly in the Herefords. Again, the herd differences were not significant and the results compared favorably with the analyses defining productivity as the sum of calf weaning weights of a heifer.

TABLE XLV

PERCENTAGE OF HEIFERS ABOVE MEDIAN IN MPPA CLASSIFIED INTO THE FOURTH QUARTILE

Herd			
Angus 1	Hereford	Angus 2	χ^2
15.8 (158)[a]	17.3 (81)	20.8 (48)	.66[NS]

[a] Numbers in parentheses are numbers of above median heifers.

Discriminant analyses were also performed using heifer birth weight, weaning weight, weaning conformation, postweaning ADG and first parity weaning weight. Classifications were made into quartiles of productivity based on the sum of calf weaning weights beginning with the second parity. Analyses were performed for the second and third parity, second through fourth parity, second through fifth parity, second through sixth parity and second through seventh parity. This was done in order to ascertain if information on the first calf was beneficial in improving correct classification.

Table XLVI presents the linear discriminant functions developed from heifer birth weight, weaning weight, weaning conformation, postweaning ADG and first parity weaning weight. As in the previous analyses, heterogeneity of variance-covariance matrices among the different quartiles was detected in some of the herd and parity groupings. In the Angus herd 1, (Appendix Table LXXI) it appeared that the covariances between first parity weaning weight and heifer prebreeding traits were different in heifers from the third quartile in the analyses considering the second and third parities. Also, it appeared there was more variation among first parity weaning weights in heifers from the fourth quartile. In this same herd, in the analyses considering the second through seventh parity calves, (Table LXXII) a few apparent patterns was suggested. The covariance between birth weight and weaning weight was larger for the first quartile heifers and the covariance between birth weight and postweaning ADG was positive in the first quartile heifers and negative at about the same magnitude in the third quartile heifers. The covariance between birth weight and first parity weaning weight was negatively larger in

TABLE XLVI

LINEAR DISCRIMINANT FUNCTIONS DEVELOPED FROM HEIFER TRAITS (INCLUDING FIRST PARITY WEANING WEIGHT) FOR CLASSIFICATION INTO QUARTILES OF PRODUCTIVITY AS MEASURED BY THE TOTAL POUNDS OF CALF WEANED FOR EACH PARITY GROUP

Parity	Trait	Angus Herd 1				Hereford Herd				Angus Herd 2			
		Quartile				Quartile				Quartile			
		1	2	3	4	1	2	3	4	1	2	3	4
2-3	Constant	-	-	-	-	-429.11	-398.24	-406.64	-394.00	-	-	-	-
	Birth Wt.	-	-	-	-	.19	.20	.16	.21	-	-	-	-
	Weaning Wt.	-	-	-	-	.58	.54	.56	.55	-	-	-	-
	Weaning Conf.	-	-	-	-	26.39	26.40	26.78	26.57	-	-	-	-
	Postweaning ADG	-	-	-	-	110.51	104.76	107.17	107.06	-	-	-	-
	First Parity Wean. Wt.	-	-	-	-	.30	.28	.27	.25	-	-	-	-
2-4	Constant	-479.10	-465.03	-467.15	-465.01	-354.72	-342.53	-341.37	-331.06	-253.05	-227.25	-220.09	-223.54
	Birth Wt.	.67	.65	.72	.69	.12	.08	.11	.16	- .10	.02	- .03	- .07
	Weaning Wt.	.44	.42	.41	.42	.48	.48	.48	.47	.37	.34	.33	.32
	Weaning Conf.	37.26	37.35	37.57	37.77	23.30	23.33	23.69	23.77	11.50	10.88	11.32	11.94
	Postweaning ADG	134.34	132.32	133.34	132.00	94.91	93.04	91.87	93.26	111.72	102.66	105.05	100.83
	First Parity Wean. Wt.	.30	.28	.28	.26	.21	.20	.18	.15	.16	.15	.14	.14
2-5	Constant	-478.33	-475.58	-465.30	-469.14	-332.21	-330.34	-320.43	-313.21	-239.58	-227.23	-208.22	-221.59
	Birth Wt.	.68	.64	.71	.67	.18	.13	.21	.23	.39	.31	.33	.24
	Weaning Wt.	.43	.43	.41	.43	.43	.43	.43	.43	.24	.25	.24	.25
	Weaning Conf.	35.62	35.89	36.01	35.90	21.38	21.57	21.66	22.02	12.30	12.23	12.00	13.18
	Postweaning ADG	148.79	149.80	146.91	152.23	86.17	85.46	83.59	85.41	80.15	78.58	79.28	76.36
	First Parity Wean. Wt.	.32	.32	.30	.29	.24	.23	.21	.17	.22	.20	.18	.19

TABLE XLVI (continued)

Parity	Trait	Angus Herd 1				Hereford Herd				Angus Herd 2			
		Quartile				Quartile				Quartile			
		1	2	3	4	1	2	3	4	1	2	3	4
2-6	Constant	-511.21	-513.85	-493.16	-503.51	-352.22	-353.77	-343.68	-352.67	-374.57	-340.05	-346.34	-327.19
	Birth Wt.	1.02	.91	1.01	.90	.33	.38	.50	.48	1.48	1.32	1.37	1.20
	Weaning Wt.	.54	.55	.54	.55	.49	.53	.53	.52	.38	.37	.36	.36
	Weaning Conf.	35.67	35.63	35.54	35.75	25.01	24.79	24.19	25.55	14.95	14.39	15.37	15.67
	Postweaning ADG	140.43	139.10	136.25	141.87	101.18	101.41	100.74	102.18	150.49	146.44	145.60	140.29
	First Parity Wean. Wt.	.34	.35	.31	.32	.14	.10	.08	.06	.29	.26	.25	.23
2-7	Constant	-	-	-	-	-	-	-	-	-458.16	-457.61	-431.83	-442.57
	Birth Wt.	-	-	-	-	-	-	-	-	2.13	2.08	2.04	2.06
	Weaning Wt.	-	-	-	-	-	-	-	-	.48	.47	.46	.48
	Weaning Conf.	-	-	-	-	-	-	-	-	18.07	15.24	18.12	18.99
	Postweaning ADG	-	-	-	-	-	-	-	-	196.21	196.66	192.06	189.30
	First Parity Wean. Wt.	-	-	-	-	-	-	-	-	.33	.34	.30	.29

the second quartile heifers compared to the other groups. The covariances between heifer weaning weight and first parity weaning weight appeared to decrease as the productivity decreased. Also, the variation among first parity weaning weights appeared smaller in the third quartile heifers and larger in the second quartile. There were other differences suggested between quartiles but the above mentioned differences were considered the primary ones. In the Hereford herd, (Appendix Table LXXIII) in the analyses considering the second through seventh parity, it appeared that the variation among heifer weaning weights and the variation among first parity weaning weights was larger in the heifers from the first quartile. Also, in this herd, the covariances between heifer birth weight and weaning weight and between heifer postweaning ADG and first parity weaning weight appeared to be larger in heifers from the first quartile. Two other things were apparent. Firstly, there is some indication that the covariances between heifer birth weight and first parity weaning weight decreased from the first through the third quartile and this covariance became negative in the fourth quartile. Secondly, there was some indication that the covariances between heifer weaning weight and first parity weaning weight was positive in the first two quartiles and negative in the last two quartiles. There was no obvious pattern of heterogeneity in the Angus herd 2 in the analysis considering the second and third parities (Appendix Table LXIII). It appeared that the heterogeneity in this analysis was largely a result of different variances and covariances for the second and/or third quartile.

The proportions of correct classifications using the discriminant functions develpped from heifer birth weight, and weaning weight, weaning conformation, postweaning ADG and first parity weaning weight are presented in Table XLVII and the actual numbers are presented in Table XLVIII These numbers in Table XLVII represent the proportion of heifers from a given quartile of productivity that were classified into the respective quartiles by the discriminant function. It appears that inclusion of information on the first calf weaning weight has generally improved the proportions of correct classifications for the Angus herd 1 and Hereford herd. This is primarily due to increased accuracy of classifications in the middle two quartiles. In the Angus herd 1, it appears that classification was more successful in the first and third quartile for the analysis considering the second and third parity calves. Differences in proportion of correct classification among quartiles were detected in this analysis (P < .05) but in all other analyses in this Angus here 2 there were no significant differences among the quartiles. In the Hereford herd, differences in the proportions of correct classification were detected in the analysis involving the second through fourth parities (P < .05). In this analysis the proportions of correct classification into the second and third quartiles were slightly lower. No other significant differences among the quartiles of productivity were found for any of the parity groupings in the Herefords. In the Angus herd 3 significant differences among the quartiles were found for the analyses considering the second through fifth and second through sixth parities. Primarily, it appeared that the proportions of correct classifications are lower for the second and third quartiles, respectively, for each analysis.

The overall proportions of each herd that were correctly classified into the proper quartile are given in Table XLIX. Additional

TABLE XLVII

PERCENTAGE OF HEIFERS FROM EACH QUARTILE OF PRODUCTIVITY AS MEASURED BY TOTAL POUNDS OF CALF WEANED CLASSIFIED INTO QUARTILES BY DISCRIMINANT FUNCTIONS DEVELOPED FROM HEIFER TRAITS AND FIRST PARITY WEANING WEIGHT

From Quartile[a]	Herd	Classified Into Quartile[a]: 1					2					3					4				
		Parity					Parity					Parity					Parity				
		2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7
	Angus 1	52.6	52.3	47.2	39.1	100.0	24.6	18.2	19.4	26.1	0.0	21.0	15.9	22.2	17.4	0.0	1.8	13.6	11.1	17.4	0.0
1	Hereford	60.0	66.7	47.1	81.8	100.0	20.0	4.8	23.5	0.0	0.0	10.0	14.3	23.5	9.1	0.0	10.0	14.3	5.9	9.1	0.0
	Angus 2	76.5	64.3	66.7	70.0	22.2	5.9	7.1	6.7	20.0	44.4	5.9	14.3	20.0	10.0	22.2	11.8	14.3	6.7	0.0	11.1
	Angus 1	30.4	21.7	22.9	21.7	0.0	35.7	37.0	37.1	43.5	100.0	26.8	19.6	22.9	17.4	0.0	7.4	21.7	17.1	17.4	0.0
2	Hereford	12.5	28.6	36.8	18.2	0.0	45.8	39.3	36.8	72.7	100.0	31.2	21.4	21.0	9.1	0.0	12.5	10.7	5.3	0.0	0.0
	Angus 2	5.6	18.8	38.5	27.3	11.1	72.2	31.2	23.1	36.4	55.6	5.6	25.0	15.4	18.2	22.2	16.7	25.0	18.2	18.2	11.1
	Angus 1	12.5	23.3	8.6	18.2	12.5	14.3	9.3	17.1	4.6	0.0	57.1	34.9	48.6	50.0	87.5	16.1	32.6	25.7	27.3	0.0
3	Hereford	12.5	7.7	21.0	0.0	0.0	18.8	26.9	10.5	8.3	16.7	43.8	38.5	52.6	75.0	83.3	25.0	26.9	15.8	16.7	0.0
	Angus 2	11.8	6.2	23.1	53.3	11.1	17.6	18.8	0.0	16.7	0.0	47.1	56.2	61.5	16.7	66.7	23.5	18.8	15.4	33.3	22.2
	Angus 1	10.7	17.4	17.1	22.7	0.0	19.6	10.9	8.6	18.2	0.0	32.1	23.9	31.4	22.7	0.0	37.5	47.8	42.9	36.4	100.0
4	Hereford	6.1	0.0	0.0	15.4	0.0	15.2	11.1	5.3	15.4	16.7	21.2	22.2	21.0	23.1	16.7	57.6	66.7	73.7	46.2	66.7
	Angus 2	11.8	11.1	7.1	0.0	0.0	11.8	22.2	7.1	0.0	0.0	11.8	5.6	28.6	36.4	37.5	64.7	61.1	57.1	63.6	62.5

[a] Quartile 1 = upper 25%, 2 = upper middle 25%, 3 = lower middle 25%, 4 = lower 25%.

TABLE XLVIII

NUMBER OF HEIFERS FROM EACH QUARTILE OF PRODUCTIVITY AS MEASURED BY TOTAL POUNDS OF CALF WEANED CLASSIFIED INTO QUARTILES BY DISCRIMINANT FUNCTIONS DEVELOPED FROM HEIFER TRAITS AND FIRST PARITY WEANING WEIGHT

		Classified Into Quartile[a]:																			
From Quartile[a]	Herd	1					2					3					4				
		Parity					Parity					Parity					Parity				
		2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7
	Angus 1	30	23	17	9	9	14	8	7	6	0	12	7	8	4	0	1	6	4	4	0
1	Hereford	18	14	8	9	6	6	1	4	0	0	3	3	4	1	0	3	3	1	1	0
	Angus 2	13	9	10	7	2	1	1	1	2	4	1	2	3	1	2	2	2	1	0	1
	Angus 1	17	10	8	5	0	20	17	13	10	8	15	9	8	4	0	4	10	6	4	0
2	Hereford	4	8	7	2	0	14	11	7	8	5	10	6	4	1	0	4	3	1	0	0
	Angus 2	1	3	5	3	1	13	5	3	4	5	1	4	2	2	2	3	4	3	2	1
	Angus 1	7	10	3	4	1	8	4	6	1	0	32	15	17	11	7	9	14	9	6	0
3	Hereford	4	2	4	0	0	6	7	2	1	1	14	10	10	9	5	8	7	3	2	0
	Angus 2	2	1	3	4	1	3	3	0	2	0	8	9	8	2	6	4	3	2	4	2
	Angus 1	6	8	6	5	0	11	5	3	4	0	18	11	11	5	0	21	22	15	8	8
4	Hereford	2	0	0	2	0	5	3	1	2	1	7	6	4	3	1	19	18	14	6	4
	Angus 2	2	2	1	0	0	2	4	1	0	0	2	1	4	4	3	11	11	8	7	5

[a] Quartile 1 = upper 25%, 2 = upper middle 25%, 3 = lower middle 25%, 4 = lower 25%.

information on the first calf seems to improve the proportion of correct classifications in the Angus herd 1 and Hereford herd, particularly when larger numbers of calves are involved. There were some differences suggested among the herds in terms of proportions of correct classifications.

TABLE XLIX

PERCENTAGE CORRECT CLASSIFICATION FOR EACH PARITY GROUP INTO THE PROPER QUARTILE FOR PRODUCTIVITY BY DISCRIMINANT FUNCTIONS DEVELOPED FROM HEIFER TRAITS AND FIRST PARITY WEANING WEIGHT

Herd	2-3	2-4	2-5	2-6	2-7	$\bar{y}$	$\hat{\beta}$
Angus 1	45.8 (225)[a]	43.0 (179)	44.0 (141)	42.0 (90)	97.0 (33)	54.4	10.16
Hereford	40.6 (160)	52.0 (102)	52.7 (74)	68.1 (47)	87.0 (23)	60.1	10.89**
Angus 2	65.2 (69)	53.1 (64)	52.7 (55)	45.4 (44)	51.4 (35)	53.6	-3.53
X^2	11.94**	3.06	.99	8.68*	21.60**		

[a]Numbers in parentheses are numbers in the analyses.

* $P < .05$

**$P < .01$

The Angus herd 2 had an apparently higher proportion of correct classifications in the analysis involving the second and third parity calves. The Hereford herd exceeded both Angus herds in proportion of correct classifications in the analysis considering productivity based on the weights of the second through sixth parity calves. Also the proportion of correct classifications appeared lower in the Angus herd 2 than the other two herds in the analysis considering the second through seventh parity calves. There did not appear to be much evidence of a linear change in proportion of correct classifications in the Angus herds as the number of calves considered in the analyses increased. The Herefords' proportions of correct classifications, however, appeared to increase as the number of calves considered in the analyses increased.

The proportions of heifers from the different herds that were above median and classified into the upper two quartiles and below median and classified into the lower two quartiles are presented in Table L. It generally appeared that some improvement in identification of above or below median heifers can be made by the inclusion of information on the first calf. For the most part the proportions of correct classifications by the discriminant function derived from heifer traits plus first parity weaning weight were higher than the proportion of correct classifications from the discriminant function derived from the heifer prebreeding traits only. There were few herd differences evident in proportions of classification of above or below median heifers back into the above or below median groupings. The Hereford herd appeared to have a lower proportion of acceptable classification than the Angus herds in the analysis involving the second and third parities. There was some evidence that Angus herd 2 was lower in percentage acceptable classification in the analysis considering the second through seventh parity weaning weights, although the difference was not large. There was also little evidence of a linear trend in the Angus in acceptable proportions of classification as the number of calves considered in the analyses increased. However, in the Herefords, it appears that the proportions of correct classifications increased as the number of calves considered increased.

TABLE L

PERCENTAGE CLASSIFICATION OF HEIFERS OF ABOVE MEDIAN PRODICTIVITY INTO THE FIRST TWO QUARTILES AND HEIFERS OF BELOW MEDIAN PRODUCTIVITY INTO THE LAST TWO QUARTILES[a,b]

Herd	2-3	2-4	2-5	2-6	2-7	$\bar{y}$	$\hat{\beta}$
Angus 1	71.6 (225)[c]	67.0 (179)	68.8 (141)	66.7 (90)	97.0 (33)	74.2	1.87
Hereford	56.2 (160)	73.5 (102)	77.0 (74)	83.0 (47)	91.3 (23)	76.2	7.97**
Angus 2	76.8 (69)	65.6 (64)	74.5 (55)	75.0 (44)	80.0 (35)	74.4	1.58
X^2	13.47**	1.46	1.59	4.20	5.2[+]		

[a] Productivity based on the total pounds of calf weaned.

[b] Classification by discriminant functions developed from heifer traits and first parity weaning weight.

[c] Numbers in parentheses are the number in the analyses.

[+] $P < .10$

** $P < .01$

Ignoring the few herd differences detected, these data indicate that around 75 percent of the heifers were classified into the first or second quartile if they were actually above median or into the third or fourth quartile if they were actually below median in productivity. Thus, it appears that using a linear discriminant function developed from heifer prebreeding traits and first parity calf weaning weight might be reasonably successful in identifying heifers above or below average in lifetime productivity.

The proportions of the above median heifers that would be culled if culling the lower 25 percent of the herd as classified by the discriminant function are presented in Table LI. Inclusion of the first parity weaning weight seems to have lowered these percentages, particularly in the Herefords. Few herd differences were noted in this part of the analysis. The Angus herd 1 appeared to have a lower proportion of above median heifers classifed into the fourth quartile considering the second and third parity calves as compared to the other two herds ($P < .10$). All other differences among the herds were not significant. There was some evidence that the proportion of above median heifers classified into the fourth quartile decreased as the number of calves considered was increased in the Hereford herd but not particularly in the Angus. In summary, on the average only 10 percent of the above median heifers could have been culled.

There are obviously many other ways in which these classifications can be interpreted. These methods of interpretation were chosen to reflect the overall success of classification in addition to success under some of the possible alternate uses of these classifications.

TABLE LI

PROPORTION OF ABOVE MEDIAN HEIFERS CLASSIFIED INTO LOWER QUARTILE AS CLASSIFIED BY DISCRIMINANT FUNCTION[a]

Herd	2-3	2-4	2-5	2-6	2-7	$\bar{y}$	$\hat{\beta}$
Angus 1	4.4 (113)[b]	17.8 (90)	14.1 (71)	17.4 (46)	0.0 (17)	10.7	- .92
Hereford	11.3 (62)	12.2 (40)	5.6 (36)	4.5 (22)	0.0 (12)	6.7	-3.03*
Angus 2	14.3 (35)	20.0 (30)	14.3 (28)	9.5 (21)	11.1 (18)	13.8	-1.69
X^2	4.70[+]	1.01	1.90	2.47	3.3		

[a] Discriminant function developed from heifer traits and first parity weaning weight.

[b] Numbers in parentheses are the number of above median heifers.

[+] $P < .10$

[*] $P < .05$

It is difficult to summarize the results of these analyses concisely without making some assumptions. If we can ignore any herd by parity grouping interaction in the Angus herds and assume that the probability that a heifer will be culled is the same across the parity groupings in all herds, then the average across parities of the Angus herds and the Hereford herd can be used to generally indicate expectations.

It appears that classification into quartiles of productivity based on heifer prebreeding traits would only be moderately successful. In the Angus we might expect about 56.6%, 38.9%, 35.2% and 49.2% correct classification into the first, second, third and fourth quartiles, respectively. In the Herefords, there were 47.1%, 29.9%, 37.3%, and 42.4% correct classifications into the first, second, third and fourth quartile, respectively. When the weaning weight of the first calf was included in the development of the discriminant function, there was some improvement in proportion of correct classifications. In the Angus, around 59.1%, 47.2%, 52.6% and 57.4% correct classifications could be expected for the first, second, third, and fourth quartiles, respectively. In the Herefords, these same proportions averaged 71.1%, 58.5%, 58.6 % and 62.2%, respectively. Information on the first calf did not appear to be as helpful in Angus as it was in Herefords. This was probably a reflection of the higher repeatability of calf weaning weight noted in the Herefords.

When the data were summarized as proportions of heifers correctly classified into the proper quartiles, the previous results were generally reflected. In the analyses using only heifer prebreeding traits to discriminate among quartiles of productivity around 44.8% and 39.1% overall correct classifications might be expected in the Angus and Herefords, respectively. When the first parity weaning weight was included as a heifer trait to aid in discrimination, around 54.0% and 60.1% of the Angus and Herefords were correctly classified. Again, it is suggested that information on the first calf was more beneficial in the Herefords than in the Angus as evidenced by a 20 percent increase in correct classification in the Herefords and only a 9 percent increase in the Angus.

Under certain circumstances, it may be satisfactory to classify an above median heifer into either the first or second quartile and a below median heifer into either the third or fourth quartile. When the data was summarized in this manner, there were about 62.1% and 59.0% acceptably classifications in the Angus and Herefords, respectively, discriminating on heifer prebreeding traits only. Inclusion of the first parity weaning weight into the discriminant function resulted in 74.3% and 76.2% acceptably classifications in the Angus and Herefords, respectively.

When culling the bottom 25 percent of the heifers in a herd it is of interest to estimate the proportion of above median heifers that would be culled. When classification was based on heifer prebreeding traits only, 18.2% and 20.8% of the above median cows in the Angus and Hereford herds were classified into the fourth quartile of productivity. Information on the first calf lowered these percentages to 12.2% in Angus and 6.7% in Herefords.

These interpretations are contingent on the extent of any failures of differences in the Angus herds to remain the same as the number of calves considered increases. However, these mean percentages reported do serve the purpose as a general summary of the results of the discriminant classifications. Also, because it is highly uncertain as to when a cow will be culled based on unsoundness or failure to breed, these averages are probably satisfactory estimates of general results of the classifications.

The results of these analyses suggest a possible use of discriminant analysis in early culling of poor producing heifers. The method that was most promising involved culling the bottom 25 percent. If the lower quartile as classified by heifer prebreeding traits were culled then a large proportion of the above average heifers would probably be retained. Facilities permitting, these heifers retained could be allowed to calve and subsequent selection could be done based on heifer growth and the first calf. This method could provide a means of successful early culling. However, more research is needed in this area. Few authors have classified their data in retrospect to ascertain possible success in identification of above or below average producing heifers. Even with low associations between early heifer growth and subsequent productivity, it may be possible to cull heifers based on precalving performance and still retain a high proportion of the above average producers. This research does suggest that information on the first calf weaning weight would be very beneficial in identifying above or below average producers, as has been suggested by other similar research.

Regression Analyses

Multiple linear regression analyses were utilized to regress the sums of cows' calves weaning weights on cow birth weight, weaning weight, weaning grade and postweaning ADG. This was done for the first through second parities, first through third, first through fourth, first through fifth, first through sixth and first through seventh parities and weaning weight MPPA. In addition, the first parity weaning weight was included as an independent variable and the sum of calfes' weaning weights beginning with second parity were regressed on cow birth weight, weaning weight, weaning grade, postweaning ADG and first parity weaning weight.

It was the intent of these analyses to develop linear combinations of early performance traits of heifers such that the correlation between these linear combinations and linear combinations of calf weaning weights was maximum. Thus, these analyses are very similar to canonical correlations except that the coefficients on the calf weaning weights are predetermined and solutions of coefficients are found for the cow traits only. This has the obvious advantage over canonical correlation analyses that the resultant correlations are more easily interpreted.

The results of the analyses regressing the sum of calves' weaning weights on heifer prebreeding traits are present in Table LII for the three herds. The standardized partial regression coefficients are given along with the multiple correlation coefficients. In both the Angus and Hereford herds these analyses indicate that heifers above average in weaning weight and postweaning ADG tend to wean above average calves. Birth weight and weaning conformation were generally not significantly associated with subsequent productivity in these analyses. However, as indicated in previous analyses, there was a trend for heifer weaning conformation to be given a negative weight in predicting subsequent productivity in the Angus. The multiple correlation coefficients are similar to the first canonical correlations found in these herds (.24, .28, .29, .30, .35, 143 in Angus herd 1; .31, .32, .38, .40, 41, .50 in Hereford herd; .42, .47, 51, .52, .55, .58 in Angus herd 2) indicating that the restriction of equal coefficients for the calf weaning weights did not reduce the correlation to any large extent, except possibly in the Herefords. Some of the multiple correlations were slightly larger than the canonical correlations but

TABLE LII

MULTIPLE CORRELATIONS AND STANDARDIZED PARTIAL REGRESSION COEFFICIENTS OF SUM OF CALF WEANING WEIGHTS AND MPPA ON COW TRAITS FOR THE DIFFERENT PARITY GROUPS FOR THE THREE HERDS

	Angus Herd 1						
	Parity						
Independent Variables	1-2	1-3	1-4	1-5	1-6	1-7	MPPA
R:	.25**	.31**	.27*	.24^{+}	.25	.33	.25**
Birth Wt.	.02	-.08	-.10	-.04	.14	.01	.01
Weaning Wt.	.20*	.31**	.27**	.24**	.09	.34	.24**
Weaning Conformation	-.06	-.11	-.11	-.10	-.07	-.06	-.09
Postweaning ADG	.14*	.15*	.15*	.10	.10	.07	.10^{+}

	Hereford Herd						
	Parity						
Independent Variables	1-2	1-3	1-4	1-5	1-6	1-7	MPPA
R:	.27*	.24	.30	.25	.17	.30	.21^{+}
Birth Wt.	.02	.05	-.01	.01	-.11	-.02	.01
Weaning Wt.	.22*	.17^{+}	.21^{+}	.18	.18	.18	.12
Weaning Conformation	.05	.02	.01	-.02	.01	.13	-.03
Postweaning ADG	.21*	.17^{+}	.27*	.16	.16	.29	.19*

	Angus Herd 2						
	Parity						
Independent Variables	1-2	1-3	1-4	1-5	1-6	1-7	MPPA
R:	.40**	.56**	.59**	.56**	.54**	.39	.46**
Birth Wt.	.19	.14	.08	.14	.22	.20	.21^{+}
Weaning Wt.	.18	.30*	.44**	.33*	.28	.21	.23^{+}
Weaning Conformation	-.02	-.04	-.10	-.10	-.10	-.17	-.12
Postweaning ADG	.29*	.34*	.65**	.55**	.57**	.24	.34**

$^{+}$ P < .10

* P < .05

** P < .01

these correlations are estimates subject to sampling variance.

The results of the regression analyses including first parity weaning weight with the cow traits are presented in Table LIII for each parity group and herd. In the Angus herd 1 and Hereford herd, cow birth weight, weaning weight, weaning conformation and postweaning ADG generally appeared independent of subsequent productivity when the first parity weaning weight was included as an independent variable. In the Angus herd 2, cow postweaning ADG was significant in four of the five parity groupings, indicating that postweaning ADG would be useful addition to first parity weaning weight in predicting subsequent productivity in this herd. The multiple correlations in these analyses were also comparable to the canonical correlations for the different parity groups between linear combinations of cow traits including first parity weaning weight and linear combinations of subsequent calf weaning weights (.47, .50, .52, .55, .59, Angus herd 1; .64, .68, .69, .70, .72, Hereford herd; .46, .54, .56, .64, .65, Angus herd 2).

These analyses generally indicate that, if selection of heifers must be done on prebreeding performance, heifers that are heavy at weaning and still growthy during the postweaning phase should be selected. When information on the first calf is available, this should be more indicative of subsequent procutivity than the heifers' prebreeding traits.

In many situations it would be satisfactory to be able to cull a certain proportion of heifers based on early performance if a low percentage of the heifers culled were good producers. The heifers in each herd were ranked on their predicted values for productivity based on prebreeding performance and predicted values based on prebreeding

TABLE LIII

MULTIPLE CORRELATIONS AND STANDARDIZED PARTIAL REGRESSION COEFFICIENTS OF SUM OF CALF WEANING WEIGHTS ON COW TRAITS (INCLUDING FIRST PARITY WEANING WEIGHT) FOR THE DIFFERENT PARITY GROUPS IN THE THREE HERDS

	Angus Herd 1					Hereford Herd					Angus Herd 2				
	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7	2-3	2-4	2-5	2-6	2-7
R:	.46**	.42**	.42**	.44**	.62*	.63**	.72**	.69**	.67**	.75**	.41*	.53*	.61**	.63**	.55^{+}
Independent Variables															
Birth Wt.	-.04	-.06	-.02	.17	.42	.01	-.11	-.13	-.13	-.32	.09	.12	.26	.37^{+}	.30
Weaning Wt.	.14^{+}	.10	.12	-.05	-.22	.06	.06	-.01	-.09	.11	.19	.28^{+}	.15	.14	-.07
Weaning Conformation	-.07	-.12^{+}	-.11	-.07	.10	.02	-.04	-.07	-.06	.24	-.06	-.14	-.21	-.20	-.31^{+}
Postweaning ADG	.03	.04	-.01	-.02	-.22	.11	.17*	.15	.04	.04	.30*	.46*	.34^{+}	.44*	.18
First Parity Weaning Wt.	.41**	.38**	.38**	.40**	.70**	.60**	.69*	.69**	.69**	.80**	.10	.13	.36*	.35*	.38^{+}

performance plus first parity weaning weight and ranked on first parity weaning weight. The bottom 10%, 20%, 30%, 40% and 50% were then evaluated for the proportion of those deciles containing heifers that were actually in the upper 50% and upper 25% of the herd based on productivity through the fifth parity. The results of these evaluations are presented in Tables LIV, LV, and LVI.

In the Angus herd 1 and Hereford herd about 40% and 46% of these heifers culled based on prebreeding performance were in the upper half of the herd in actual productivity. The Angus herd 2 was lower with only approximately 27% of the heifers culled actually in the upper half of the herd but this difference was not significant. In the Angus herd 1 and Hereford herd only 25% and 20% of the heifers culled were in the upper 25% of the herd in actual productivity and only 7% of the heifers culled in the Angus herd 2 were in the upper 25% based on actual productivity. Thus, on the average, 41% of the culled heifers were from the upper half and 14% of the culled heifers were from the upper quartile. There is no apparent pattern of changes in percent of culled heifers from the upper half of the herd as the culling intensity changes. This suggests that these heifers in the upper half were proportionally distributed throughout these deciles of predicted productivity. However, there was some indication that the proportions of heifers culled actually from the upper quartile decreased as the culling intensity decreases.

Table LV presents the results of similar evaluations where the predicted values are based on prebreeding traits plus first parity weaning weight. Culling was based on the predicted values for the sum of the second through fifth parity weaning weights and the results were

TABLE LIV

PROPORTIONS OF HEIFERS CULLED ON THE BASIS OF PREDICTED[a] VALUES THAT WERE ACTUALLY ABOVE MEDIAN IN PRODUCTIVITY OR IN THE UPPER QUARTILE OF PRODUCTIVITY[b]

Culling Intensity lower:	Percent of culled heifers from upper half: Herd				Percent of culled heifer from upper quartile: Herd			
	Angus 1	Hereford	Angus 2	χ^2	Angus 1	Hereford	Angus 2	χ^2
50%	45.2 (73)[c]	42.2 (45)	29.6 (27)	2.0	19.2	20.0	11.1	1.1
40%	50.0 (58)	38.9 (36)	27.3 (22)	3.3	20.7	19.4	9.1	1.5
30%	47.7 (44)	48.1 (27)	18.8 (16)	4.5	13.6	22.2	6.2	2.1
20%	48.3 (29)	44.4 (18)	27.3 (11)	1.4	10.3	16.7	9.1	.5
10%	53.3 (15)	55.6 (9)	33.3 (6)	.8	13.3	22.2	0.0	1.5

[a] Predicted values derived from heifer prebreeding traits.

[b] Sum of first five parity weaning weights.

[c] Number of heifers culled.

TABLE LV

PROPORTIONS OF HEIFERS CULLED BASED ON PREDICTED[a] VALUES FOR PRODUCTIVITY[b] THAT WERE ACTUALLY FROM THE UPPER HALF OF UPPER QUARTILE

Culling Intensity lower:	Percent of culled heifers in upper half: Herd				Percent of culled heifers in upper quarter: Herd			
	Angus 1	Hereford	Angus 2	χ^2	Angus 1	Hereford	Angus 2	χ^2
50%	37.0 (73)[c]	26.7 (45)	22.2 (27)	2.6	17.8	15.6	7.4	1.7
40%	37.9 (58)	25.0 (36)	18.2 (22)	3.6	17.2	16.7	9.1	.9
30%	36.4 (44)	11.1 (27)	12.5 (16)	7.3*	15.9	3.7	6.2	3.0
20%	37.9 (29)	5.6 (18)	9.1 (11)	7.2*	10.3	5.6	9.1	.3
10%	13.3 (15)	0.0 (9)	0.0 (6)	2.1	6.7	0.0	0.0	1.0

[a] Predicted values derived from heifer prebreeding traits plus first parity weaning weight.

[b] Sum of second through fifth parity weaning weights.

[c] Number of heifers culled.

TABLE LVI

PROPORTIONS OF HEIFERS CULLED BASED ON FIRST PARITY WEANING WEIGHT THAT WERE ACTUALLY FROM THE UPPER HALF OR UPPER QUARTILE IN PRODUCTIVITY[a]

Culling Intensity	Percent of culled heifers in upper half				Percent of culled heifers in upper quarter			
lower:	Angus 1	Hereford	Angus 2	χ^2	Angus 1	Hereford	Angus 2	χ^2
50%	38.4 (73)[b]	30.4 (46)	33.3 (33)	.8	17.8	17.4	15.2	.1
40%	36.2 (58)	27.0 (37)	23.1 (26)	1.8	15.5	10.8	11.5	.5
30%	31.8 (44)	17.9 (28)	20.0 (20)	2.1	15.9	7.1	10.0	1.3
20%	24.1 (29)	5.6 (18)	15.4 (13)	2.8	17.2	5.6	7.7	1.7
10%	6.7 (15)	0.0 (9)	0.0 (7)	1.1	0.0	0.0	0.0	0.0

[a] Sum of second through fifth parity weaning weight.

[b] Number of heifers culled.

evaluated as to the actual productivity for these parities. The percentages of the culled heifers that were actually in the upper half or upper quartile were lower than in the analyses using only the cow prebreeding traits. There was also a tendency for the proportion of culled heifers in the upper half or upper quartile to decrease as the percentage of heifers culled decreased. There was also some evidence that the Angus herd 1 was higher than the other two herds in these proportions when culling the bottom 20% or 30% of the herd.

Table LVI presents the percentage of culled heifers in the upper half or upper quartile where culling was based solely on the first parity weaning weight. The measure of actual productivity considered was the sum of the second through the fifth parity weaning weights. These proportions were very similar to those found using the predicted values based on cow traits and first parity weaning weight. This suggests that culling based solely on first calf weaning weight would be very comparable to culling on the basis of predicted values based on prebreeding traits and first parity weaning weight.

An interesting aspect on these analyses was the evaluation of the classifications relative to the multiple coefficient of determination associated with each analysis. The regression of the sum of the first five parity weaning weights on cow prebreeding traits accounted for only 5.8%, 6.25% and 31.4% of the total variation in the Angus herd 1, Hereford herd and Angus herd 2, respectively. In the Angus herd 1 and Hereford herd, nearly half of the culled heifers were actually from the upper half of the herd in productivity as might be expected from the small proportion of total variation accounted for. In the Angus herd 2, where more of the total variation was accounted for by cow prebreeding traits, less than one-third of the culled heifers were actually from the upper half of the herd in productivity. In the Angus herd 1 and Hereford herd, about 15% and 20% of the heifers culled based on their prebreeding performance were in the top quartile of productivity, depending somewhat on the culling rate. In Angus herd 2 this figure was close to 7%. When the weaning weight of the first calf was included with the cow traits the coefficients of determination increased to 17.6%, 47.6% and 37.2% for the Angus herd 1, Hereford herd and Angus herd 2, respectively. Accordingly, the percentages of culled heifers from the upper half of the herd in productivity or from the upper quartile decreased and these proportions seemed to depend more on the culling rate.

These results were also summarized as the proportions of the upper half and upper quarter that were culled if culling the bottom 10%, 20%, 30%, 40% or 50% of the herd. This type of evaluation provides information relative to proportions of the higher producing heifers culled whereas the previous evaluation summarized the proportions of the culled heifers that were high producers. The distinction between these two types of summaries can best be made by example. Suppose in a herd of 100 heifers, the lower 20 heifers were culled and 10 of these were eventually to be high producers. Thus, 50% of the heifers culled were high producers whereas 20% of the high producers (10÷50) were culled. By evaluating the regressions on the basis of the proportion of high producers culled we have some indication as to the high producers left after culling.

Table LVII presents the proportions of heifers in the upper half and upper quarter that were culled on the basis of prediction for

TABLE LVII

PROPORTIONS OF THE UPPER HALF AND UPPER QUARTILE OF PRODUCTIVITY THAT WERE CULLED BASED ON PREDICTED[a] VALUES FOR PRODUCTIVITY[b]

Culling Intensity lower:	Percent of upper half culled				Percent of upper quarter culled			
	Herd				Herd			
	Angus 1	Hereford	Angus 2	χ^2	Angus 1	Hereford	Angus 2	χ^2
50%	45.2 (73)[c]	42.2 (45)	29.6 (27)	2.0	38.9 (36)[d]	39.1 (23)	21.4 (14)	1.5
40%	39.7	31.1	22.2	2.9	33.3	30.4	14.3	1.8
30%	28.8	28.9	11.1	3.6	16.7	26.1	7.1	2.2
20%	19.2	17.8	11.1	.9	8.3	13.0	7.1	.5
10%	11.0	11.1	3.6	.3	5.6	8.7	0.0	1.3

[a] Predictions based on heifer prebreeding traits.

[b] Sum of first five parity weaning weights.

[c] Numbers of heifers in upper half are in parentheses.

[d] Number of heifers in upper quarter are in parentheses.

productivity (first-fifth parity derived from heifer prebreeding traits. These proportions decreased expectedly as the culling intensity increased in each herd. There was little evidence of any herd differences at any of the culling levels. On the average, 39%, 31%, 23%, 16% and 9% of the upper half were culled at the 50%, 40%, 30%, 20% and 10% culling levels, respectively. At these same culling levels, 33%, 26%, 17%, 9% and 5% of the upper quarter were culled.

Table XVIII presents the proportions of heifers in the upper half and upper quartile that were culled on the basis of prediction equations for productivity (second-fifth parity) derived from cow prebreeding traits plus first parity weaning weight. The proportions were lower than those found where culling was done on the basis of prebreeding traits only. It appears tha Angus herd 1 was higher than the other two herds at 20% and 30% culling levels. However, on the average, 29%, 22%, 12%, 7% and 1% of the upper half were culled at the 50%, 40%, 30%, 20% and 10% culling levels, respectively. At this same culling rate, 27%, 23%, 10%, 7% and 1% of the upper quarter were culled.

Table LIX presents the proportions of heifers in the upper half and upper quartile that were culled for productivity (second-fifth parity) based on the weaning weight of their first calf. There were no apparent herd differences in this evaluation of the regressions. On the average there were 34%, 23%, 14%, 6% and 0% of the upper half culled on the basis of first weaning weight for the 50%, 40%, 30%, 30%, and 10% culling rate, respectively. There were 34%, 20%, 14%, 8% and 0% of the upper quartile culled for these same culling rates.

Thus, these analyses provide some indication of the proportion of variation in productivity that must be accounted for before culling can

TABLE LVIII

PROPORTIONS OF THE UPPER HALF AND UPPER QUARTILE OF PRODUCTIVITY[a] THAT WERE CULLED BASED ON PREDICTED VALUES FOR PRODUCTIVITY DERIVED FROM HEIFER TRAITS AND FIRST PARITY WEANING WEIGHT

Culling Intensity	Percent of upper half culled				Percent of upper quarter culled			
lower:	Herd				Herd			
	Angus 1	Hereford	Angus 2	χ^2	Angus 1	Hereford	Angus 2	χ^2
50%	37.0 (73)[b]	26.7 (45)	22.2 (27)	2.6	36.1 (36)[c]	30.4 (23)	14.3 (14)	2.3
40%	30.1	20.0	14.9	3.1	27.8	26.1	14.3	1.0
30%	21.9	6.7	7.4	6.6*	19.4	4.4	7.1	3.4
20%	15.1	2.2	3.7	6.8*	8.3	4.4	7.1	.4
10%	2.7	0.0	0.0	2.0	2.8	0.0	0.0	1.0

[a] Sum of the second through fifth parity weaning weights

[b] Number of heifers in upper half are given in parentheses.

[c] Number of heifers in upper quartile are given in parentheses.

be accomplished at an acceptable error rate. These analyses also suggest that culling based on prebreeding traits will result in a large proportion of the culled animals being from the upper half of the herd in productivity but that many of these heifers culled will not be in the upper quartile. It was further suggested from these results that selection based on first calf performance is comparable to selection based on heifers' prebreeding traits and first parity weaning weight. The proportions of culled heifers from the upper quartile were very similar whether the culling was based on cow traits, cow traits and first parity weaning weight or first parity weaning weight alone. If the desired objective was to replace 10% of the cow herd each year then it might be possible to cull 20% to 30% of heifer calves on the basis of their prebreeding performance without culling a large proportion of the heifers that would eventually be in the upper quartile of productivity. Subsequently, heifers could be culled on the basis of their first parity weaning weight.

Conclusions

These analyses present several alternatives for prediction of productivity or classification of heifers into productivity groups. Principal components, canonical correlations, discriminant functions and multiple linear regression were used to evaluate their potential in identifying heifers with above average lifetime productivity. The standards used to compare the results from this research were the correlations between heifer prebreeding traits and subsequent productivity as measured by MPPA and the repeatabilities of weaning weight estimated by Boston, et al. (1975a). In this research, correlations

TABLE LIX

PROPORTIONS OF THE UPPER HALF AND UPPER QUARTILE IN PRODUCTIVITY[a] CULLED ON THE BASIS OF FIRST PARITY WEANING WEIGHT

Culling Intensity	Percent of upper half culled				Percent of upper quarter culled			
lower:	Herd				Herd			
	Angus 1	Hereford	Angus 2	χ^2	Angus 1	Hereford	Angus 2	χ^2
50%	38.4 (73)	30.4 (46)	33.3 (33)	.8	36.1 (36)	34.8 (23)	31.2 (15)	.1
40%	28.8	21.7	18.2	1.6	25.0	17.4	18.8	.6
30%	19.2	10.9	12.1	1.8	19.4	8.7	12.5	1.4
20%	9.6	2.2	6.1	2.5	13.9	4.3	6.2	1.7
10%	1.4	0.0	0.0	1.1	0.0	0.0	0.0	0.0

[a] Sum of second through fifth parites.

between MPPA and cow birth weight, preweaning ADG, weaning weight, weaning conformation, postweaning ADG and yearling weight were .12, .19, .20, -.01, .10 and .23 for Angus herd 1; .14, .10, .13, .00, .17 and .21 in the Hereford herd and .29, .23, .27, -.02, .33 and .37 in Angus herd 2. The estimates of repeatability reported by Boston et al. (1975a) were .27 for Angus and .50 for Herefords. The correlations with MPPA and repeatabilities will be compared to the results of the multivariate analyses where the first five parity calves are considered. Because of the large number of parity groupings considered, only one parity grouping of the first five parities considered calves from cows up to six years of age and yet the numbers of cows involved were sufficient to have some confidence in the estimates obtained.

In the principal component analyses the first principal component for calf weaning weights was judged to be a satisfactory measure of productivity in that it generally described a group of half-sibs with above average weaning weights. This principal component generally weighted each calf equally and would therefore be very comparable to the average calf weaning weight or MPPA. This was reflected in the correlations of the principal component with the heifer prebreeding traits. The largest correlations found in the first five parities were between the first principal component for calf weights and heifer yearling weight and were .19, .26 and .37 for the Angus herd 1, Hereford herd and Angus herd 2, respectively. The principal components for cow traits were also correlated with the first principal components for calf weaning weights. The correlations between the first principal component for cow traits and the first principal component for the first five parity weaning weights were .19, .20 and .34 for the Angus herd 1, Hereford herd and Angus herd 2. respectively. Thus, in terms of predicting productivity from the heifer prebreeding traits, there appears to be little advantage associated with the use of principal components. Yearling weight would seem to be the best indicator based on its ease of measurement. When the first parity weaning weight was included with the cow traits the correlations between the third principal component for cow traits and the first principal component for the second through fifth parity weaning weights were .35, .58 and -.39 for the Angus herd 1, Hereford herd and Angus herd 2. All of these correlations indicated a favorable relationship. This third principal component for cow traits gave much weight to first parity weaning weight. There appears to be some advantage to using this principal component over just first parity weaning weight but this advantage would be relatively small.

Canonical correlations were also estimated between cow traits and subsequent calf weaning weights. For the analyses considering heifer prebreeding traits and the first five parity weaning weights these were .30, .40, and .52 for the Angus herd 1, Hereford herd and Angus herd 2, respectively. The canonical correlations between cow traits plus first parity weaning weight and second through fifth parity weaning weights were .52, .69 and .56 for the Angus herd 1, Hereford herd and Angus herd 2, respectively. These are a substantial improvement over the correlations obtained between cow traits and MPPA and over the repeatabilities of weaning weights for the two breeds. However, the canonical variates in all of the parity groups for calf weaning weights did not always describe a set of half-sibs with each half-sib above average in weaning weight. This was particularly true in the Herefords. These analyses indicate that the canonical variates might be useful in predicting up to the fourth or fifth parity but if prediction beyond that is desired, yearling weight of the heifer and/or first parity weaning weight should be used instead of the canonical variate for cow traits.

Discriminant functions were also used in evaluating cow productivity. In the discriminant analyses considering productivity as measured by the first through fifth parity weaning weights, around 46% of the heifers were correctly classified into the proper quartile of productivity by the discriminant analysis using heifer prebreeding traits. Although this is better than random classification, it is less accurate than is desired. Thus, accurate classification into quartiles of productivity based solely on prebreeding traits does not appear promising. When cross-classification of heifers between the first and second quartiles and between the third and fourth quartiles was ignored, around 63% of the above and below median heifers were classified into above and below median quartiles, respectively. Again, this appears better than chance but can hardly be called accurate. When the proportions of above median heifers classified into the lower quartile were summarized, it was found that around 18% of these above median heifers were misclassified in this manner by the cow prebreeding traits. This is about what would be expected if classification was done at random. Thus, classification of heifers into subsequent productivity groups based on prebreeding performance would probably be only moderately successful and this is probably a consequence of the low associations found between heifer growth and subsequent productivity.

The first parity weaning weight was included with the cow traits to develop a discriminant function to classify heifers into quartiles of productivity. In the analyses defining productivity as the sum of the second through fifth parity weaning weights about 50% of the heifers were correctly classified into the correct quartile of productivity. This is very comparable to the analyses done without the first parity weaning weight. Thus, additional information on the first calf was not beneficial in this case. When cross-classification was allowed between the first and second quartile and third and fourth quartile, around 73% of the heifers were correctly classified. This is substantially better than the previous analyses. The proportions of above median heifers classified into the fourth quartile by a linear function of cow traits and first parity weaning weight averaged around 11%. This again is an improvement over the previous analyses.

Thus, the results of these discriminant analyses suggest that classification into productivity groups based on prebreeding traits would be of limited utility. Information on the first calf would probably be needed to raise the proportions of correct classifications to an acceptable level.

In the regression analyses considering the first five parities correlations between linear combinations of heifer prebreeding traits and subsequent productivity were .24, .25 and .56 for the Angus herd 1, Hereford herd and Angus herd 2, respectively. Compared to the correlations between yearling weight and MPPA (.23, .21, .37 for each herd, respectively) there appeared to be little advantage in using a linear combination of prebreeding traits as compared to using just yearling weight. When the first parity weaning weight was included with the cow traits these correlations were .42, .69 and .61 for the Angus herd 1, Hereford herd and Angus herd 2, respectively. These appear to be slightly better than the repeatabilities of .27 for Angus and .50 for

Herefords reported by Boston et al. (1975a) but not largely so. In the Angus herd 1 and Hereford herd, the partial regression of first parity weaning weight on productivity was the only significant one but in the Angus herd 2 postweaning ADG was also significant. When the results of these analyses were summarized as the proportion of the heifers culled by the regression function that were from the upper half of the herd, approximately 41% of those culled were incorrectly culled using heifer prebreeding traits, about 20% of those culled using prebreeding traits and first parity weaning weight were incorrectly culled and 21% of those culled using first parity weaning weight were incorrectly culled, using average percentages over all herds and culling levels.

Thus, these regression analyses also indicate the difficulty of predicting subsequent productivity from prebreeding traits of heifers and indicate that selection will be more accurate when the first parity weaning weight is known.

In evaluation of these multivariate techniques, none had an apparent advantage in accuracy. The canonical correlations were limited by the negative signs on some of the calf weaning weights and the discriminant functions were limited by the apparent heterogeneity of covariance matrices. Thus, since the weights on the calf weaning weights in the regression are predetermined and the technique does maximize the correlation between early traits and subsequent productivity, its use should be recommended over the other analyses.

These analyses consistently demonstrated the low association between heifer prebreeding traits and subsequent productivity that has been found by many researchers. The apparent inability of these multivariate techniques to improve the association between early heifer performance and subsequent productivity may be due to a negative association between the maternal effects associated with prebreeding traits and direct effects for weaning weight. Much evidence has been presented that suggests that a negative environmental and/or genetic correlation exists between preweaning growth and maternal ability which could cause a phenotypic antagonism between these traits. This research does not provide any evidence relative to the existence of these negative associations but the results are certainly affected by any relationships that do exist. If they are negative as the literature suggests, they are not sufficiently strong to result in the phenotypic associations between cow prebreeding traits and subsequent productivity to be mostly negative as evidenced by the phenotypic estimates obtained in this study and other research in the literature. It is possible, however, that these low associations between heifer growth and subsequent productivity could be the result of some negative relationships existing between effects for early heifer growth and effects for subsequent maternal ability.

Based on the results of this research and other research in the same area the following general conclusions can be made:

1. The phenotypic associations between heifer prebreeding traits and subsequent productivity are positive and strong enough to do some limited culling on the basis of heifer prebreeding traits. From the indications of this research, it would be best to cull heifers lower in both weaning weight and postweaning ADG. This seems reasonable in that these types of heifers have little growth potential preweaning and very little growth potential postweaning.

2. Because the associations between heifer prebreeding traits and subsequent productivity are low and the associations between half-sib weaning weights are generally higher, final selection of heifers should be based on the weaning weight of the first calf. If the weaning weight of the first calf is known, the heifer prebreeding traits appear to be of little additional value in predicting subsequent productivity. Although no evidence was presented in this research, it seems reasonable to consistently evaluate a cow on the weaning weight of each parity calf.
3. Little evidence was found in the literature suggesting breed differences between Angus and Herefords in phenotypic relationships between heifer prebreeding traits and subsequent productivity. There was little evidence in this research that suggested any differences might exist. If any such differences exist they are probably small and difficult to separate from the large environmental differences present in beef cattle.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this study were to: (a) develop and evaluate linear combinations of cow's traits from birth to yearling and calf weaning weights through the use of principal component analyses to ascertain their usefulness in describing interrelationships between early heifer performance and subsequent productivity and in predicting productivity from early measured traits, (b) characterize the phenotypic dependency structure among measures of growth and performance in heifers and growth of their calves through the use of canonical correlations, (c) develop and evaluate procedures to identify, at as early an age as possible, cows that are potentially above herd average in lifetime productivity as measured by weaning traits of calves through the use of discriminant analyses and multiple linear regression techniques and (d) determine the extent of differences that may exist between Angus and Herefords in terms of procedures and the accuracy of predicting lifetime productivity potential.

Records on 2,039 Angus calves and their 500 dams and on 836 Hereford calves and their 202 dams were studied. Records through yearling were available on 418 Angus cows and on 182 Hereford cows. These data were collected as part of a beef cattle selection project conducted under range conditions in Oklahoma.

The cow birth weights, preweaning ADG, weaning weights, weaning conformations, postweaning ADG and yearling weights were corrected for age of dam and year effects by additive correction factors estimated by least squares techniques from this data. The calf weaning weights were corrected for age of dam and year effects by additive correction factors estimated from the data and corrected for sex by multiplicative correction factors estimated from the data. Age of dam corrections were to a five year cow basis and sex was corrected to a heifer equivalent. Cow productivity was measured by the sum of the weaning weights of her calves. Since the number of calves per cow was highly variable, separate analyses were run in every case to consider the first two calves, the first three calves, the first four calves, the first five calves, the first six calves and the first seven calves.

The principal component analyses developed linear combinations of heifer traits that generally described a heifer above average in all traits and accounted for a large proportion of the original variation. These analyses also developed linear combinations of calf weaning weights that described a set of maternal half-sibs above average in weaning weight and also accounted for a large proportion of the total original variation. Many of the other principal components derived were difficult to interpret and accounted for a smaller portion of the original variation. The correlations derived between heifer growth traits and the first principal component for calf weaning weights indicated that yearling weight was as strongly associated with this first principal component as any other trait. The correlations between the first principal components for heifer growth traits and the first principal components for calf weaning weights indicated that heifer yearling weight was comparable to the first principal component for heifer growth traits in their association with subsequent productivity. When the first parity weaning weight was included with the heifer traits, the larges associations between principal components for heifer traits and principal components for subsequent calf weaning weights was only slightly better than the repeatabilities of weaning weights for the Hereford and Angus.

Canonical correlations were estimated between heifer traits and subsequent calf weaning weights and between heifer traits plus first parity weaning weights and subsequent productivity. The associations between heifer traits and subsequent productivity appeared slightly superior to the association between yearling weight and MPPA which was the standard of comparison. However, the coefficients for some of the calf weaning weights were negative making the canonical variate for heifer traits a dubious predictor of subsequent productivity. When the weaning weight of the first calf was included with the heifer traits, the strength of the canonical correlations between heifer traits and subsequent productivity appeared superior to the repeatabilities of weaning weight but again some of the coefficients on the calf weaning weights were negative, casting doubt on the usefulness of these canonical correlations in predicting productivity from early performance. Thus, canonical correlations are more useful in description than prediction in this research.

Discriminant functions were also developed to classify heifers into quartiles of productivity as measure by calf weaning weights based on traits measured early in life. Analyses were done using heifer traits to classify heifers into productivity quartiles where productivity was measured beginning with the first parity. Analyses were also done using heifer traits plus first parity weaning weight to classify heifers into quartiles where productivity was measured beginning with the second parity calf weaning weight. Generally, these analyses indicated that classification based on heifer traits alone was only slightly better than random classification and that inclusion of the first parity weaning weight into the heifer traits was needed to reach an acceptable level of correct classifications.

Multiple linear regression analyses were also done in a manner analogous to the canonical correlation analyses. Heifer birth weight, weaning weight, weaning conformation and postweaning ADG were used as independent variables to predict productivity as measured by the sum of cow's calve's weaning weights. Heifer traits plus first parity weaning weight were used as independent variables to predict productivity as measured by the sum of weaning weights beginning with the second parity. The multiple correlations between linear combinations of heifer traits and subsequent productivity were comparable to the canonical correlations. Thus, these regression analyses were judged superior to canonical correlations in that the linear combinations of calf traits were indicative of productivity for each calf in the regression analyses. When the first parity weaning weight was included as an independent variable, the resultant multiple correlations were slightly superior to the repeatabilities of calf weaning weights. However, in these analyses, first parity weaning weight was generally the only significant partial regression coefficient. Classifications into productivity groups were also done using the predicted values from these regression analyses. The results were very similar to those of the discriminant analyses indicating that classification based on heifer traits only would be only moderately successful and that information on the first parity calf would be desired.

The only breed differences between Herefords and Angus suggested by this research reflected the differences in repeatability found by Boston et al. (1975a) where the weaning weights of Herefords were more repeatable than Angus. When the weaning weight of the first parity calf was included with the heifer traits, the resultant improvement was greater in the Herefords than in the Angus.

The following general conclusions can be made from the results of this research and from other research in this area:

1. The phenotypic relationships between heifer prebreeding traits and subsequent productivity are low, possibly due to negative genetic associations between heifer growth and subsequent productivity, but positive. Limited culling on the basis of prebreeding traits could be recommended to cull those heifers obviously inferior in weaning weight and postweaning ADG.
2. Selection accuracy can be substantially increased by inclusion of information on the first parity weaning weight into the selection criteria. There was some indication from this research that heifer prebreeding traits add only slight additional information if the first parity weaning weight is known.
3. The multivariate methods with the most promising potential for identification of superior producing heifers were principal components, multiple linear regression and discriminant functions. The results of these methods were comparable to or slightly superior to the associations of yearling weight with subsequent productivity or the repeatabilities of calf weaning weights.

4. The breed differences noted in this research were mostly a function of the differences in repeatability of weaning weights found by Boston et al. (1975a). When the first parity weaning weight was not included with the heifer traits, few breed differences were noted.

Further study of the phenotypic relationships between heifer growth or development and subsequent productivity is suggested by this research. Other growth or size measurements could provide additional information that might strengthen these relationships or additional ancestral information might be beneficial.

LITERATURE CITED

Anderson, T. W. 1958. An Introduction to Multivariate Statistical Analysis. John Wiley and Sons, Inc., New York.

Bailey, C. M. and Y. O. Koh. 1974. Maternal sib correlations for weaning weights in Hereford populations under diverse environments. J. Anim. Sci. 38:923.

Barr, A. J., J. H. Goodnight, Sall and Helwig. 1976. Statistical Analysis System. SAS Institute Inc. Raleigh, N.C.

Benyshek, L. L. and T. J. Marlowe. 1973. Relationship between Hereford cow weight and progeny performance. J. Anim. Sci. 37:406.

Berg, R. T. 1961. Factors influencing calf weaned weights in a commercial Aberdeen-Angus herd. J. Anim. Sci. 20:670. (Abstr.)

Boston, Andrew C., J. V. Whiteman and R. R. Frahm. 1975a. Phenotypic relationships within Angus and Hereford females. I. Repeatabilities of progeny weaning weights. J. Anim. Sci. 41:23.

Boston, Andrew C., J. V. Whiteman and R. R. Frahm. 1975b. Phenotypic relationships within Angus and Hereford females. II. Heifer growth and subsequent cow productivity. J. Anim. Sci. 41:16.

Berry, J. C. 1945. Reliability of averages of different numbers of lactation records for comparing dairy cows. J. Dairy Sci. 28:355.

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

Brinks, J. S., R. T. Clark, N. M. Kieffer and J. J. Urick. 1964. Predicting producing ability in range Hereford cows. J. Anim. Sci. 23:593. (Abstr.).

Brinks, J. S., R. T. Clark, F. T. Rice and N. M. Kieffer. 1961. Adjusting birth weight, weaning weight and preweaning gain of sex of calf in range Hereford cattle. J. Anim. Sci. 20:363.

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

Brown, C. J. 1960. Influence of year and season of birth, sex, sire and age of dam on weights of beef calves at 60, 120, 180 and 240 days of age. J. Anim. Sci. 19:1062.

Brown, J. E., C. J. Brown and W. T. Butts. 1973. Evaluating relationships among immature measures of size, shape and performance of beef bulls. I. Principal components as measures of size and shape in young Hereford and Angus bulls. J. Anim. Sci. 36:1010.

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

Cardellino, Ricardo and R. R. Frahm. 1971. Evaluation of two types of age of dam correction factors for weaning weight in beef cattle. J. Anim. Sci. 32:1078.

Carpenter, J. A., Jr., H. A. Fitzhugh, Jr., T. C. Cartwright, A. A. Milton and R. C. Thomas. 1971. Principal components for size of Hereford cows. J. Anim. Sci. 33:197 (Abstr.)

Chapman, Hollis D., T. M. Clyburn and W. C. McCormick. 1972. Comparison of cirteria for selecting introduced beef sires. J. Anim. Sci. 35:321.

Christian, L. L., E. R. Hauser and A. B. Chapman. 1965. Association of preweaning and postweaning triats with weaning weights in cattle.

Clum, H. V., R. U. Kidder and M. Koger. 1956. Environmental factors affecting weaning weights of calves at Fla. Everglades Sta. J. Anim. Sci. 15:1209 (Abstr.).

Cooper, C. R., T. M. Sutherland, P. S. Patengale and J. S. Williams. 1965. Effects of environmental factors and their two way interactions on weaning traits in Colorado beef herds. J. Anim. Sci. 24:847 (Abstr.)

Cundiff, L. V. and K. E. Gregory. 1968. Improvement of beef cattle through breeding methods. North Central Regional Pub. 120 (Rev.)

Cundiff, L. V., R. L. Willham and C. A. Pratt. 1966a. Effects of certain factors and their two-way interactions on weaning weight in beef cattle. J. Anim. Sci. 25:972.

Cunningham, E. P. and C. R. Henderson. 1965b. Repeatability of weaning traits in beef cattle. J. Anim. Sci. 24:188.

Curnow, R. N. 1961. The estimation of repeatability and heritability from records subject to culling. Biometrics 17:553.

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

Deese, R. E. and M. Koger. 1967. Maternal effects on preweaning growth rate in cattle. J. Anim. Sci. 26:250.

Dickerson, G. E. 1940. Estimates of producing ability in dairy cattle. J. Agr. Res. 61:561.

Drewry, Kenneth Joe. 1964. Beef calf weights at 100 days and 205 days as indicators of dam's producing ability. Ph.D. Thesis. Ia. State Univ., Ames.

Drewry, K. J. and L. N. Hazel. 1966. Beef calf weights as indicators of dam's producing ability. J. Anim. Sci. 25:878. (Abstr.)

Ellicott, George H., L. A. Holland and A. L. Neumann. 1970. Most probable producing ability of Hereford cows. J. Anim. Sci. 30:1030. (Abstr.)

Evans, Lee E., J. V. Craig, G. F. Cmarik and R. J. Webb. 1955. Influence of age of calf, sex and age of dam on weaning weight of Herefords. J. Anim. Sci. 14:1181. (Abstr.)

Frey, John J. 1971. Evaluation of cow type classification score and its relationship to cow productivity. M.S. Thesis. Okla. State Univ., Stillwater.

Frey, J. J., R. R. Frahm, J. V. Whiteman, J. E. Tanner and D. F. Stephens. 1972. Evaluation of cow type classification score and its relationship to cow productivity. J. Anim. Sci. 34:1.

Gaskins, Charles T., C. Boyd Ramsey and Robert C. Albin. 1975. A discriminate analysis of medium and large body types in Herefords cattle. J. Anim. Sci. 41:249. (Abstr.)

Gregory, Keith E., C. T. Blunn and M. L. Baker. 1950. A study of some of the factors influencing birth and weaning weights of beef calves. J. Anim. Sci. 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. Anim. Sci. 22:316.

Harwin, G. O., J. S. Brinks and H. H. Stonaker. 1966. Genetic and environmental interactions affecting weaning weights of Hereford calves. J. Anim. Sci. 25:779.

Hill, J. R., Jr., J. E. Legates and E. U. Dillard. 1966. Inheritance of maternal effects in beef cattle. J. Anim. Sci. 25:264. (Abstr.)

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

Hohenboken, W. D. and J. S. Brinks. 1971a. Relationships between direct and maternal effects on growth in Herefords: II. Partitioning of covariance between relatives. J. Anim. Sci. 32:26.

Hohenboken, W. D., E. R. Hauser, A. B. Chapman and L. V. Cundiff. 1973. Phenotypic correlations between dam traits expressed during development and lactation and traits of progeny in beef cattle. J. Anim. Sci. 37:1.

Holloway, J. W. and Robert Totusek. 1972. The relationship between preweaning plane of nutrition and subsequent performance of Angus and Hereford females through three calf crops. J. Anim. Sci. (submitted for publication).

Kieffer, Nat Mathan. 1959. Inheritance of certain maternal traits in beef cattle. Ph.D. Thesis. Okla. State Univ., Stillwater.

Knapp, B. J., A. L. Baker, J. R. Quesenberry and R. T. Clark. 1942. Growth and production factors in range cattle. Mont. Agr. Exp. Sta. Bul. 400.

Koch, Robert M. 1951. Size of calves at weaning as a permanent characteristic of range Hereford cows. J. Anim. Sci. 10:768.

Koch, Robert M. 1969. Influence of dam's environment on offspring phenotype. J. Anim. Sci. 29:108 (Abstr.)

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

Koch, Robert 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. Anim. Sci. 14:775.

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

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

Koger, M. and J. H. Knox. 1947. The repeatability of the yearling production of range cows. J. Anim. Sci. 6:461.

Koger, M., W. L. Reynolds, J. H. Meade, W. G. Kirk, F. M. Peacock and R. W. Ridder. 1962. Environment, sex and age of dam effects. J. Anim. Sci. 21:973. (Abstr.)

Kress, D. D. and P. J. Burfening. 1972. Weaning Weight related to subsequent most probable producing ability in Hereford cows. J. Anim. Sci. 35:327.

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

Lueker, C. E., C. J. Brown and Warren Gifford. 1963. Repeatability of cow performance traits. J. Anim. Sci. 22:245. (Abstr.)

Lush, J. L. 1945. Animal Breeding Plans (3rd Ed.). The Iowa State Univ. Press, Ames.

Lush, J. L. 1948. The Genetics of Populations. Mimeographed. Dept. of Anim. Sci., Iowa State Univ., Ames.

Mangus, W. L. and J. S. Brinks. 1971. Relationships between direct and maternal effects on growth in Herefords: I. Environmental factors during preweaning growth. J. Anim. Sci. 32:17.

Marchello, J. A., D. W. Blackmore and J. J. Urick. 1960. Heritability of 18-month weight of heifers and its relationship to birth weight and weaning weight of their first calf. J. Anim. Sci. 19:956. (Abstr.)

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

Marlowe, T. J., C. C. Mast and R. R. Schalles. 1965. Some non-genetic influences on calf performance. J. Anim. Sci. 24:494.

Martin, T. G., G. Srinivasan and V. A. Garwood. 1970. Creep feed as a factor affecting cow and calf performance. J. Anim. Sci. 31:166. (Abstr.)

McCormick, W. C., B. L. Southwell and E. J. Warwick. 1956. Factors affecting performance in herds of purebred and grade Polled Hereford cattle. Ga. Agr. Exp. Sta. Tech. Bull. N.S. 5.

Minyard, J. A. and C. A. Dinkel. 1965. Heritability and repeatability of weaning weight in beef cattle. J. Anim. Sci. 24:1072.

Morrison, Donald F. 1967. Multivariate Statistical Methods. McGraw-Hill Book Co., New York.

Muhmud, A. and E. H. Cobb. 1963. Factors affecting weaning weights, preweaning gains and conformation scores of beef calves in Hawaii. J. Anim. Sci. 22:820. (Abstr.)

Neville, W. E., E. P. Warren and W. A. Griffey. 1974. Estimates of age effects on milk production in Hereford cows. J. Anim. Sci. 38:1.

Ray, D. E., C. B. Roubicek, O. F. Pahnish and J. S. Brinks. 1970. Breeding merit of topcross parents for preweaning traits in Hereford cattle. J. Anim. Sci. 30:161.

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

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

Sellers, H. I., R. L. Willham and R. C. deBaca. 1970. Effects of certain factors on weaning weight of beef calves. J. Anim. Sci. 31:5.

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

Stanforth, Todd. 1974. Selection for weaning weight and yearling weight in Hereford cattle. M.S. Thesis. Okla. State Univ., Stillwater.

Swiger, L. A. 1961. Genetic and environmental influences on gain in beef cattle during various periods of life. J. Anim. Sci. 20:182.

Swiger, L. A., R. M. Koch, K. E. Gregory, V. H. Arthaud, W. W. Rowden and J. E. Ingalls. 1962. Evaluating preweaning growth of beef calves. J. Anim. Sci. 21:781.

Tanner, J. E., R. R. Frahm, R. L. Willham and J. V. Whiteman. 1970. Sire x sex interactions and sex differences in growth and carcass traits of Angus bulls, steers and heifers. J. Anim. Sci. 31:1058.

Thompson, C. E. and T. J. Marlowe. 1971. Methods of estimating most probable producing ability. J. Anim. Sci. 32:394. (Abstr.)

Vesely, J. A. and O. W. Robison. 1971. Genetic and maternal effects on preweaning growth and type score in beef cattle. J. Anim. Sci. 32:826.

Vogt, D. W. and T. J. Marlowe. 1966. A further study of the genetic parameters involving preweaning growth rate and weaning grade in beef calves. J. Anim. Sci. 25:265. (Abstr.)

Warren, E. P., F. A. Thrift and J. L. Carmon. 1965. Factors influencing weaning weights of Georgia beef calves. J. Anim. Sci. 24:853. (Abstr.)

Whatley, J. A., Jr. 1960. The importance of production in the beef cow. The American Hereford J. 51(1):10.

Willham, R. L. 1963. The covariance between relatives for characters composed of components contributed by related individuals. Biometrics 19:18.

Wright, S. 1932. General group and special size factors. Genetics 17:603.

Young, L. D. 1975. An analysis of the dependency structure between a gilt's pre-breeding and reproductive traits. Ph.D. Thesis. Okla. State Univ., Stillwater.

APPENDIX

TABLE LX

ANALYSES OF VARIANCE FOR ANGUS COW HERD 1

Source	d.f.	Mean Squares					
		Birth Wt.	Preweaning ADG	Weaning Wt.	Weaning Conf.	Postweaning ADG	Yearling Wt.
Year Born	10-11	214.0**	.2234**	11675.6**	3.29**	1.3579**	66379.8**
Age of Dam	3	450.0**	.6013**	32114.4**	10.46**	.1096**	8685.3**
Year X Age	27-30	52.3	.0219	1097.8	.71*	.0204*	1552.9
Error	283-293	48.5	.0177	861.5	.47	.0130	1473.9

* P < .05

** P < .01

TABLE LXI

ANALYSES OF VARIANCE FOR HEREFORD COW HERD

Source	d.f.	Mean Squares					
		Birth Wt.	Preweaning ADG	Weaning Wt.	Weaning Conf.	Postweaning ADG	Yearling Wt.
Year Born	12-14	202.1**	.0785**	3566.0**	4.90**	.5938**	35656.6**
Age of Dam	3	442.0**	.3192**	18057.6**	3.29**	.0993**	10536.7**
Year X Age	31-35	70.8	.0283+	1313.6+	1.23**	.0224	1043.2
Error	135-149	57.8	.0192	935.2	.36	.0189	1563.1

+ P < .10

* P < .05

** P < .01

TABLE LXII

ANALYSES OF VARIANCE FOR ANGUS COW HERD 2

Source	d.f.	Mean Squares					
		Birth Wt.	Preweaning ADG	Weaning Wt.	Weaning Conf.	Postwéan-ing ADG	Yearling Wt.
Year Born	4-6	178.5*	.0963**	3002.9*	5.30**	1.4703**	
Age of Dam	3	303.1**	.1198**	7253.7**	1.95+	.0160	
Year X Age	5-11	46.7	.0320	1579.3	.29	.0060	
Error	81-141	61.6	.0208	1109.5	.87	.0282	

+ P < .10

* P < .05

** P < .01

TABLE LXIII

ANALYSES OF VARIANCE FOR ANGUS CALF HERD 1

Source	d.f.	Mean Squares				
		Birth Wt.	Preweaning ADG	Weaning Wt.	Weaning Conformation	Weaning Condition
Year Born	13	304.7**	.8505**	39149.0**	13.21**	17.83**
Age of Dam	3	1009.9**	1.1800**	64499.7**	12.09*	9.58**
Sex	1	2295.5**	2.0046**	114743.1**	.84	4.66**
Year X Age	29	105.1**	.0991**	5179.5**	1.40	.87**
Year X Sex	11	60.6	.0721*	585.9	1.85	.71
Age X Sex	3	25.8	.0088	3431.9*	1.82	.73*
Error	1269	60.0	.0353	1706.6	3.26	.38

* P < .05

** P < .01

TABLE LXIV

ANALYSES OF VARIANCE FOR HEREFORD CALF HERD

Source	d.f.	Mean Squares				
		Birth Wt.	Preweaning ADG	Weaning Wt.	Weaning Conformation	Weaning Condition
Year Born	13-14	349.3**	.3741**	17867.4**	10.62**	12.92**
Age of Dam	3	3128.8**	2.8371**	161665.3**	29.52**	19.78**
Sex	1	2436.8**	1.5882**	95335.0**	.10	2.93*
Year X Age	37-38	105.1*	.0908**	4495.7**	1.10**	1.12**
Year X Sex	13-14	62.4	.0734+	4478.0+	.20	.17
Age X Sex	3	61.7	.0986+	3553.6*	.47	.80+
Error	755-761	66.4	.0435	2056.8	.61	.49

+ P < .10
* P < .05
** P < .01

TABLE LXV

ANALYSES OF VARIANCE FOR ANGUS CALF HERD 2

Source	d.f.	Mean Squares				
		Birth Wt.	Preweaning ADG	Weaning Wt	Weaning Conformation	Weaning Condition
Year Born	11	816.4**	.1336**	7577.3**	2.40**	1.74**
Age of Dam	3	1135.1**	.4745**	30478.2**	3.39**	2.37*
Sex	2	780.4**	.6244**	34182.4**	2.42*	3.26**
Year X Age	15	103.3*	.0424	2253.0	1.82**	1.04+
Year X Sex	16	37.1	.0526	2621.4+	.98	1.96**
Age X Sex	6	72.9	.0280	917.1	.31	.76
Error	648-655	60.3	.0355	1706.0	.73	.65

+P < .10
*P < .05
**P < .01

TABLE LXVI

VARIANCE-COVARIANCE MATRICES FOR THE PRODUCTIVITY QUARTILES IN THE ANALYSES CONSIDERING THE FIRST FIVE PARITY CALVES IN ANGUS HERD 1

	Quartile	Birth Wt.	Weaning Wt.	Weaning Conformation	Postweaning ADG
Birth Wt.	1	54.5	126.3	-.41	.2893
	2	46.9	84.6	.08	.0959
	3	31.2	25.7	-.08	-.0632
	4	32.1	47.8	-1.12	.1176
Weaning Wt.	1		995.8	4.57	-.6246
	2		596.6	4.72	.0655
	3		628.6	2.65	-.9197
	4		459.5	2.50	-.5066
Weaning Conformation	1			.52	-.0299
	2			.38	-.0004
	3			.26	-.0118
	4			.56	-.0578
Postweaning ADG	1				.0085
	2				.0100
	3				.0087
	4				.0174

TABLE LXVII

VARIANCE-COVARIANCE MATRICES FOR THE PRODUCTIVITY QUARTILES IN THE ANALYSES CONSIDERING THE FIRST TWO PARITY CALVES IN ANGUS HERD 2

	Quartile	Birth Wt.	Weaning Wt.	Weaning Conformation	Postweaning ADG
Birth Wt.	1	29.8	109.1	.97	.0781
	2	38.9	114.3	1.69	.3323
	3	75.5	136.8	2.67	-.0328
	4	52.0	106.2	-.80	.0879
Weaning Wt.	1		1236.0	15.42	-.5021
	2		945.8	10.40	.0721
	3		1676.9	20.78	-2.2048
	4		845.8	7.75	-.0871
Weaning Conformation	1			1.00	-.0328
	2			.54	.0344
	3			1.71	-.0638
	4			.61	-.0451
Postweaning ADG	1				.0129
	2				.0154
	3				.0222
	4				.0368

TABLE LXVIII

VARIANCE-COVARIANCE MATRICES FOR THE PRODUCTIVITY QUARTILES IN THE ANALYSES CONSIDERING THE FIRST THREE PARITY CALVES IN ANGUS HERD 2

	Quartile	Birth Wt.	Weaning Wt.	Weaning Conformation	Postweaning ADG
Birth Wt	1	45.8	163.6	1.73	.0056
	2	33.4	-9.4	-1.11	.2541
	3	49.1	113.4	-.25	-.1534
	4	50.4	128.9	1.98	.0665
Weaning Wt.	1		1495.2	16.59	-1.0973
	2		994.2	.47	-1.0833
	3		959.6	12.83	-2.6498
	4		1093.8	24.29	1.0569
Weaning Conformation	1			.93	-.0588
	2			.57	-.0738
	3			1.38	-.0156
	4			1.10	-.0412
Postweaning ADG	1				.0148
	2				.0179
	3				.0206
	4				.0405

TABLE LXIX

VARIANCE-COVARIANCE MATRICES FOR THE PRODUCTIVITY QUARTILES IN THE ANALYSES CONSIDERING THE FIRST FIVE PARITY CALVES ANGUS HERD 2

	Quartile	Birth Wt.	Weaning Wt.	Weaning Conformation	Postweaning ADG
Birth Wt	1	29.8	109.1	.97	.0781
	2	38.9	114.3	1.69	.3323
	3	75.5	136.8	2.67	-.0328
	4	52.0	106.2	-.80	.0879
Weaning Wt.	1		1236.0	15.42	-.5021
	2		945.8	10.40	.0721
	3		1676.9	20.78	-2.2048
	4		845.8	7.75	-.0871
Weaning Conformation	1			1.00	-.0328
	2			.54	.0344
	3			1.71	-.0638
	4			.61	-.0451
Postweaning ADG	1				.0129
	2				.0154
	3				.0222
	4				.0368

TABLE LXX

VARIANCE-COVARIANCE MATRICES FOR THE PRODUCTIVITY QUARTILES IN THE ANALYSES CONSIDERING THE SECOND AND THRID PARITY CALVES IN ANGUS HERD 1

	Quartile	Birth Wt.	Weaning Wt.	Weaning Conformation	Postweaning ADG	First Parity Weaning Wt.
Birth Wt.	1	47.2	90.6	-.27	.1485	28.5
	2	46.1	129.5	-.06	-.0582	36.7
	3	45.6	49.9	-1.02	.3070	-3.7
	4	44.8	74.7	.73	.1529	16.9
Weaning Wt.	1		863.0	6.54	-.0762	123.7
	2		871.1	2.21	-.6253	296.7
	3		511.5	3.11	-.0642	21.6
	4		609.2	4.84	-.4038	125.0
Weaning Conformation	1			.44	-.0116	-2.1
	2			.41	-.0091	.8
	3			.29	-.0268	2.3
	4			.34	-.0215	-4.9
Postweaning ADG	1				.0107	-.3
	2				.0109	-.3
	3				.0114	.1
	4				.0174	2.8
First Parity Weaning Wt.	1					915.2
	2					987.4
	3					863.6
	4					2278.4

TABLE LXXI

VARIANCE-COVARIANCE MATRICES FOR THE PRODUCTIVITY QUARTILES IN THE ANALYSES CONSIDERING THE SECOND THROUGH SEVENTH PARITY CALVES IN ANGUS HERD 1

	Quartile	Birth Wt.	Weaning Wt.	Weaning Conformation	Postweaning ADG	First Parity Weaning Wt.
Birth Wt.	1	52.9	123.7	-.11	.6078	18.9
	2	45.6	29.8	2.42	-.0935	-154.1
	3	25.9	33.2	-.07	-.4148	8.3
	4	27.3	48.6	.03	.0152	-3.9
Weaning Wt.	1		641.3	1.35	.5604	359.0
	2		623.7	-4.38	-.8253	312.1
	3		624.3	4.43	-.3478	121.5
	4		582.7	9.54	-.7367	-74.8
Weaning Conformation	1			.22	-.0075	-5.0
	2			.30	.0432	11.5
	3			.08	.0023	1.3
	4			.26	-.0141	-2.7
Postweaning ADG	1				.0109	-.4
	2				.0105	1.5
	3				.0091	0.0
	4				.0171	1.1
First Parity Weaning Wt.	1					618.0
	2					1165.1
	3					51.0
	4					226.3

TABLE LXXII

VARIANCE-COVARIANCE MATRICES FOR THE PRODUCTIVITY QUARTILES IN THE ANALYSES CONSIDERING THE SECOND THROUGH SEVENTH PARITY CALVES IN THE HEREFORD HERD

	Quartile	Birth Wt.	Weaning Wt.	Weaning Comformation	Postweaning ADG	First Parity Weaning Wt.
Birth Wt.	1	43.1	269.0	-1.62	.1900	231.8
	2	57.2	58.4	.26	.3985	123.2
	3	19.0	-22.4	-.38	.2613	52.3
	4	18.7	54.3	-.53	-.1044	-18.7
Weaning Wt.	1		2405.5	5.03	-1.6797	739.6
	2		407.3	8.62	2.2155	89.6
	3		494.6	-2.50	-1.9781	-291.7
	4		878.6	-1.20	-3.5347	-12.7
Weaning Conformation	1			.89	-.0780	-10.0
	2			.25	.0524	-.2
	3			.08	.0102	1.7
	4			.77	-.0098	-10.6
Postweaning ADG	1				.0162	4.0
	2				.0137	1.0
	3				.0128	1.0
	4				.0278	.5
First Parity Weaning Wt.	1					2399.2
	2					508.8
	3					597.5
	4					426.2

TABLE LXXIII

VARIANCE-COVARIANCE MATRICES FOR THE PRODUCTIVITY QUARTILES IN THE ANALYSES CONSIDERING THE SECOND AND THIRD PARITY IN ANGUS HERD 2

	Quartile	Birth Wt.	Weaning Wt.	Weaning Conformation	Postweaning ADG	First Parity Weaning Wt.
Birth Wt.	1	39.5	148.2	1.51	.1746	25.2
	2	56.0	64.5	1.29	.0478	131.5
	3	30.2	22.7	-.39	.1833	33.7
	4	65.9	205.6	-.11	-.1092	36.3
Weaning Wt.	1		1467.4	17.60	-.8103	175.9
	2		830.5	-1.63	.0502	387.0
	3		726.3	15.50	-.7104	175.1
	4		1752.3	25.14	-2.1134	464.1
Weaning Conformation	1			.76	-.0360	-13.2
	2			.89	-.0356	19.5
	3			.93	-.0585	-9.6
	4			1.37	-.0092	7.5
Postweaning ADG	1				.0162	4.0
	2				.0099	-1.6
	3				.0497	-.4
	4				.0171	1.2
First Parity Weaning Wt.	1					2103.5
	2					2780.7
	3					1776.4
	4					880.1

VITA

Michael Adrian Brown

Candidate for the Degree of

Doctor of Philosophy

Thesis: MULTIVARIATE EVALUATION OF PHENOTYPIC RELATIONSHIPS AMONG HEIFERS' EARLY PERFORMANCE AND SUBSEQUENT PRODUCTIVITY IN HEREFORD AND ANGUS CATTLE

Major Field: Animal Breeding   Minor Field: Statistics

Biographical:

Personal Data: Born in Tulsa, Oklahoma, June 14, 1950, the son of Mr. and Mrs. Adrian Mr. Brown; married Sherry Jeanne Woods, August 15, 1970; the father of one son, Daniel Adrian, born January 31, 1975.

Education: Graduated from Broken Arrow High School, May, 1968; received the Bachelor of Science degree from Oklahoma State University, May, 1972 with a major in Animal Science; received the Master of Science degree from Oklahoma State University in May, 1974, with a major in Animal Science; completed requirements for the Doctor of Philosophy degree at Oklahoma State University, Fall, 1976.

Experience: Worked on polo horse, quarter horse and beef farm and on small grain, beef and dairy farm, 1964-1968; worked in Mouse Genetics Laboratory, Oklahoma State University, 1970-1972; worked on and associated with commercial Hereford and registered Polled Hereford ranch, 1970-1976; Graduate Assistant, Department of Animal Science, Oklahoma State University, 1972-1974; Graduate Assistant, Department of Statistics, Oklahoma State University, 1974-1976.

Professional Organizations: American Society of Animal Science, Biometrics Society, Sigma Xi, Mu Sigma Rho.

Date of Degree: December, 1976.